Study Report

SR391 [2018]

The cost of Homestar: A case study on how to achieve a 6–10-Homestar rating for stand-alone and terraced housing in Hobsonville Point

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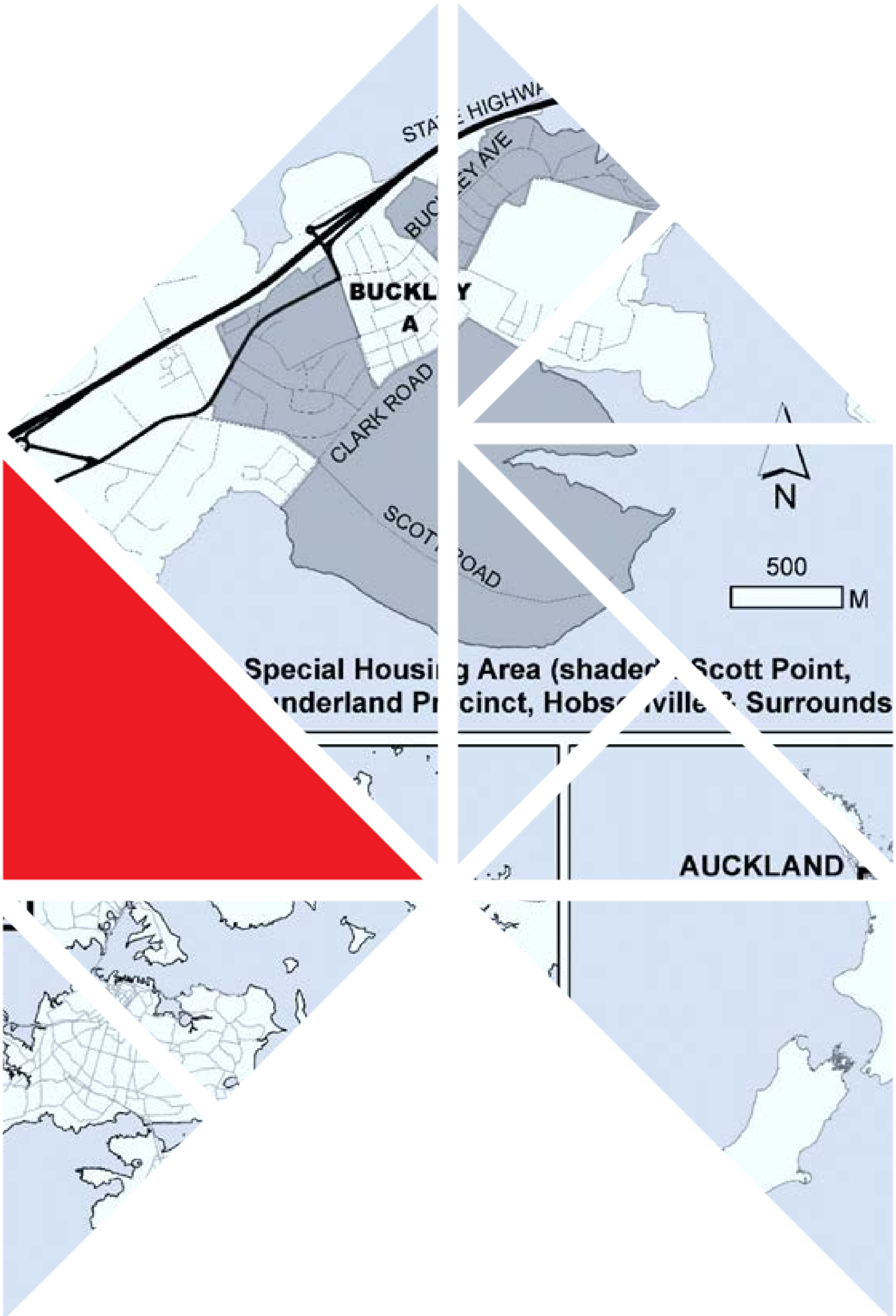

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Funded from the
Building Research Levy

The work reported here was funded by BRANZ from the Building Research Levy.

ISSN: 1179-6197

Preface

This research aimed to determine the various additional capital cost commitment that would be required to achieve a 6, 7, 8, 9 and 10-Homestar rating from a standard Building Code-compliant design for 10 case study dwellings comprising of stand-alone and terraced housing in the Hobsonville Point submarket.

Acknowledgements

Thanks to Shanika Ekanayake BSc (QS) for reviewing and confirming the costs associated with each case study dwelling.

Further thanks to the tireless efforts of Dr Michael Rehm of Auckland University for reviewing and providing input and feedback on a constant basis.

Additional thanks to Jason Quinn for reviewing and providing feedback and input into the Passive House Planning Package (PHPP) modelling process.

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Reference

Ade, R. (2018). *The cost of Homestar: A case study on how to achieve a 6–10-Homestar rating for stand-alone and terraced housing in Hobsonville Point.* BRANZ Study Report SR391. Judgeford, New Zealand: BRANZ Ltd.

Abstract

This research performed a desktop analysis of 10 Building Code-compliant stand-alone and terraced residential designs to determine the additional capital cost investment required to achieve the higher levels of Homestar. The designs analysed were selected from the Hobsonville Point submarket and had not considered Homestar in their basic design.

This report has a narrow focus, reviewing only the costs and benefits of Homestar that can be readily quantified. The benefits considered only relate to energy and water use savings and do not consider other benefits such as health, resale value, comfort, quality or resource depletion. It is acknowledged that the choice to include 'green' features in new housing is not made solely or even predominantly on cost-saving measures. Hence, the results in this report are only one part of the decision-making process.

The results show that Homestar version 4 (v4) has greatly reduced the capital cost of achieving the different levels of Homestar ratings compared to previous Homestar assessment (Homestar v2 and v3), with a 6-Homestar dwelling costing approximately 4% more to construct than basic Building Code-compliant dwelling.

