RESEARCH

AT WHAT COST? AN ANALYSIS OF THE GREEN COST PREMIUM TO ACHIEVE 6-HOMESTAR IN NEW ZEALAND

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ABSTRACT

In the green building industry there is an implicit understanding that the use of a green building rating tool will attract additional capital cost. This phenomenon has been well studied in commercial buildings, with mixed results, but has received little focus in the residential, single family context.

In New Zealand the local green building council advises the market that they have reduced the time and cost to implement their green building rating tool, Homestar, through modifications to version 4 of the rating tool, which include the use of a new 6-Homestar checklist.

This research investigates this claim using a comparative cost methodology to determine the potential additional capital cost commitment that would be required to achieve a 6-Homestar certification, utilising ten standalone and terraced house designs from the Hobsonville Point development in Auckland, NZ.

This research determines that there is an additional cost to achieve 6-Homestar of 3–5%. This is nearly double compared to previous research into Homestar and also finds that, for the houses reviewed, the use of the 6-Homestar checklist is less cost effective than other options. Therefore, in this instance the advice and guidance of the green building council is erroneous and misleading to the market.

KEYWORDS

Homestar, Green Building, Sustainability, Rating Tools, Green Building Council

BACKGROUND AND INTRODUCTION

Green building ratings tools were established in the 1990s as a mechanism to help the property industry avoid accusations of greenwashing and to standardise the methods used to make building more environmentally friendly (Hoffman & Henn, 2008). In New Zealand the New Zealand Green Building Council (NZGBC) released its first green building rating tool for commercial buildings, Green Star NZ, in early 2008.

In 2009 the NZGBC, in conjunction with the Building Research Association of New Zealand (BRANZ) and Beacon Pathways developed another rating tool, this time specifically for the residential property market in New Zealand. This is called Homestar. The Homestar version 1 technical manual states that the overarching objective of the Homestar rating tool is . . .

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"to improve the performance and reduce the environmental impact of new and existing New Zealand homes, making them warm, healthy, comfortable places to live."

This objective formed a direct response from the NZGBC to research that showed that New Zealand homes are under-heated by international standards, falling at least 2 degrees Celsius short of the World Health Organisation's minimum indoor daytime temperature of 18 degrees Celsius (Howden-Chapmen et al, 2007).

Homestar version 1 was originally designed for use in the existing housing market and was released for public use in 2010, but did not experience any significant uptake in this market. A new version of Homestar (version 2) was released in 2013 that facilitated the ability of the rating tool to be used on new constructions with a 'Design Rating' option added to the existing 'Built Rating' certification. However, version two of the rating tool still did not experience any significant uptake. Further iterations of the tool, version 3 and version 4, have been released in 2016 and 2017 respectively.

A review of the New Zealand Building Code by the International Energy Agency (IEA, 2017) found it is below the standard required in most IEA countries with comparable climates. International Energy Agency. (2017). *Energy policies of IEA countries: New Zealand 2017 review*. Retrieved from: https://webstore.iea.org/energy-policies-of-iea-countries-new-zealand-2017-review. This led two local governments in New Zealand to explore the opportunity to address concerns around an outdated building code by mandating the use of the Homestar v2 rating tool; specifically, by requiring a minimum 6-Homestar rating for new constructions in their draft Unitary and District Plans (NZGBC, 2014a; NZGBC, 2014b).

Ultimately, the 6-Homestar requirement was removed from the final versions of both the Auckland Unitary Plan and Christchurch District Plan, after industry and national government objections, but not before two leading, independent consultancies published case studies reflecting on the potential additional construction cost that a 6-Homestar rating could attract (Ecubed, 2013; Jasmax, 2013a; Jasmax, 2013b).

This study critically reviews these reports and updates the information presented with a more detailed analysis and differing conclusion on the theoretical cost to achieve a 6-Homestar v4 rating.

This study has significant policy implications as the NZGBC has previously advocated for the adoption of 6-Homestar as a minimum standard for the new Kiwibuild program, which aims to build 100,000 new homes in New Zealand (NZGBC, 2018a; NZGBC, 2018b).

LITERATURE REVIEW

One of the key barriers to the adoption of green building and in particular green building rating tools is the perception of increased construction cost (Park, Nagarajan, & Lockwood, 2008). Whilst previous studies have sought to determine this effect, consensus has not yet been reached, with a large proportion of the literature reporting a cost premium for the use of a green building rating tool, the seminal work of Kats *et al.* (2003) the most cited literature in this area (Chegut, Eichholtz, & Kok, 2014; Dwaikat & Ali, 2016). Some studies find cost neutrality (Kaplan, Matthiessen, Morris, Unger, & Sparko, 2009; Matthiessen & Morris, 2004; Matthiessen & Morris, 2007; Rehm & Ade, 2013) with a much smaller portion finding the potential for a cost saving (Davis Langdon, 2010). However, this literature is heavily grounded in commercial property, with only nine (shown in Table 1) out of approximately thirty studies investigating the residential market.

TABLE 1. Summary of the literature on green cost premiums for residential dwellings.

Author(s)	Cost premium estimation method	N	Building type	Rating Tool	Green Building Cost Premiums
Hwang, Zhu, Wang, & Cheong, 2017	Survey	57	Commercial	Green Mark	3.8% to 8%
		10	Office		2.5% to 4.2%
		52	Residential		1.3% to 12.5%
Kim, Greene, & Kim, 2014	Case study	2	Single family home	Green Building Code	10.77%
MOHURD 2014 as reported by (Zhang, 2018)	unknown	unknown	Residential	CGBL	3-Star: 5.4% 2-Star: 2.9% 1-Star: 1.0%
(Yip, Li, & Song, 2013) as reported by (Zhang, 2018)	unknown	unknown	Residential	CGBL	3-Star: 0.5% to 1.5% 2-Star: 0.9% to 2.6% 1-Star: 0% to 0.75%
(Glossner, Adhikari, & Chapman, 2015)	Communication with LEED professionals		Single family home	LLED	Certified: 4% Silver: 7% Gold 10% Platinum: 13%
Zhang, X., Platten, A., & Shen, L. (2011).	Case study and interviews	3	Hotel Residential Office	Not disclosed	8.5% to 13.9%
Reposa Jr, 2009	Case study	2	Single family home	LEED	4.9%
(Matthiessen & Morris, 2007)	Unpaired t-test of actual green bldg costs against 22 non-green bldg costs	15	High-rise apartments	LEED	No statistically significant cost difference
(Bradshaw, Connelly, Cook, Goldstein, & Pauly, 2005)	Survey		Single family home	'green projects'	–18% to 8%

Of these ten studies only four are available that review the potential impact of green building rating tools on the construction cost of single family dwellings, with the rest addressing multi-unit dwellings. Whilst providing interesting and valid results, the studies on multi-unit residential dwellings are not always directly applicable to single family residential projects due to inherent differences in the way these types of dwellings are designed and constructed. For example, external washing lines on balconies are frequently prohibited in multi-unit developments for aesthetics; however, their implementation is promoted and awarded points in single family specific rating tools such as Homestar. In addition, research in New Zealand comparing multi-unit to detached single-storey construction has found that large-scale builders who produce multi-storey dwellings can produce housing significantly cheaper than most low volume builders suggesting that there is a significant cost associated with one-off designs that are currently the most common house type in New Zealand (Page, 2008). All of these factors make it currently challenging to directly compare the potential green cost premium of multi-unit dwellings to standalone family houses.

Reviewing the literature on single family homes, an early study was undertaken in 2005 by the Tellus Institute, that was survey based, and reviewed the reported construction cost of 16 houses. From this they determined that the total cost for green projects ranged from 18% below to more than 8% above conventional project costs, with a mean premium of 2.4% and median of 2.9% (Bradshaw, Connelly, Cook, Goldstein, & Pauly, 2005). However this study occurred nearly 15 years ago and these results are likely no longer valid with subsequent market changes, including wider uptake of green building ratings bringing implementation costs down.

A second early study in 2009 by the National Association of Home Builders (NAHB) found that the minimum additional cost to certify a green home, with a base price of approximately $150,000, was approximately $7,450 for LEED for Homes (Reposa Jr, 2009). This equates to a cost increase of 4.9%. However, this study only reviewed the soft costs of verification, and the additional fees that are required for the LEED for Homes program, and did not attempt to review any ‘hard’ construction costs, such as energy and water efficiency features. It therefore cannot be considered to be an authority on green cost premiums that could be attributed to the use of a residential green building rating tool.

A third more recent study does not review the construction cost impact of a green building rating tool per se, instead researching the impact of a new Green Building Code finding that its incopration increases costs by 10.77% (Kim, Greene, & Kim, 2014). Kim *et al.* utilised a comparative cost, case study approach, comparing the cost schedules of two single family homes in Los Angeles. Comparative cost analysis is a quantitative research technique usually applied to situations where there are a set number of analysis paths. Kim *et al.* (2014) note that they chose the case study research method because it provides a detailed, side-by-side analysis of the strategies of how the green building code impacts project owners that are making decisions concerning investment of green building features, such as energy efficiency.

Finally, Glossner *et al.* (2015) attempted to analyze the cost effectiveness of building new single family homes to the LEED for Homes standard determining that LEED Certified and Silver rated homes had a payback period of less than 30 years. The costs used in this study were not gathered by the authors from market participants or from actual cost data. Instead, the baseline cost was determined by applying 2013 NAHB research that showed that the cosntruction cost of a house was 61.7% of its value. The added construction costs for LEED for Homes were then applied to this figure through the use of percentage cost increases 4% for Certified, 7% for Silver, 10% for Gold and 13% for Platinum. The authors state that these percentages were ‘figured’ though communications with LEED professional and home building organisations that have previously built LEED certified homes. Whilst not explicity stated it appears that these figures are from personal communications with only two industry participants rather than from independent, academic research.

Each of these four studies find a cost premium for the use of a green buiding rating tool or code on a single family dwelling, however two of the studies are dated (Reposa Jr, 2009; Bradshaw *et al.*, 2005), whilst Glossner *et al.*, 2015 does not represent a strong finding on a green cost premium due to its use of 'figured' percentages. In addition there is a basic assumption in all of these studies that all construction markets are the same, whereas in reality it is likely that regional factors such as availability of materials, industry knowledge and experience etc. will play a key role in influencing a green cost premium, both internationally as well as within different regions of the same country.

The NZGBC addresses the industry perception that the use of a green building rating will attract a cost premium with a value case that states "*If you're building, achieving a 6 Homestar rating adds just 1.5% to the purchase price of a typical three-bedroom house—or nothing at all if the house is slightly smaller than today's larger homes*" (NZGBC, 2018c).

However few studies, and no independent academic research, has been completed on the residential building sector of New Zealand to determine the existence and extent of construction cost premiums associated with green home certification.

In 2013, the consultancy firm, eCubed Building Workshop, undertook a study (commissioned by the Auckland Council) to identify the costs and benefits of achieving 5, 6 and 7-Homestar. This study was commissioned to enable the Auckland Council to understand the impact of integrating Homestar into its Unitary Plan. Although eCubed is an experienced, independent consultant, their 2013 study featured several key methodological flaws and omitted information on its data and methods which inhibits interpretation of the study's findings. Examples of the shortcomings include the report's failure to stipulate the number of houses that were reviewed, the size, location and orientation of the dwelling(s), and the construction types. This lack of disclosure makes it impossible to critically analyse or vet the estimated costs of Homestar.

Two additional studies by an architectural firm, Jasmax (2013a; 2013b), looked at the theoretical cost premium to achieve a 5, 6 and 7-Homestar rating for a sample 3-bedroom/180 m^2 new dwelling in Auckland (which at the time of undertaking the study (June 2012) sold for around $550,000) and a 4-bedroom/190 m^2 new dwelling in Christchurch. These studies determined cost premiums of 0.6% to 5%.

These studies feature flaws common to the eCubed (2013) study again only reviewing a single dwelling and thus prohibiting the ability to infer findings to a wider range of housing stock. Different houses require different thermal upgrades to enable them to achieve 6-Homestar depending on their basic design, location and orientation on site. Some may require low-e glazing, or even thermally broken low-e glazing, whilst others will not. Therefore, reviewing a single design and then proclaiming that all other houses will experience the same cost uplift is erroneous.

In early 2018 the NZGBC commissioned a new report from eCubed to update the value case for Homestar using the new version 4 of the rating tool. Unfortunately, as this report built on the previous eCubed research it has retained some of the previous flaws as well as introducing new ones. Firstly, the research is again based on a single, theoretical rather than actual, dwelling. Secondly, in its opening sentence the report specifically states that is has been commissioned by the NZGBC to "*identify the costs and benefits of achieving 6, 7 and 8-Star Homestar above the NZBC standard*." However, in the very next paragraph it is then stated that the study has *not* included any of the capital costs that would be associated with materials selection, ecology, home management features or waste minimisation. The report, as well as all previous Homestar studies, also explicitly disregards any soft costs, which can be in the order of $3,800 (Ade, 2018), instead focussing solely on the ‘direct hard cost benefits’ of energy and water efficiency. The study then goes on to estimate that the capital cost investment for 6-Homestar in Auckland is a mere $1,142. This cost is limited to increasing the ceiling from R3.2 to R4.0 and wall insulation from R2.0 to R2.4.

In summary, the literature on the potential green cost premium for residential developments is sparse as documented in Table 1, with only nine international studies identified. Of these the majority are focussed on multi-unit developments rather than terraced or standalone dwellings with only four studies (Reposa, 2009; Bradsaw *et al.*, 2005; Kim *et al.*, 2014; Glossner *et al.*, 2015) presenting any findings in this context.

To date no independent, academic research has been undertaken into Homestar, with all existing research on this rating tool having been commissioned by the NZGBC or Auckland Council. These studies find a cost premium for 6-Homestar of between 0.2% to 5% as shown in Table 2. The present study presents a counterpoint to the manner in which the costs of 6-Homestar are being evaluated, enhancing previous work in this area by undertaking an independent review of the potential of a green building rating tool to attract a green cost premium.

TABLE 2. Summary of single family cost studies.