Keywords

Homestar rating tool, costs, benefits, sustainable, new housing, energy efficiency, thermal performance.

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Executive summary

This research aimed to determine the additional capital cost required to achieve a 6, 7, 8, 9 and 10-Homestar rating from a standard Building Code-compliant design. Ten case study dwellings were used, comprising stand-alone and terraced housing in Hobsonville Point, Auckland, that had not considered Homestar in their basic design.

Each dwelling has a different owner and different builder. Some have been developed by large developers, some by group home builders and some by individual homeowners, thus representing a wide cross-section of the general residential construction submarket in Hobsonville. However, since Hobsonville is a master-planned development, the designs selected for study may lack some of the natural variation that might occur if the dwellings were selected at random from other submarkets in Auckland or around the country.

This research performed a desktop analysis of the residential designs to determine the additional capital cost investment required to achieve the higher levels of Homestar using the different versions of the rating tool – Homestar versions 2, 3 and 4.

The results of this desktop analysis have indicated there is an additional cost to achieve not only 6-Homestar but also the higher levels of Homestar in all versions of the rating tool. This is to be expected, as the quality of the dwelling is being increased from a Building Code baseline.

For a 6-Homestar rating, the study has determined a median additional cost of 3–5% depending on the version of the rating tool that is used, with 7-Homestar attracting an additional cost of 12% for Homestar v2 and v3 but only 4% for Homestar v4. The expected additional costs determined differ from those of previous studies, with this analysis estimating the expected costs as higher than the previous studies.

The results also show that Homestar v4 has greatly reduced the capital cost of achieving the different levels of Homestar ratings compared to previous Homestar assessment (Homestar v2 and v3).

The certification costs of Homestar can vary from as little as $380 to as much as $3,800 per dwelling. For a single, unique dwelling design, the certification cost is in the region of $3,800. This study examined only one-off homes (unique design for each home) and, therefore, certification makes up a significant portion of the total cost of achieving 6 and 7-Homestar. However, if a single dwelling design is repeated numerous times, the cost of certification is spread across each home and can be as low as $380 per dwelling. This report determines that the median cost of achieving a 6-Homestar rating is reduced from 3% to 2% if more than 10 dwellings are certified from a single design.

It is also noted that analysing the benefits of Homestar only in terms of its operational savings does not allow consideration of the additional potential benefits of a green building rating tool such as improved indoor environmental quality, leading to improved occupant health, comfort and satisfaction, and increased sales price. It is therefore highly important that the benefits be discussed within a wider context.

It is also suggested that an additional piece of research is undertaken comparing and contrasting the requirements of Homestar v4 with the Building Code, highlighting where they cover the same issues and where Homestar covers elements that the

Building Code does not. This research should also seek to determine which elements of Homestar would benefit from being included in the base Building Code as a minimum requirement for all dwellings.

1. Introduction

In the New Zealand construction industry, there is currently an underlying assumption that implementing environmental options in residential buildings will automatically increase the total cost of constructing that dwelling.

In the international market, particularly in countries where green building rating tools have been used for longer, this assumption has been challenged (Matthiessen & Morris, 2004; Matthiessen & Morris, 2007). In some cases, buildings that have used a green building rating tool have been constructed for less than a traditional building (Davis Langdon, 2010).

In New Zealand, only a few studies have been undertaken into the residential building sector to determine the existence and extent of construction cost premiums associated with green home certification (eCubed Building Workshop, 2013; Jasmax, 2013). In 2013, eCubed Building Workshop undertook a study at the request of Auckland Council to identify the costs and benefits of achieving 5, 6 and 7-Homestar (the version of Homestar is not stated but it is assumed to be version 1 of the rating tool). Their desktop study determined the theoretical additional costs of achieving a 5, 6 or 7-Homestar rating as being $2,223, $5,223 and $14,337 respectively.

A second study also undertaken in 2013 by Jasmax determined Homestar ratings 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) could be achieved for the following construction cost increases over typical practice, shown in Table 1 (Jasmax, 2013).

Table 1. Cost increase for 5, 6 and 7-Homestar rating in Auckland.

Homestar rating	$ increase	% increase on $550k capital cost
5-Homestar	$3,237.50	0.6%
6-Homestar	$6,437.50	1.2%
7-Homestar	$16,241.50	3%

Jasmax undertook a second study in the same year, this time studying a theoretical 4-bedroom/190 m^2 new dwelling in Christchurch. At the time of undertaking the study (December 2013), construction cost increases over typical practice are shown in Table 2 (Jasmax, 2013).

Table 2. Cost increase for 5, 6 and 7-Homestar rating in Christchurch.

Homestar rating	$ increase	% increase on $550k capital cost
5-Homestar	$2,260	0.4%
6-Homestar	$3,612.50	0.7%
7-Homestar	$27,332.50	5%

This BRANZ study aims to build on this limited body of knowledge by further exploring the potential additional costs that a dwelling could be expected to experience across the different levels of 6–10 Homestar v2, v3 and v4.

2. Background to Homestar

Homestar is a comprehensive, national, voluntary environmental rating tool that evaluates the attributes of New Zealand's stand-alone homes, townhouses and apartment dwellings. Homestar allows homeowners and tenants to assess their home, providing a scale that creates value around warm, healthy, sustainable and efficient homes. Homestar rewards and recognises improvements in both the home's comfort as well as the impact that the home has on the environment. A Homestar Built rating is an official confirmation of how well a home performs or will perform against the Homestar criteria.

2.1 Star bands

Homestar has been developed to enable both existing and newly built homes to undergo assessment. Older homes have not been built to modern Building Code standards, and the Building Code itself does not address all the categories covered by Homestar. The star bands for Homestar have to cater for a variety of standards of housing and their environmental attributes. The Homestar star bands and scores are shown in Table 3.

Table 3. Homestar score required for different star ratings.