Study	Rating Tool	Methodology	Cost Premium
Reposa Jr, 2009	LEED	Modelled costs on two dwellings	4.9%
Bradshaw et al., 2005	None—‘green’	Survey of actual costs on 16 houses	–18% to 8% Median 2.9%
eCubed, 2013	5,6 & 7-Homestar	Modelled costs on a single dwelling	0.4% to 2.9%*, **
Jasmax, 2013a	5,6 & 7-Homestar	Modelled costs on a single dwelling	0.6% to 3%
Jasmax, 2013b	5,6 & 7-Homestar	Modelled costs on a single dwelling	0.4% to 5%
Kim et al., 2014	Green Code	Case study	10.77%
Glossner et al., 2015	LEED	Personal communications with industry professionals	4% to 13%
Hwang et al., 2017	Green Mark	Survey	1.3% to 12.5%
Ecubed, 2018	6, 7 & 8-Homestar	Modelled costs on a single dwelling	0.2%*, **
Rawlinsons, 2018	6, 7 & 8-Homestar	Modelled costs on a single dwelling	1.1%**

* direct hard cost benefits’ of energy and water efficiency only
**based on an assumed build cost of $500,000

RESEARCH OBJECTIVES AND METHODOLOGY

This research uses a case study, comparative cost analysis methodology to independently determine what, if any, potential additional capital cost commitment would be required to achieve a 6-Homestar certification under version 4 of the rating tool. Comparative cost analysis is a quantitative technique usually applied to situations where there are a set number of analysis paths. This methodology is therefore appropriate for use in the review of green building rating tools which frequently provide different, but deemed to be equivalent, thermal analysis pathways.

The combination of case studies with comparative cost analysis has been employed by previous researchers in the green building space to analyse the potential capital cost impacts of green building rating tools with success (Kim *et al.*, 2014, Gabay *et al.*, 2014). This research methodology was deemed most appropriate for use in this study as it can provide a detailed, side-by-side analysis of how a green building rating tool can impact the design decisions on a project, and thus affect the capital cost.

This paper is unique in that it presents a comparative cost analysis on residential property development from the perspective of an industry practitioner. Extensive market experience is typically required to effectively implement a green building rating tool on a building, and without such grounding in the market, effective and accurate research into the costs and benefits of green building ratings tools can be difficult. The lead author has extensive experience in the area of green building consultancy, having conducted in excess of 450 Homestar assessments over 150 typologies in New Zealand.

For this study ten New Zealand Building Code (NZBC) dwellings were randomly selected from a pool of 100 designs from the lead author's consulting business in a new housing development in Hobsonville Point, Auckland, New Zealand (the physical characteristics of the dwellings are shown in Table 3 with an example dwelling layout shown in Figure 1). The use of ten dwellings, in counterpoint to the single dwelling approach of previous studies, allows the calculation of mean and median costs, helping to account for outliers in terms of theoretical green cost premium. The dwellings represent a cross section of group home builders, large developers and individual small builders and each dwelling had not considered Homestar when the basic design was being undertaken.

In the experience of the authors, it is typical for a house design to be fully developed, usually to the level of building consent documentation, before a Homestar Assessor is engaged. Homestar is then typically 'bolted on' to the existing design. This results in the number of bedrooms/bathrooms, floor area, orientation, compactness and glazing areas of the design being set, with a Homestar Assessor only able to influence items such as insulation levels and types of glazing. Often the aforementioned items have been pre-consented through the Resource Consent process and developers are not able to modify any of these items without seeking a new Resource Consent. In addition, the sales and rental market is typically the driving force behind the number of bedrooms/bathrooms, floor area etc., and even if they could be modified, the authors have found that developers will not do so for fear that the end product will no longer be desirable to the market.

A dwelling has two options when it comes to demonstrating 6-Homestar (version 4) compliance.

- The first is to use the 6-Homestar checklist. The checklist contains a large set of mandatory requirements and once all of those have been achieved then the dwelling only needs

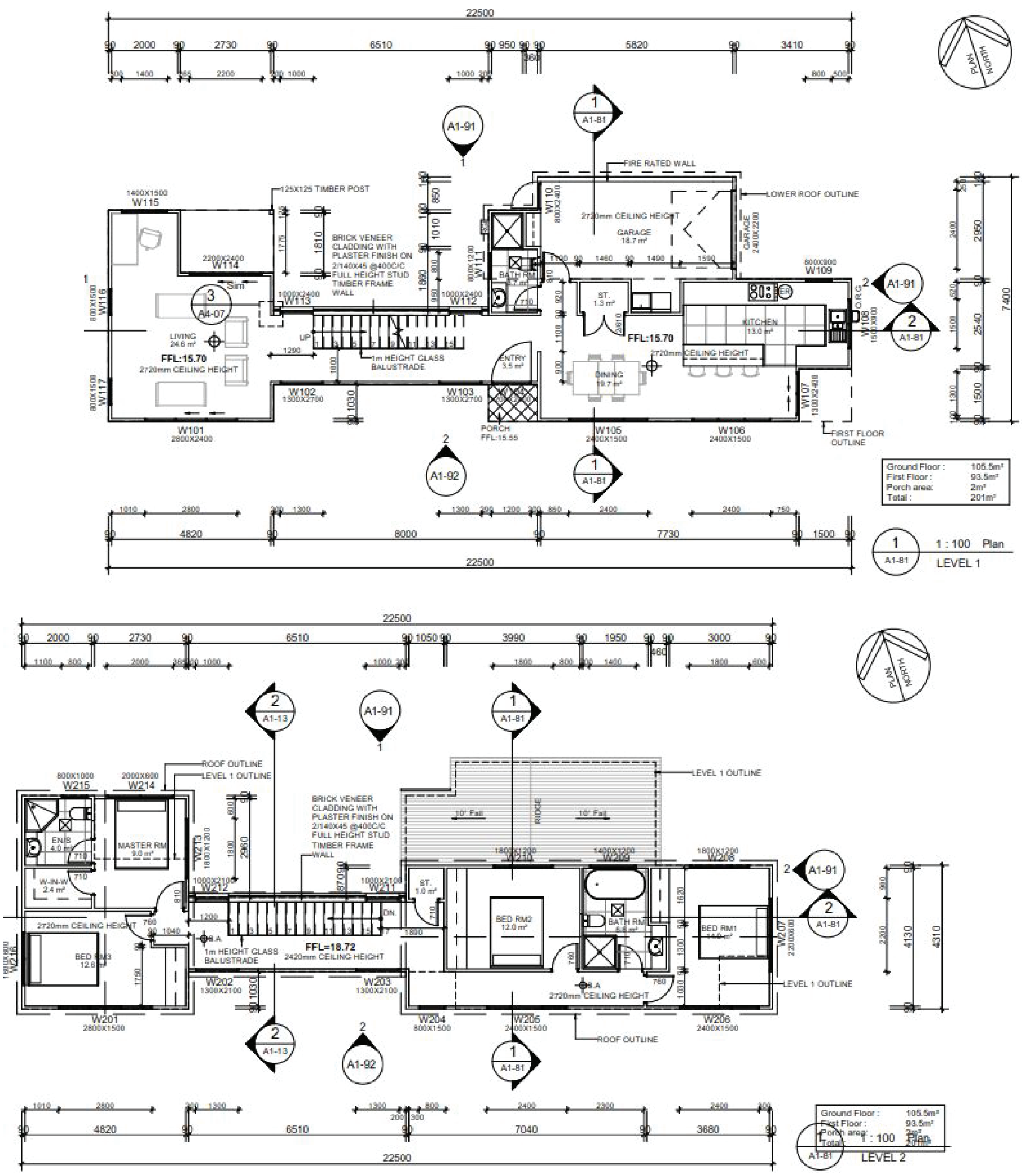
TABLE 3. Summary of design characteristics of the 10 case study dwellings.