Rating	Homestar v2 and v3 required score	Homestar v4 required score
1-Homestar	0–19.9	rating level removed
2-Homestar	20–29.9	rating level removed
3-Homestar	30–39.9	rating level removed
4-Homestar	40–49.9	rating level removed
5-Homestar	50–59.9	rating level removed
6-Homestar	60–69.9	60–69.9
7-Homestar	70–79.9	70–79.9
8-Homestar	80–89.9	80–89.9
9-Homestar	90–94.9	90–99.9
10-Homestar	95–100	100+

2.2 Homestar rating

Some core issues within Homestar are considered so important that a minimum performance level needs to be achieved before progress up the stars can be made. These are referred to as mandatory minimum levels. If the assessed dwelling fails to achieve these mandatory minimum levels, no matter what the performance is in other areas of the tool, the minimum levels will limit the final star rating. Apart from these mandatory minimums, Homestar is flexible and the homeowner or tenant can choose which credit criteria to meet. To achieve a Homestar rating, a house must meet the mandatory minimum requirements of the version of the tool that is being used and then achieve the requisite number of points required to achieve the desired Homestar rating level. For example, for 6-Homestar, 60 points must be obtained. Details of the minimum levels, as well as further information on Homestar, is provided in Appendix B.

3. Methodology of the study

Ten case study dwellings were selected, semi-randomly, from the Hobsonville Point development area in Auckland . The dwellings were selected from the data set of a complementary BRANZ study, examining the cost and value of Homestar in Special Housing Areas (SHAs), and were selected to allow a cross- section of group home builders, large developers and individual small builders to be represented.

The dwellings selected were buildings that had not considered Homestar when the basic design was being undertaken and therefore orientation, compactness and glazing areas were not optimised as may have occurred if Homestar was used from concept design. To reflect resource consent limitations that frequently occur in master-planned developments such as Hobsonville Point, the basic design of each dwelling, in terms of orientation and floor area, was held constant throughout this analysis.

These dwellings were analysed using the different Homestar versions to determine the various cost impacts of the different star bands. The dwellings were selected from the Hobsonville Point area to enable a direct comparison, complementing another BRANZ study examining the cost and value of Homestar in Special Housing Areas (SHAs).

3.1 Hard costs related to Homestar v2 and v3

Hard costs relate to tangible items that need to be procured to complete the building, including the cost of acquiring the site, the building structure, finishes, materials and landscaping. When calculating the additional hard costs experienced, the researcher has taken a baseline of what would typically be done to satisfy the Building Code. For example, water efficiency of fixtures and fittings is not considered in the Building Code. Therefore, to determine the potential additional costs to achieve Homestar, the researcher selected the least-expensive fixture or fitting that is available on the Bunnings website. Once the compliant device was selected, the additional cost of Homestar was determined by calculating the difference between the Building Code-typical and least-expensive 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. Therefore, any items that attract additional cost within any product or material would also attract a margin. It is also worth noting that trade discounts might be applicable to some costs and therefore costs may be overestimated in some areas, representing a worst-case scenario.

When building up the points scores for each level of Homestar rating, the researcher has taken the approach of targeting the most cost-effective points first. For example, in some instances, to get the higher levels of Homestar, the researcher has decided to target points in the innovation category rather than targeting the WAT-3 (greywater reuse) credit as it was determined to be cheaper to achieve the innovation points. The researcher has also targeted just enough points to push a dwelling over a rating threshold. In practice, 3–5 buffer points would typically 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 lower than reality.

The researcher has then determined the additional cost of Homestar using the assumptions set out in sections 3.1.1–3.3.7).

3.1.1 Energy, health and comfort (EHC)

In most cases for the 10 case study dwellings, space heating (EHC-1) is to be provided using plug-in electric wall heaters heating 100% of the dwelling. These will be supplied by owners, and there is therefore no cost. However, in some instances, the space heating, as detailed on the building consent plans, was to be provided by a heat pump. In the cost analysis, we have not included this as an additional Homestar cost as this was already shown on the plans before Homestar was considered. For the higher levels of Homestar where fixed space heating is required to achieve additional points, the use of a heat pump has been assumed. This has been costed using information from www.heatpumpguys.co.nz/heat-pump-faqs, which indicates that a heat pump system can be supplied and installed for $4,500.

In most dwellings, hot water (EHC-2) is to be provided by a mains-pressure hot water cylinder. This was costed using www.hotwatercylinders.nz, and an installed price of $1,700 was used. In some instances, the building consent drawings detail an instantaneous gas heater. In these cases, the same website was used to determine a supply and install price of $2,800. In the basic cost analysis, we have not included any cost differential for these items as they were already shown on the plans before Homestar was considered. For higher levels of Homestar, we have assumed that hot water will to be provided by a hot water heat pump (270 L) with the cylinder located outdoors. This has been costed using information from www.aquafire.co.nz/promo.aspx, which indicates that a hot water heat pump can be supplied and installed for $4,995. The respective hot water cylinder and instantaneous gas prices have then been subtracted from this figure as appropriate.

Lighting (EHC-3) is typically required to be LED throughout a dwelling for both interior and exterior lighting to achieve full marks. As building consent drawings do not require lighting designs to be shown, the researcher has assumed that there will be approximately 30 light bulbs in the dwelling in line with the Home Lighting Survey (Burgess et al., 2009). All interior and exterior lights were assumed to be LED in line with current market practice in New Zealand. To be awarded the full lighting points, all exterior lighting is also required to be either sensor activated with daylight cut off or be photovoltaic powered. An HPM light patrol movement sensor has been costed from Bunnings for $36.40.

Whiteware and appliances (EHC-4) were selected using www.priceme.co.nz. The cheapest fridge on this website, the Iceland KS245L ($350), which has no energy rating, was used as the benchmark. The Westinghouse WRM2400WD ($1,149.50), currently the cheapest fridge with a 2.5 energy rating, was then used as the Homestar price benchmark. For the dishwasher, the Vogue VGDWW2 ($395), which has no energy rating, was used as the benchmark. The Imprasio IDW14STS ($699), the cheapest dishwasher with a 4 energy rating, was used as the Homestar price benchmark.