Design characteristics	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Orientation	NE	S	NE	NE	NE	NW	NE	NW	NW	NW
Conditioned Floor Area	$146m^2$	$166m^2$	$153m^2$	$145m^2$	$110m^2$	$156m^2$	$134m^2$	$160m^2$	$160m^2$	$164m^2$
Building Footprint	$73m^2$	107^2	91.8^2	86^2	$72m^2$	$104m^2$	$89m^2$	$103m^2$	$98m^2$	$85m^2$
Gross Floor Area	$166m^2$	$203m^2$	$186m^2$	$175m^2$	$143m^2$	$168m^2$	$151m^2$	$195m^2$	$165m^2$	$187m^2$
Number of bedrooms	4	4	5	5	4	4	4	4	4	4
Number of bathrooms	2.5	2.5	3.5	3.5	2.5	3.5	2.5	3.5	2.5	3.5
Number of storeys	2	2	2	2	2	2	2	2	3	2
Type	Standalone	Standalone	Standalone	Standalone	Terraced	Standalone	Standalone	Standalone	Terraced	Standalone
Total wall area	$195\ m^2$	$349\ m^2$	$256m^2$	$240m^2$	$156m^2$	$255m^2$	$260m^2$	$320m^2$	$166m^2$	$234m^2$
Total window area	$66m^2$	$99m^2$	$64m^2$	$50m^2$	$45m^2$	$65m^2$	$76m^2$	$76m^2$	$45m^2$	$89m^2$
Roof Area	$73m^2$	$109m^2$	$89.4m^2$	$83m^2$	$71m^2$	$111.2m^2$	$90m^2$	$103m^2$	$67m^2$	$85m^2$
Average ceiling height	2.55m	2.72m	2.68m	2.68m	2.66m	2.72m	2.7m	2.72m	2.62m	2.7m
Roof Material	Longrun metal roof	Longrun metal roof.	Asphalt shingle on 15mm plywood.	Longrun metal roof.	Longrun metal roof	Longrun metal roof	Asphalt shingle on 15mm plywood.	Longrun metal roof	Longrun metal roof	Longrun metal roof
Ceiling Framing	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900	90 × 45 @900

Ceiling Insulation	R3.2	R2.9	R3.2	R3.2	R3.2	R3.6	R3.2	R3.2	R3.2	R3.2
Wall Cladding	Fibre cement panels & fibre cement boards	Bevelback & Vertical timber weatherboard Plaster Finish on Brick Veneer.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.	Bevelback & vertical timber weatherboard.
Wall Framing	90 × 45 @600 c/c	90 × 45 @600 c/c & 90 × 45 @400 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c	90 × 45 @600 c/c
Wall insulation	R2.2	R1.9	R2.2	R2.2	R2.2	R2.8	R2.2	R2.2	R2.2	R2.2
Floor	Waffle Pod[a] Area/perimeter ratio = 2.5	Waffle Pod: Area/perimeter ratio = 1.2	Waffle Pod: Area/perimeter ratio = 1.94	Waffle Pod: Area/perimeter ratio = 1.84	Waffle Pod: Area/perimeter ratio = 1.84	Waffle Pod: Area/perimeter ratio = 1.36	Waffle Pod: Area/perimeter ratio = 1.25	Waffle Pod: Area/perimeter ratio = 1.34	Waffle Pod: Area/perimeter ratio = 2.0	Waffle Pod: Area/perimeter ratio = 2.0
Glazing	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed with low-e film and argon gas	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed low-e	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed	Aluminium frames, no thermal break, double glazed

[a]A waffle pod foundation is an on-ground slab, with air pockets created by the polystyrene pods, forms an insulating layer between the structure and the ground

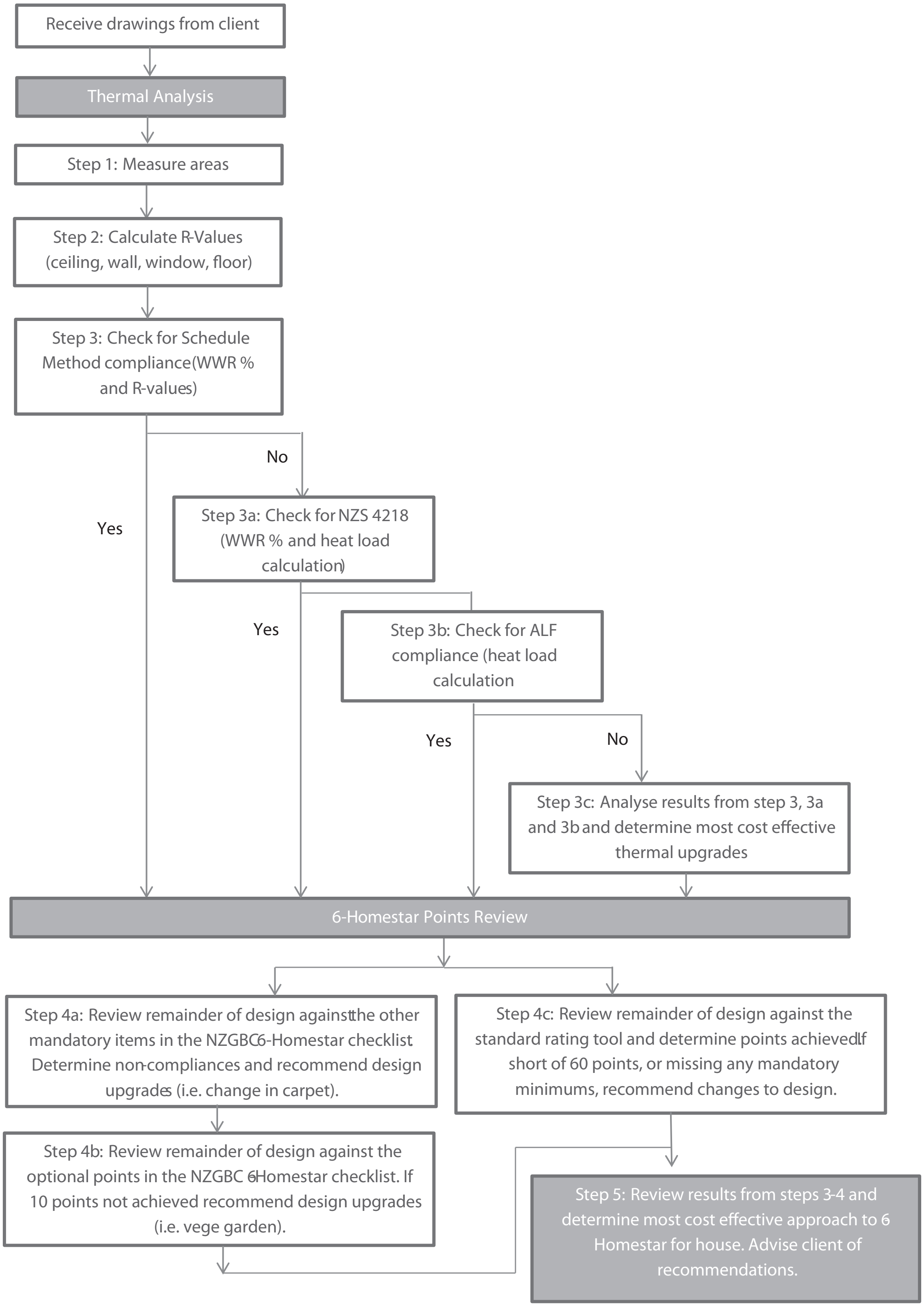
FIGURE 1. Example house layout (House 2).



to achieve 10 points from an optional credit list. The NZGBC promotes this approach as the most efficient way to achieve 6-Homestar (NZGBC, 2018d).

- The second is to use the more traditional credits and points approach. In this approach there are 5 mandatory credits that have to be achieved which equate to approximately 21.5 points. Once all of those have been achieved then the project only needs to target and achieve additional points from credits throughout the tool to reach a total of 60 points to achieve 6-Homestar.

FIGURE 2. Homestar Assessor flowchart.



The typical process, that an expert Homestar assessor would follow, to undertake an analysis in preparation for a certification is shown in Figure 2. This is the process that has been used in this research.

Two particular cost elements have been reviewed in this study, (i) hard construction costs and (ii) soft construction costs. Hard costs relate to tangible items that need to be procured to complete the dwelling, such as insulation, glazing etc. When calculating the additional hard costs experienced, the authors have taken a baseline of what would typically be done to satisfy the NZBC. For example, water efficiency of fixtures and fittings is not considered in the NZBC, therefore, to determine the potential additional costs to achieve 6-Homestar, the lead author selected the least-expensive fixture or fitting that is available on a leading New Zealand building merchant's website (Bunnings.co.nz). Once a compliant fixture or fitting was identified, the additional cost of 6-Homestar was determined by calculating the difference between the NZBC typical and least-expensive 6-Homestar-compliant costs.

A contractor's margin of 15% has been added to the final costs. This represents the standard New Zealand construction practice of summing all the construction costs and then adding a margin to enable the contractor to cover overheads and make a profit. This has been included to allow the final cost figures determined to be usable in the general residential construction market, especially if these are communicated directly to the end user (i.e. homeowner). It is worth noting that trade discounts might be applicable in some instances and therefore the costs presented may be overestimated, representing a worst-case scenario.

When building up the points scores for 6-Homestar rating, the authors have taken the approach of targeting the most cost-effective points first, as well as targeting just enough points to push a dwelling over a rating threshold. In practice, three to five buffer points might be targeted allowing a project to miss or drop points during the design and construction process without losing the ability to achieve the rating desired. Therefore, the calculated additional construction costs may be slightly lower than reality.

The authors have determined the additional cost of 6-Homestar using the assumptions set out below.

Energy, health and comfort

EHC-1 Thermal Comfort

Homestar version 4 has four pathways available for a dwelling to illustrate thermal comfort compliance:

1. Schedule Method (6 or 7 Homestar ratings only)
2. Heating load calculations using the on-line BRANZ Annual Loss Factor (ALF) calculator (6 or 7 Homestar ratings only)
3. Energy Modelling: using NZGBC approved software and protocol
4. Passive House Certification.

For this study only the schedule method and BRANZ ALF calculations were evaluated as the third and fourth method are typically only used for ratings of 8-Homestar and above.

When evaluating the thermal comfort of each dwelling against the requirements of Homestar version 4, the NZBC design was used as a baseline and this design was modified until it met the requirements of both the schedule method and BRANZ ALF calculation. These changes were then costed using the assumptions in Table 4.

TABLE 4. EHC-1 costing assumptions.

Foundations	
Waffle pod slab	\$160/m².
MAXRaft (fully insulated) slab	\$135/m²
Climafoam 50 × 1200 × 600 mm XPS (under slab insulation)	\$36/m²
R1 slab edge insulation	\$49/lineal metre supplied and installed with a \$50 delivery fee and \$30 cost per external corner.
Walls/Framing	
90 × 45mm H1.2 treated timber external wall framing at 600crs (pre-fabricated)	\$49.70/m²
10mm GIB Standard™ plasterboard wall lining including fixings, adhesives, stopping to level 4 and paint finish	\$54.10/m²
Insulation	
Installation labour	\$65/hour
Knauf wall insulation—R2.2	\$5.23/m²
Knauf wall insulation—R2.4	\$7.4/m²
Knauf wall insulation—R2.6	\$9.57/m²
Knauf wall insulation—R2.8	\$14.66/m²
Knauf wall insulation—R3.2	\$6.97/m²
Knauf wall insulation—R3.6	\$10.84/m²
Knauf wall insulation—R4.1	\$16.95/m²
Knauf ceiling insulation—R2.9	\$6.1.4/m²
Knauf ceiling insulation—R3.3	\$6.77/m²
Knauf ceiling insulation—R3.6	\$7.24/m²
Knauf ceiling insulation—R4.1	\$7.97/m²
Knauf ceiling insulation—R5.2	\$11.58/m²
Knauf ceiling insulation—R6.3	\$13.65/m²
Knauf ceiling insulation—R2.9	
Glazing	
Double glazing	\$530/m²
Double glazing with low-e film	\$580/m²
Thermally broken double glazing with low-e argon	\$750/m²
Cladding	
Standard fibre-cement weatherboard	\$209/m²
Flooring	
Carpet/timber flooring	\$45 m²
Concrete sealing and polishing	\$55 m²

In all instances, the layout floor plans were held constant, with only the construction systems and glazed areas being modified to achieve thermal performance requirements.

ALF was used to 'model' the theoretical space heating energy demand (using the Homestar v4 20°C set point) of each dwelling design for NZBC, the schedule method as well as the heat load calculation method. The resulting required thermal envelope upgrades are shown in Table 5.

EHC-2 (efficient space heating)

It is a Homestar v4 mandatory minimum requirement for a fixed heating source to be provided to the main living area (except when the dwelling is a certified Passive House or has an annual heating demand of 15 $kWh/yr/m^2$ or less). Electric wall-mounted panels heaters ($39 each) were costed as the most cost-effective fixed heating mechanism. These can be plugged straight into a power point, so a half an hour has been allocated for a builder to mount the heater on the wall.

EHC-3 (ventilation)

Compliance with the Homestar v4 mandatory minimum requirement can be achieved by providing:

- a dedicated range hood vented to the outside for the kitchen
- a dedicated extraction system vented to the outside for each bathroom, automated to turn off so the fan runs long enough to ensure effective moisture removal (such as a delay timer)
- net openable area of windows to the outside of no less than 5% of the floor area.

The only item above that was not included in the building consent drawings for each case study dwelling was the delay timer. A Sim-x Manrose fan run on a fixed timer with a run-on time of 7 minutes and a start-up delay of 45 seconds can be purchased on trademe.co.nz for $50. A standard Manrose extractor fan can be purchased on the same website for $37. No additional installation cost was allowed for as the building consent drawings already show an extract fan to be installed to each bathroom.