Where points for renewable energy (EHC-5) would be needed for higher levels of Homestar, the researcher has assumed that 12 solar panels (or 3 kW) would be supplied by Mercury Energy. This was priced using the Mercury Energy website (https://www.mercury.co.nz/Products/Solar.aspx?gclid=CjwKEAjwpdnJBRC4hcTFtc6fwEkSJABwupNiQdObuibNmt8GrHJVfVvUlRhGM0p8VvkqkFxhMIxM9BoCks3w_wcB) as being supplied and installed for $10,495.

In terms of whole-dwelling thermal performance (EHC-6), we discuss the detailed implications individually for each of the case study dwellings in Appendix A.

In terms of moisture control (EHC-7), a dwelling has to provide either overflows to all sinks and tubs or install floor wastes for all wet areas. Typically, this can be achieved with no additional cost. The bathroom extracts must be automated (for example, using a humidistat) or hard wired to a light switch with a suitable delay. The researcher has assumed that this will be achieved through hard wiring to a light switch, and there will be no additional cost. The extract grilles then need to have angled blades and a weather cover. Again, this can typically be achieved with no additional cost, as these types of grilles are typically provided on Building Code-compliant houses in the experience of the researcher. Security stays are then required to be fitted to all openable windows required for natural ventilation, allowing them to be secured against intruder entry while open (i.e. to at least 10 mm along one edge). For this, the independent quantity surveyor has used QV costbuilder to cost window stays (bronze, $29.50 each) from Bunnings. The number of opening windows was counted off the drawings, and it was assumed that installation would take a half an hour for each security stay at an hourly rate of $33.21/hour for a building labourer.

For washing lines (EHC-8), the researcher has assumed that no washing line would be provided as a worst-case benchmark. A main washing line outside with at least 18 metres of line as required by the Homestar Technical Manual was priced from Bunnings (Wattle Retractable Clothesline 6-Line Grey, $148.98), with a secondary washing line of the same provided in the garage/carport. It was then assumed that it would take a building labourer half an hour to install these at an hourly rate of $33.21/hour.

For acoustics (EHC-9), 0.25 points are available for each of the following features:

- **Windows – perceived sound reduction (PSR) >25% or sound transmission class (STC) of 33**
  Standard double glazing units of 4/12/4 have an STC of 30. Increasing the glazing to 6/12/6 improves the STC to 34, which is compliant with the requirement. The researcher has been advised by Viridian Glass that the additional cost associated with this would be $80/m^2.
- **Mechanical ventilation or trickle vents**
  At no time did the researcher target the mechanical ventilation or trickle vents points due to the additional cost implications of this technology.
- **Noisy room with double layer of plasterboard, provision of a noisy room and solid core door to noisy room**
  When pricing the additional cost for the noisy room points, the researcher determined one room of the dwelling (likely a bedroom) would be designated as a noisy room. This room would receive acoustic insulation and a double layer of plasterboard along with a solid-core door. The bedroom designated as a noisy room has a wall area of 20 m^2. Using Earthwool glass wool wall insulation from EHC-6 (R2.8 6.73 m^2, $111.56 from Bunnings), three rolls of insulation would be required. Assuming standard 2.4 x 1.2 m plasterboard, we allowed for 10 additional sheets (wastage) at a cost of $20 per sheet. The researcher then assumed that it would take the builder 2 hours to install these additional items at an hourly rate of $65/hour. A standard hollow-core Hume door can be purchased for $49.50 from Bunnings, while a new solid-core door was located on Trade Me for $284. No additional labour has been allocated for the installation of this door.
- **Carpet or acoustic insulation to 80% of liveable rooms (by count)**
  The researcher assessed whether the dwellings' original proposed Building Code

design was compliant with the criteria. It the design was compliant, points would be awarded. If the design was not already compliant, no changes were made to allow these points to be achieved due to the high cost and design impact of the change and the low number of Homestar points available (0.25 points) and therefore there is no cost associated with this part of the credit.

- **Non-rigid plumbing**
  It was determined that non-rigid plumbing connections could be provided for no additional cost.

When targeting points for the higher levels of Homestar in this credit, the researcher started with the carpet points and would then add the three noisy room points followed by others as required.

No additional hard cost was determined to be applicable to inclusive design (EHC-10) when 3 or 4-star Lifemark was targeted, as these items can typically be achieved through the design process and changes that would only be implemented before construction starts on site. It is noted that certain elements of the inclusive design requirements could potentially attract additional cost that has not been considered in this study. For example, it has been assumed that level access for showers and front doors can be achieved at no additional cost and that there would be no additional framing costs for showers and toilets as offcuts on site could be used. The researcher did, however, allow 3 hours of additional consultant time at $150/hour for reviewing and modifying the drawings. For 5 star Lifemark certification, an additional cost of $495 was added for the Lifemark certification fee.

The case study dwellings were all assessed to be already compliant with receiving full points for natural lighting (EHC-11 in Homestar v3 only) without requiring any changes to the Building Code design. Therefore no additional costs have been attracted here.

3.1.2 Water

For rainwater harvesting (WAT-1), a 3,500 L rainwater tank connected to WCs and laundry was assumed. The cost allocated to the provision of this tank was costed in the following manner:

- The use of an above-ground Devan water tank 3,500 L ($1,000 delivered to site, www.devan.co.nz/online/Water_Tanks_Products).
- A potable water pump ($370, www.pumpstore.co.nz/auto-water-tank-pressure-pumps-c-28_32_37.html?zenid=m6sb725ge63ks8b15n6nemvu43).
- An estimate of $250 for PVC piping.
- A $1,000 allowance for a plumber.
- A $1,000 allowance for groundworks and the creation of a concrete pad for the rainwater tank to sit on.