EHC-4 (surface and interstitial moisture)

For each dwelling to meet the EHC-1 R-value requirements using the schedule method slab edge insulation was required. Therefore, 1 point can be awarded here for each dwelling at no additional cost as any additional cost is accounted for in EHC-1. In addition, suspended timber floors are also required to have insulation to meet the mandatory minimums, and therefore another point can be awarded in this credit at no additional cost. Yet another point can be awarded for all the dwellings where, for a timber-framed building, there are no concrete or steel penetrations through the insulation layer. Therefore, no additional costs have been allocated for this credit.

EHC-5 (hot water heating)

All of the dwellings can achieve 6-Homestar compliance using either instantaneous gas or an electric hot water cylinder. Therefore, no additional costs have been allocated for this credit.

EHC-6 (lighting)
All dwellings specified LED lighting and required no changes to achieve points in this credit. Therefore, no additional costs have been allocated for this credit.

EHC-7 (natural lighting)
The dwellings were all assessed to be already compliant with receiving full points for this credit without requiring any changes to the NZBC compliant designs. Therefore, no additional costs have been allocated for this credit.

EHC-8 (renewable energy), EHC-9 (sound insulation) & EHC-10 (inclusive design)
These credits are not typically targeted for 6-Homestar as the required 60 points can be achieved without achieving points in these, typically expensive, credits.

EHC-11 (efficient clothes drying)
Two washing lines (18 metres of line length), one for outdoors use and a second for covered use in the garage, were priced at $148.98 from Bunnings (Wattle Retractable Clothesline 6-Line Grey). It was assumed that it would take a building labourer half an hour to install these at an hourly rate of $33.21/hour.

WAT-1 (water use in home)
It is a Homestar version 4 mandatory minimum requirement that all showerheads must be <9 L/min (WELS 3*) and toilets be dual 6/3L flush (WELS 3*). The lowest cost shower listed on the Bunnings website was the WELS 3* Flexispray Aurora hand shower, retailing at $29. For lowest cost toilet suite listed on the Bunnings website is the Dux Delmonte cistern (WELS 3*) for $95.35. Therefore, no additional costs have been allocated for this credit.

WAT-2 (sustainable water supply)
This credit is not typically targeted for 6-Homestar as the required 60 points can be achieved without achieving points in these, typically expensive, credits.

WST-1 (construction waste minimisation).
Two hours of consultant/contractor time, at $150/hour, was allowed to write a site-specific waste management plan. The target of >70% of construction waste diversion from landfill has been included at no additional cost as standard waste providers in Auckland can achieve this at no additional cost.

WST-2 (household waste minimisation) credit
It is standard industry practise for a two-division waste bin to be installed in a new kitchen and for there to be space outside for the council-provided recycling bin to be located. Therefore, no additional cost has been allocated here.

Security (MAN-1)
No additional costs have been allocated to this credit as the provision of a main entrance visible from the street that is well labelled, a window in the dwelling that allows street surveillance and a clearly defined boundary between public and private areas are common features of new dwellings. The provision of energy-efficient security lighting to entrance and garage doors is also standard industry practise.

TABLE 5. 6-Homestar required thermal envelope upgrades.

Required 6-Homestar upgrades	**Dwelling 1**	**Dwelling 2**	**Dwelling 3**	**Dwelling 4**	**Dwelling 5**	**Dwelling 6**	**Dwelling 7**	**Dwelling 8**	**Dwelling 9**	**Dwelling 10**
Schedule Method										
Ceiling	R3.8 ceiling insulation R2.2 internal garage ceiling	R3.8 ceiling insulation R2.2 internal garage ceiling	R2.2 internal garage ceiling	R3.8 ceiling insulation R2.2 internal garage ceiling	R2.2 internal garage ceiling	R3.8 ceiling insulation R2.2 internal garage ceiling	R2.2 internal garage ceiling	R4.1 ceiling insulation R2.2 internal garage ceiling	R3.8 ceiling insulation	R3.8 ceiling insulation
Walls	R2.2 internal garage wall	R2.2 internal garage wall R2.4 wall insulation	R2.2 internal garage wall R2.4 wall insulation	R2.2 internal garage wall R2.4 wall insulation	R2.2 internal garage wall R2.4 wall insulation	R2.2 internal garage wall R2.4 wall insulation	R2.2 internal garage wall	R2.2 internal garage wall	—	R2.4 wall insulation
Floor	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation
Windows	Delete 7.4m^2 of glazing	Delete 6.7m^2 of glazing	—	—	—	—	Delete 2m^2 of glazing	—	—	Delete 12.5m^2 of glazing
Total Cost	**$515**	**–$998**	**$3,546**	**$3,143**	**$3,178**	**$2,817**	**$2,737**	**$3,713**	**$1,349**	**–$1,302**

ALF										
Ceiling	R2.2 internal garage ceiling R3.8 ceiling insulation	R2.2 internal garage ceiling R3.6 ceiling insulation	R2.2 internal garage ceiling	R2.2 internal garage ceiling	R2.2 internal garage ceiling	R2.2 internal garage ceiling	R2.2 internal garage ceiling R3.8 ceiling insulation	R2.2 internal garage ceiling	—	R3.8 ceiling insulation
Walls	R2.2 internal garage wall R2.8 wall insulation	R2.2 internal garage wall R2.8 wall insulation	R2.2 internal garage wall R2.8 wall insulation	R2.2 internal garage wall	R2.2 internal garage wall R2.8 wall insulation	R2.2 internal garage wall	R2.2 internal garage wall R2.8 wall insulation	R2.2 internal garage wall	—	R2.8 wall insulation
Floor	R1 slab edge insulation	R1 slab edge insulation + R1.2 under slab insulation Exposed concrete slab to ground floor	R1 slab edge insulation Exposed concrete slab to ground floor	R1 slab edge insulation Exposed concrete slab to ground floor	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	R1 slab edge insulation	—	R1 slab edge insulation
Windows	Low-e glazing	Thermally broken framing with low-e glazing + argon gas	Low-e glazing	—	—	Low-e glazing	Low-e glazing	Low-e glazing	—	Low-e glazing
Total Cost	**$6,176**	**$35,218**	**$8,877**	**$3,984**	**$4,626**	**$4,877**	**$9,973**	**$3,768**	**$0**	**$6,131**

MAN-2 (environmental management plan) & MAN-3 (home user guide)

Two hours of consultant/contractor time, at $150/hour, was allowed to write each of these plans/guides.

MAT-1 (sustainable materials) & MAT-2 (healthy materials)

In the experience of the lead author, points in these credits can be achieved using standard NZ building products such as GIB plasterboard, Resene/Dulux/Wattyl paints, Pink Batts/Autex/Knauf/Bradford Gold insulation and Colorsteel roofing. Although these are frequently used building products in the NZ market, they may not be the most effective option and the potential for them to attract additional cost was therefore verified during the research as shown in Table 6

Table 6 shows that plasterboard, applied coatings and floor coverings all attract additional cost for an eco-label and these additional costs have been used in the analysis for these credits. For MAT-2 points can be achieved at no additional cost by using the above building products for applied coatings and floor coverings as long as they constitute 50% or greater of the use, which was the case for the majority of the case study dwellings.

STE-1 (stormwater management)

For this credit the approach was taken that, if the NZBC design did not achieve the basic requirements of this credit then the points would not be targeted due to the large design impact of a change here on the layout of the external landscaping areas and the low numbers of points on offer. Additional costs have therefore not been allocated to this credit.

TABLE 6. MAT-1 costings.

Construction system	Cheapest product on Bunnings website	Cheapest product with NZGBC-recognised eco-label on Bunnings website
Wall	Proroc Plasterboard 10 × 2700 mm $19.95 per sheet	GIB 10 × 2700 mm $25.30 per sheet (Green Tag)
Ceiling	Proroc Plasterboard 10 × 2700 mm $19.95 per sheet	GIB 10 × 2700 mm $25.30 per sheet (Green Tag)
Floor coverings—Carpet	Uncertified* $49/m^2	CIAL ECS L4 certified* $75/m^2
—Timber	HanWood Laminate Flooring 7 mm Honey Oak (coverage per pack 2.37 m^2) $33.18	Kronoflooring from Laminate Direct (Blue Angel) $48/m^2
Roof	Colorsteel (ECNZ)	Colorsteel (ECNZ)
Applied coatings	Spring Interior/Exterior paint low sheen 10 L $48.40 (coverage 14/m^2)	Dulux 10 L Ceiling Paint $92.87 (ECNZ) (coverage not stated, assumed to also be 14/m^2), Dulux 10 L Wash & Wear $148.98 (ECNZ) (coverage not stated, assumed to also be 14/m^2)
Insulation	Knauf Earthwool (Green Tag)	Knauf Earthwool (Green Tag)

STE-2 (native planting)

No additional cost has been assumed for this credit, as to achieve points a project just needs to select native New Zealand plants rather than overseas exotic varieties.

STE-3 (neighbourhood amenities)

No additional costs were allocated to this credit as it is location based. If the site was compliant then points were awarded.

STE-4 (cycling)

Points are allocated in this credit for including cycle parks in the dwelling. The Saris Cycle Glide from www.fishpond.co.nz ($499) was priced and an allowance provided for a builder to spend 1 hour at a rate of $65/hour to install this.

Innovation

Innovation is not typically targeted for 6-Homestar as 60 points can be achieved without any points from this credit.

Soft Costs

In addition to the hard costs, there are soft costs associated with 6-Homestar certification. For this analysis, the costs detailed in Table 7 have been assumed.

Baseline

When determining the relative cost comparison for 6-Homestar, QV Cost Builder was used. Table 3 indicates that the range of dwelling sizes for the 10 dwellings is from 110m^2 to 164m^2. The 150m^2 baseline from QV Cost Builder was therefore selected as this sits in the centre of the size range of the study dwellings. The mid-point of the cost range of $1,975m^2 was then used in the analysis. This correlates well with anecdotal market information provided to the lead author that indicates a typical building rate of $1,800–2,000/m^2 for a NZBC compliant dwelling as shown in Table 8.

RESULTS

In this study three approaches to 6-Homestar have been analysed: (i) the 6-Homestar checklist (using the schedule method), (ii) 6-Homestar points approach (using the schedule method),

TABLE 7. Soft costs associated with Homestar.

Homestar administration and audit fee	Fees determined using the NZGBC Excel pricing calculator dated 1 March 2016	$1,213
Homestar assessor fees	Quote received from a consultant Homestar assessor to undertake the design and built ratings only (no consultancy) on a single dwelling	$2,070
Additional design fees	3 hours of additional design work allowed to enable the architect to include the Homestar features on the plans	$517
Soft costs subtotal (including GST)		**$3,800**

TABLE 8. Exert from QV Cost Builder.

House 150m^2	Unit m^2	AKl $
2.7m high stud to ground and 2.4m high stud to first floor. Rib raft floor slab, colorsteel roof, floor tiles to bathrooms and kitchens, half height wall tiles to bathroom, three or four bedrooms. Medium quality		
Weatherboard cladding, Linea TM		1,875–2,075

and (iii) 6-Homestar points approach (using the ALF calculation). Table 9 summarises the calculated additional costs for each case study dwelling for each of the different compliance paths.

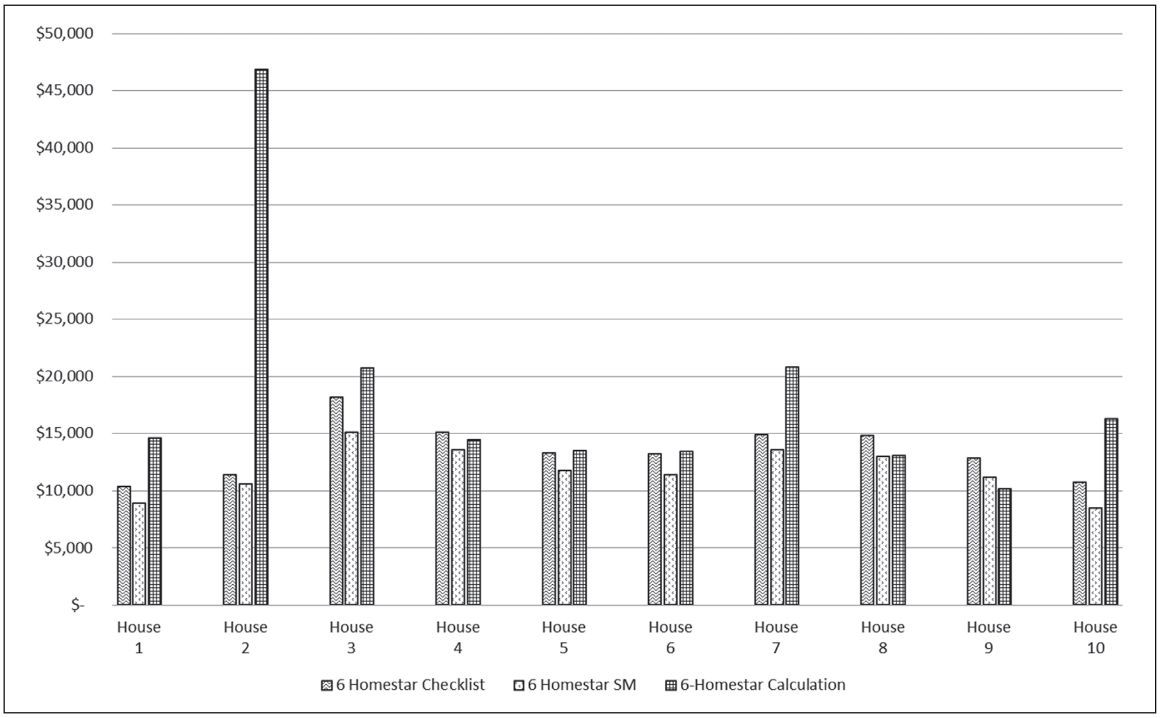
Using the information from QV Cost Builder and applying the median cost of $1,975m^2 to the gross floor area of each dwelling, it is possible to determine a median baseline construction cost of $355,655. Using this baseline, the median increase in capital cost for the case study dwellings to achieve 6-Homestar under version 4 would be between 3–5% depending on the compliance path chosen. For each dwelling the compliance path with the lowest percentage increase is highlighted with **bold grey** while the highest compliance path is highlighted in black with white text.