In addition, some dwellings required a larger 15,000 L tank to achieve higher points here. For, this an above-ground Devan water tank 15,000 L was costed ($2,600 delivered to site, www.devan.co.nz/online/Water_Tanks_Products).

In terms of fixtures and fittings (WAT-2), the researcher is aware that most showerheads meet the mandatory minimum requirement of <9 L/min and that most WCs these days meet the mandatory minimum requirement of being dual flush with a 6/3 L flush. However a check was undertaken to confirm this. The Bunnings website listed the cheapest shower as the Flexispray Aurora hand shower, retailing at $29. This shower has a WELS 3-star rating with a 6-Homestar-compliant flow rate of 9 L/min.

The cheapest basin mixer for sale at Bunnings was the Modella Basin Miser Main ($44), which had a WELS 3-star rating. This matches the cheapest kitchen sink mixer (Modella Cadenza sink mixer, $44), which holds a WELS 3-star rating. Unfortunately, taps need to have a WELS 4-star rating to be awarded any points in Homestar, so should these points be targeted, an upgrade would be required. The cheapest WELS 4-star rated basin mixer on the Bunnings website was the Foreno Espree Basin Mixer for $69.95. The least expensive kitchen mixer with a WELS 4-star rating on the Bunnings website was the Modella Cadenza sink mixer extended lever all pressures. This retails for $109.

For toilet suites, the cheapest listed on the Bunnings website is the Dux Delmonte cistern and seat pack for $95.35. This has a WELS 3-star rating and is compliant with the 6-Homestar requirement. However as a consultant, the researcher typically suggests that a WELS 4-star toilet be provided. The cheapest listed on the Bunnings website with a WELS 4-star rating was the Stylus cistern and seat Tasman MK II White for $173.19. The researcher therefore added these additional costs into the calculations where appropriate.

For the dishwasher, the Imprasio IDW14STS from EHC-4 has a WELS 4.5-star rating.

In terms of washing machines, the researcher again referred to www.priceme.co.nz. The cheapest washing machine available on this website, the Vogue WM.VG.6KG ($350), held a WELS 3-star rating, automatically achieving 0.3 points in Homestar. The researcher therefore used this as the benchmark. A WELS 5-star clothes washing machine, Miele WMV960WPS, was priced at $4,499. The benchmark of the Vogue WM.VG.6KG ($350) with a WELS 3-star rating from the 6-Homestar rating was then subtracted from this figure where appropriate.

In the few instances when greywater reuse (WAT-3) points have been targeted (typically for the high levels of Homestar rating), this has been accounted for through the assumed installation of a greywater treatment system connected to irrigation, laundry and toilets. The Aqualoop 6 by ALOAQUA was priced with a supply cost of $7,580. The researcher has then allowed an additional $2,000 for PVC piping in conjunction with a lump sum of $2,000 for plumbing installation based on expert advice. Homestar requires that the greywater system be council approved. An allowance of $5,000 for this approval to be sought has therefore been included.

3.1.3 Waste

For construction waste management (WST-1 and WST-2), the researcher has allowed for a consultant to spend up to 2 hours at $150/hour to write a site-specific waste management plan. Then if the dwelling was built using the services of a waste management company like Green Gorilla (who can recycle 80–90% of the construction waste at their waste diversion facility), it should be possible for the dwelling to divert its construction waste from landfill at no additional cost.

To verify this, the researcher checked the websites for a number of bin providers and determined that Green Gorilla advertise 9 m^3 bins for $350, while Just Bins advertise a 9 m^3 bin for $350, Discount Bins advertise a 9 m^3 bin for $350 and Blue Bins also advertise a 9 m^3 bin for $350. In most instances, lower levels of waste diversion have been targeted, which is in line with Green Gorilla's performance of being able to divert around 80% of construction waste from landfill. However, some dwellings have needed to target higher points for WST-2 to achieve the different levels of Homestar. In these instances, the researcher has allocated an additional $1,000 of management time to enable these higher levels of diversion to be achieved.

For internal and external recycling facilities (WST-3), it is relatively standard 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, the researcher has assumed no additional cost here.

For internal and external composting facilities (WST-4), again it is simple for a 2 L ice cream container to be provided in the kitchen, and the researcher has therefore assumed no cost here. In terms of external facilities, a worm farm ($105) from Bunnings has been priced.

3.1.4 Management

Security (MAN-2) contains a number of different elements, the majority of which will attract no cost. For example, the provision of a main entrance visible from the street, a window in the dwelling that allows street surveillance, hot water to be no more than 55°C at the tap (a Building Code requirement), smoke alarms to be located within 3 m of bedrooms (a Building Code requirement) and a storage location for hazardous materials either greater than 1.2 m in height or with childproof locks should all be achievable with no additional capital cost.

However, two items would attract additional cost. The first – security stays for windows and locks for doors – has already been accounted for in EHC-7. The second – a family shield fire extinguisher (2.5 kg) – can be purchased for $52.98 from Bunnings. The researcher has further allowed that installation would take a half an hour for each security stay at an hourly rate of $33.21/hour for a building labourer (source: QV costbuilder).

For management issues such as the home use guide (MAN-3) and environmental management plan (MAN-4), the researcher has allowed for a consultant to spend up to 2 hours at $150/hour to write each of these plans.

3.1.5 Materials

Many people believe that Homestar is heavily interested in materials and that it will therefore be hard and costly to achieve points in these credits. This is not the case in Homestar v2 and 3, and full points can currently be achieved in MAT-1 using relatively standard building products such as GIB plasterboard, Resene/Dulux/Wattyl paints, Pink Batts/Autex/Knauf/Bradford Gold insulation and Colorsteel roofing. When starting this study, the researcher believed that these were all standard products used on almost every dwelling and therefore should have attracted no additional cost. However, it was important that this was verified, as during the course of the interviews undertaken throughout the concurrent Homestar cost and value study, builders have indicated an average additional cost of around $2,000 to purchase carpets that hold an eco-label recognised by the NZGBC (in most instances, CIAL ECS L4). In addition, some commented that more cost-effective plasterboard and paints would have been selected if not for the Homestar MAT-1 credit.

This surprised the researcher, and therefore the costings have been researched and determined for the construction systems materials points are typically targeted under (Table 4).

Table 4. MAT-1 costings.

Construction system	Cheapest product on Bunnings website	Cheapest product with NZGBC-recognised eco-label on Bunnings website
Wall	Proroc Plasterboard 10 x 2700 mm $19.95 per sheet	GIB 10 x 2700 mm $25.30 per sheet (Green Tag)
Ceiling	Proroc Plasterboard 10 x 2700 mm $19.95 per sheet	GIB 10 x 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)

*Prices determined using www.floorwise.co.nz.

It can be seen that plasterboard, applied coatings and floor coverings all attract additional cost for products with an eco-label. The researcher has therefore used these additional costs in our analysis for this credit.

For VOCs and toxic materials (MAT-2), points can be achieved 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. For higher levels of Homestar ratings, additional VOCs and toxic materials (MAT-2) points can be achieved for adhesives and sealants and engineered wood. For adhesives and sealants and engineered wood, the researcher verified, using the Bunnings website, the most cost-effective products in each category type. In each case, that product was compliant with the NZGBC low-VOC criteria. However, an additional hour of consultant time has been allocated to track the materials used and verify their VOC compliance.

Table 5. MAT-2 costings.

	Cheapest product on Bunnings website	Cheapest VOC-compliant product on Bunnings website
Adhesive and sealant		
Wallboard adhesive	Bostick Gold Ultra Wallboard adhesive 375 ml	
Shower waterproofing	Cemix Rubberguard 15 L	
Tile adhesive	ADOS Greenstik tile adhesive 4 L	
Tiling sealant	Cemix 310 ml white tiling sealant	
Engineered wood product		
Plywood	1200 x 600 x 18 mm with E0 emission	
Internal door	Hume pre-primed MDF skin honeycomb core flush door – low VOC and FSC certified	
Kitchen, bathroom, wardrobe cabinetry	Melteca with E0	

3.1.6 Site

The inclusion of a rainwater tank in WAT-2 allows 0.5 additional points in STE-1 (stormwater) to be achieved for dwellings that have a good roof area:tank size ratio at no additional cost, as the rainwater tanks are retaining stormwater on site. In various instances for the higher levels of Homestar ratings, the researcher targeted points for higher percentages of the site (area not under roof) to be permeable. In reality, this would likely result in cost savings for many projects as it is cheaper to provide grassed areas rather than concrete and/or paving. However, as a worst-case scenario, the researcher has assumed that these changes will be cost neutral.

For landscaping (STE-2), all that is required is to select native New Zealand plants rather than overseas exotic varieties. The researcher has therefore assumed no additional cost. For the higher levels of Homestar ratings, this credit ties in with achieving STE-1 above, as greater areas of the site are required to be permeable. These can be planted in native grasses and plants.

On-site food production (STE-3) requires the installation of a minimum 4 m^2 vegetable garden and four fruit trees for a house with 4 or more bedrooms. The researcher has therefore costed the installation of three Eco-Box Macrocarpa Kitset Gardens 20 x 900 x 2,000 mm ($91.99 each) from Bunnings and allowed a building labourer 1 hour to assemble at an hourly rate of $33.21/hour. The purchase of four Citrus Lemon & Lime Double ($36.96 each) from Bunnings has also been costed with an allowance for a building labourer 1 hour to install at an hourly rate of $33.21/hour.

The final credit in the tool where points have been targeted, transport (STE-4), is based on the location of the site, and therefore no additional cost has been assumed.

3.1.7 Innovation

The purpose of the innovation section in Homestar is to recognise and encourage the uptake of building initiatives that are not currently included in the rating tool but that significantly reduce the environmental impact of the home. In most instances for the higher levels of Homestar ratings, innovation points are required to be targeted. Using the NZGBC's innovation summary, we have targeted the simplest previously awarded innovations.

The first of these (INN-1) is the inclusion of an electric car charging point in the garage of the dwelling. The researcher has costed this using https://juicepoint.myshopify.com/ as being able to be supplied and installed for $1,299.

The second (INN-2) is a shower drain heat recovery unit on one shower in the dwelling. Indicative pricing from www.heatback.co.nz/order shows one of these can be supplied and installed for $1,200.

The third (INN-3) is around information sharing. To achieve this innovation, projects need to set up and maintain an information blog or website about the dwelling project. The researcher has allocated $500 for this innovation. In general, the researcher assumes that single-home owners who are targeting higher levels of Homestar would probably undertake this innovation in their own time at no additional capital cost. However, in some instances, perhaps a project team member would be engaged to do this work, and therefore we have allowed $500 for someone to set up and periodically maintain a simple website using something like wix.com or Facebook.

The fourth innovation (INN-4) is for the use of the GIB EzyBrace system, which helps reduce thermal bridging. The researcher has not allocated any additional cost for this innovation as this system is readily available for use at no additional cost in the market according to builders consulted.

The fifth (INN-5) is for including cycle parks in the dwelling. The researcher has priced the Saris Cycle Glide from www.fishpond.co.nz for $499 with an allowance for a builder for 1 hour at a rate of $52.98/hour to install this.

3.2 Soft costs

In addition to the hard costs, there can be some soft costs associated with Homestar. For this analysis, the researcher has assumed the costs detailed in Table 6.