The (i) checklist method for 6-Homestar was implemented by the NZGBC to reduce the time and cost associated with 6-Homestar assessments. However, as shown in Table 9 and Figure 3, the analysis determined that, for every case study dwelling, this (i) checklist will cost more to implement than the (ii) 6-Homestar points approach (using the schedule method).

TABLE 9. Additional cost for 6-Homestar for each dwelling.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10	Median
i) the 6-Homestar checklist (schedule method—thermal compliance)	3.5%	3.8%	5.9%	5.0%	4.4%	4.4%	4.9%	4.9%	4.3%	3.6%	3.5%
ii) 6-Homestar points approach (schedule method—thermal compliance)	**3.0%**	**3.6%**	**5.0%**	**4.5%**	**3.9%**	**3.8%**	**4.5%**	**4.3%**	3.7%	**2.9%**	**3.0%**
(iii) 6-Homestar points approach (ALF calculation for thermal complianec)	4.8%	14.0%	6.7%	4.8%	4.5%	4.5%	6.7%	**4.3%**	**3.4%**	5.3%	4.8%

FIGURE 3. Options for achieving 6-Homestar in Homestar v4.



Since the schedule method has been used to determine EHC-1 thermal comfort compliance in both the (i) the 6-Homestar checklist and (ii) 6-Homestar points approach in this study, the difference in cost is experienced in other credits in the tool and not in required thermal performance upgrades. In particular, this study finds that additional costs are incurred in the materials credits, especially in relation to eco-label floor coverings which is a mandatory requirement of the (i) checklist approach. This research therefore shows that care should be taken by Homestar practitioners as the approach promoted by the NZGBC as the cheapest and easiest approach to 6-Homestar is in reality more costly to implement.

CONCLUSIONS

This analysis has determined that there is an additional cost to achieve 6-Homestar of 3–5% (as shown in Table 9). This is nearly double compared to previous research into Homestar (Ecubed, 2013; Jasmax, 2013a; Jasmax, 2013b; Rawlinsons, 2018). The use of the schedule method in conjunction with targeting points from the full rating tool is more cost effective then using the NZGBC 6-Homestar checklist in counterpoint to the approach advised as the most cost effective by the NZGBC.

It is clear from Table 10 that the soft costs of Homestar contribute to a significant portion of the overall cost of achieving the certification. One third of the cost of the rating can be attributed to these soft costs, and the majority of that soft cost is built up from the NZGBC admin and audit fee as well as the Homestar Assessors fees. As the overall construction cost of a project decreases, for example in affordable or social housing, the effect of the additional cost from Homestar certification, both in terms of hard and/or soft costs, would become more significant.

TABLE 10. Median additional cost for each 6-Homestar compliance option.

	Checklist with schedule method	Points with schedule method	Points with ALF Calculation method
Median total cost increase from NZBC baseline ($0)	$13,248	$11,677	$14,618
% increase from NZBC baseline using a median cost $355,655 calculated using QV Cost Builder	3.5%	3.0%	4.8%
Median hard costs	$9,448 (71% of total cost)	$7,775 (67% of total cost)	$10,716 (74% of total cost)
Median soft costs	$3,800 (29% of total cost)	$3,800 (33% of total cost)	$3,800 (26% of total cost)

Large, high quality, standalone dwellings will be more likely to be able to absorb the additional costs of 6-Homestar certification when compared to small, efficient affordable/social housing.

Therefore, whilst the calculated additional cost from this study may not appear large, or a barrier to rating tool adoption, anecdotal evidence provided from the market has indicated that the margins in the residential construction market in New Zealand are tight and cannot support any additional cost impact. Indeed, the authors are aware of a least two group home builders in NZ who have dropped their original voluntary implementation of Homestar due to cost considerations. Both of these group home builders have indicated that the consumer is currently ignorant of the benefits of Homestar certification and are therefore not willing to pay a cost premium for rated dwellings. Therefore, whilst the 3–5% range of additional cost may not sound significant, if the consumer is not willing to pay a price premium for the rating, the calculated cost premium would directly erode the developer's margins. This is particularly important in the context of the existence of the multiple stakeholders involved in residential building and the resulting split incentive and principle-agent problem (Fuerst, McAllister, Nanda, & Wyatt, 2016). At this time the green cost premiums are being borne by developers while the purported benefits of reduced operating costs and improved comfort (which are not included or analysed in this research) are enjoyed by occupants. Therefore, whilst lifecycle cost analysis can help identify that the green cost premium associated with thermal performance upgrades can be offset through operational savings if the developer is not also the occupant then the green cost premium may not be acceptable. Zhang (2018) believes that it is only when all stakeholders find the incremental investment for "going green" to be financially feasible can they be stimulated to voluntarily adopt green building. Financial feasibility for green building may therefore only be demonstrable to developers through sales premiums for green buildings, which the literature has identified and recognised in certain world property markets (Eichholtz, Kok, & Quigley, 2010; Fuerst & McAllister, 2011; Miller & Pogue, 2009; Pivo & Fisher, 2009). Future research could therefore focus on whether or not there is a sales price premium associated with 6-Homestar rated dwellings.

In addition, this research highlights the importance of studying a range of house designs. House designs are not generic with items such as glazing area, roof area, floor area and wall area all varying. Each house will therefore tend to need a tailored design response to enable thermal performance benchmarks of 6-Homestar to be obtained. This can significantly impact on construction cost as indicated by Table 9 with three dwellings experiencing additional capital costs of between 6.7% to 14.7% using the ALF compliance path. Each dwelling therefore must be treated as a unique assessment for a 6-Homestar rating, and Homestar Assessors and Practitioners, who wish to provide an appropriate service to their clients, must follow the flowchart presented in Figure 2 and undertake an analysis under each thermal analysis pathway. To not do this, and instead follow the suggested path from the NZGBC of using the schedule method, could result in a poor service to clients as this is in almost all cases the most costly method of compliance, as shown in Table 9.

This comparative cost analysis has built on previous research into the cost of Homestar providing more robust findings being based on actual rather than theoretical house designs and a larger sample size. All previous research into Homestar has focused on single dwelling designs using a single thermal analysis pathway. This research concludes that it is not possible to draw relevant conclusions on capital cost impacts from studies such as these, due to the inherent nuance and complexity of holistic rating tools, like Homestar and its myriad thermal assessment methodologies. In particular the impact of Homestar on potential outliers such as Dwelling 2 is lost in research that focuses on a single dwelling design. It is also clear from this research that there is not one path that fits all and that different designs are best to tackle different thermal compliance paths. In this study whilst 90% of the dwellings would find the schedule method the most cost effective thermal analysis methodology, 10% of dwellings (Dwelling 9) would be better off using ALF.

Whilst improving upon previous research this study is currently limited in its widespread applicability to the New Zealand residential market as it is grounded in a series of ten case study dwellings in one sub-market in Auckland. Whilst providing stronger results than the previous research to date, care should be taken if trying to apply this research to other climate zones within New Zealand as the results would likely differ due to the different thermal performance benchmarks for each climate zone in Homestar, and future research could therefore focus on applying this methodology to alternative climate zones of New Zealand to allow a more national perspective.

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