Table 6. 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**

These are the soft costs that would be associated with undertaking Homestar on a single dwelling. Should the same design be replicated a number of times throughout a larger development, this cost would reduce on a per dwelling basis. For example, if one design was replicated 10 times, the costs from Table 6 would be spread across 10 dwellings, resulting in a cost per dwelling of $380 rather than $3,800, as advised by Sam Archer from the NZGBC. This could make a large difference to the overall cost of implementing Homestar and should be considered when making decisions on the use of Homestar and how best to apply it. Replicating a smaller number of designs many times will always be more cost efficient when compared to single, one-off or bespoke designs, which is what this report addresses.

3.3 Hard costs related to Homestar v4

3.3.1 Energy, health and comfort

Homestar v4 differs greatly from the previous versions of Homestar and the previous EHC-6 (whole-dwelling thermal performance), which is now EHC-1 (thermal comfort). The costs associated with EHC-1 are discussed in Appendix A.

The mandatory minimums have also changed in Homestar v4, and it is now a requirement in EHC-2 (efficient space heating) 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 have been costed as the most cost-effective fixed heating mechanism. These retail for $39 each on the Bunnings website, and the researcher has allowed for one to be installed in the main living room in accordance with the mandatory minimum requirements. These can be plugged straight into a power point, so the researcher has only allocated half an hour for a builder to mount it on the wall.

The previous EHC-7 mandatory minimum requirement has been moved to EHC-3 (ventilation). This can now be achieved by providing:

- a dedicated rangehood 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 is not currently included in the building consent drawings for the case study dwellings is a 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 Trade Me for $50. A standard Manrose extractor fan can be purchased on the same website for $37. No additional installation cost has been allowed for here as the building consent drawings already show an extract fan to be installed to each bathroom.

Another new mandatory minimum requirement has been added to the new EHC-4 (surface and interstitial moisture) credit. In general, for the case study dwellings to meet the EHC-1 mandatory minimums, slab edge insulation was required to reach the required R-value of R1.3. 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 were also required to have insulation to meet the mandatory minimums, and therefore another point can be awarded in this credit at no additional cost as any additional cost is accounted for in EHC-1. 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. The researcher has therefore allocated no additional cost to attaining points in this credit.

Hot water is now addressed in EHC-5, and the approach is unchanged from Homestar v2 and v3. The researcher has therefore not changed the costing approach from what was discussed earlier.

Lighting was previously addressed in EHC-3 but is now addressed in EHC-6. To be consistent with our conservative approach for Homestar v2 and v3, the researcher has again used Tellus halogen downlights from Lighting Plus ($21.90 each) as a benchmark price and then upgraded to Saturn (RD) 8W LED downlights also from Lighting Plus ($22.90 each) as the Homestar lighting.

The case study dwellings were all assessed to be already compliant with receiving full points for natural lighting (EHC-6) without requiring any changes to the Building Code-compliant design. Therefore, no additional costs have been attracted here. The researcher has also not modified the approach to EHC-8 (renewable energy), and the same additional costs as previously detailed remain valid.

The EHC-9 (sound insulation) credit has been simplified from Homestar v2 and v3, with the new credit comprising of three simple items, attracting 1 point each.

- **Windows – PSR >25% or STC33**
  6/12/6 double glazing achieves the STC33 requirement. However, the researcher was advised during the course of the research that 4/12/4 is the most common type of double glazing and this only has an STC of 30. The researcher has been advised by Viridian Glass that the additional cost associated with this would be $80/m^2$.

- **Mechanical ventilation or trickle vents**
  The third point in this credit is around ventilation and the dwelling having either trickle vents or being mechanically ventilated. At no time did the researcher target the mechanical ventilation or trickle vents points due to the additional cost implications of this technology.
- **Carpet or acoustic insulation to 80 % of liveable rooms (by count)**
  The carpet or acoustic ceiling tile point has been modified from Homestar v2 and v3 from a measurement 80% by room count to 80% by m^2. Where dwellings have achieved the requirement, the points have been awarded, but the researcher has not specifically modified the designs of the dwellings the high cost and design impact of the change and therefore no cost has been allocated here.

EHC-10 (inclusive design) has not changed from Homestar v3, and therefore the same approach as before applies.

For washing lines (EHC-11 – efficient clothes drying), the researcher has again assumed that washing lines would be used to comply, and therefore the same approach (and additional costs) as before applies.

3.3.2 Water

The water category has undergone a number of changes in Homestar v4 when compared to Homestar v2 and v3. The WAT-1 credit has changed and is now called water use in the home and contains items that were previously contained within the WAT-2 credit in Homestar v2 and v3. The dishwasher and washing machine have been removed from consideration, and this credit now only addressed showers, lavatories, wash hand basins and the kitchen tap. The number of points available here has also increased and this credit is now worth 10 points, up from 6 points in Homestar v2 and v3. The requirements for these remaining items have not changed, and the researcher has therefore used the same costings as for Homestar v2 and v3.

The WAT-2 credit is now called sustainable water supply and contains the criteria of the previous WAT-1 credit. The number of points available has decreased from 6 points down to 4 points, but the credit criteria remain the same as Homestar v3. The same costings approach as for Homestar v3 has therefore been used.

3.3.3 Waste

The previous WST-1 and WST-2 credits have been combined into a new WST-1 (construction waste minimisation) credit. The researcher has maintained a consistent approach to targeting points and allocating costs in this new credit, as was described for Homestar v2 and v3, again allowing for a consultant to spend up to 2 hours at $150/hour to write a site-specific waste management plan and then targeting >70% of construction waste diversion from landfill at no additional cost .

The previous WST-3 and WST-4 are combined into a new WST-2 (household waste minimisation) credit. As with Homestar v2 and v3, it is relatively standard 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, the researcher has assumed no additional cost here.

3.3.4 Management

Security (MAN-1) now only contains a four of different elements from Homestar v2 and v3, all of which will attract no cost. 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 will attract no additional cost. The provision of energy-efficient security lighting installed to the entrance door and garage areas is also standard and was included on the Building Code-compliant drawings for the case study dwellings.

For management issues such as the home user guide (MAN-2) and environmental management plan (MAN-3), the researcher has again allowed for a consultant to spend up to 2 hours at $150/hour to write each of these plans.

3.3.5 Materials

The materials credits have been changed in Homestar v4, but they have not been made significantly harder, and it is still possible to achieve full points using fairly standard building products such as GIB plasterboard, Resene/Dulux/Wattyl paints, Pink Batts/Autex/Knauf/Bradford Gold insulation, Colorsteel roofing and Melteca. The same costing approach as Homestar v2 and v3 has therefore been applied here again.

3.3.6 Site

The STE-1 credit (stormwater management) has been modified subtly to require dwellings to capture and retain the first 10 mm of any storm event on site to achieve greater than 0.5 points. The researcher has taken the approach that, if the Building Code-compliant design does not achieve the basic requirements to achieve 0.5 points (i.e. that 75% of the site area not under roof is permeable), additional 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.

For native planting (STE-2), all that is required is to select native New Zealand plants rather than overseas exotic varieties. We have therefore assumed no additional cost.

The neighbourhood amenities (STE-3) credit is based on the location of the site, and the researcher has therefore assumed no additional cost.

The final credit in the tool where points have been targeted is a new credit for cycling (STE-4). Points are allocated here for including cycle parks in the dwelling. The researcher has again priced the Saris Cycle Glide from www.fishpond.co.nz for $499 and allowed a builder for 1 hour at a rate of $65/hour to install this.

3.3.7 Innovation

In Homestar v4, the number of points available for innovation has increased to 10. The researcher has retained the same innovation as Homestar v2 and v3, with the exception of cycle parks, which has been incorporated into the rating tool itself. Greywater recycling has been dropped out of the water category for Homestar v4, and the researcher has therefore included it as an innovation worth 3 points using the same costing as were applied for Homestar v2 and v3. A new innovation around the inclusion of a green wall in the dwelling has also been included. A green wall of 1.5 m high by 3 m long has been costed using Verticals Garden (www.verticalgarden.co.nz) woolly pockets. A 2.8 x 0.38 m row of five pockets costs $200 (including GST). The researcher has allocated an additional $200 to supply plants and potting mix as well as for installation.

3.4 Reference/baseline costs

When undertaking relative cost comparisons for Homestar with the Building Code, the baseline costs shown in

Figure 1 were used. Table 9 indicates that the range of dwelling sizes for the 10 case study dwellings is from 110 m^2 to 164 m^2. The researcher therefore selected the 150 m^2 baseline as this sits nicely in the centre of the size range of the study dwellings. The mid-point of the cost range of $1,975 m^2 was then used in the analysis. This correlates well with anecdotal market information that has been gathered through interviewing different builders in the concurrent study who have indicated a typical building rate of $1,800–2,000/m^2 for a Building Code-compliant dwelling.

House, 150m², 2.7m high stud to ground and 2.4m high stud to first floor. Ribraft floor slab, Colorsteel® roof, floor tiles to bathrooms and kitchen, half height wall tiles to bathroom, 1 or 2 bathrooms, three or four bedrooms. Medium qualit	Unit	Auck $	Wgtn $	Chch $	Dun $	Waik $	PNth $
Weatherboard cladding, LineaTM	m2	1,875-2,075	1,750-1,950	1,925-2,125	1,725-1,925	1,775-1,975	1,750-1,950

Figure 1. Baseline costs from QV costbuilder.

3.5 Thermal analysis

Homestar v2 and v3 used an 18°C set point in terms of heating demand, while Homestar v4 has increased this to a 20°C set point to bring Homestar in line with World Health Organization recommendations.

In Homestar v2 and v3, there is a mandatory minimum requirement of 10 points for 6-Homestar and 11.5 points for 7-Homestar in the EHC-6 credit. Therefore, unless a dwelling is designed to a certain level of passive thermal performance (i.e. it will not use more than 26 kWh/yr/m^2 for 6-Homestar or 21 kWh/yr/m^2 for 7-Homestar in space heating for the Auckland climate zone), it cannot achieve these Homestar levels.

In Homestar v4, the 6-Homestar mandatory minimum requirement has been increased to 12 points or 35 kWh/yr/m^2 to account for the raising of the heating temperature set point to 20°C from the 18°C used in Homestar v2 and v3.

In the different versions of the Homestar rating tool, there are also some fundamental changes in both the way the thermal performance of dwellings is assessed as well as the standard that the dwellings are required to achieve to attain the different levels of Homestar rating.

In Homestar v2, thermal performance, measured in terms of space heating demand, was determined using an Excel calculator based on the ALF (Annual Loss Factor) algorithm from BRANZ. In Homestar v3, the same ALF algorithm was used, but this time it was a web-based version hosted by BRANZ. In Homestar v4, a simple schedule method for 6 and 7-Homestar has been introduced into the tool. Dwellings targeting 6 and 7-Homestar can also undertake a heating load calculation using the online BRANZ ALF calculator, while a dwelling targeting 8-Homestar and above must undertake energy modelling using an acceptable modelling protocol to demonstrate compliance. Dwellings targeting 7-Homestar also have the option of energy modelling, but dwellings targeting 6-Homestar do not.

3.5.1 6-Homestar

Homestar v2 and v3

When approaching the thermal analysis for Homestar v2 and v3, the researcher has in the first instance analysed the Building Code-compliant design in the EHC-6 calculator. This was then translated into ALF online. The design of each dwelling was then modified until the EHC-6 calculator indicated that the modelled dwelling was compliant with the 6-Homestar mandatory minimum requirement. This compliant design was then replicated in ALF online. In all instances, the layout floor plans were held constant, with only the construction systems, glazing and glazing sizes being modified to achieve thermal performance requirements.

It should be noted that, after Homestar v3 was launched, the NZGBC also released a stand-alone EHC-6 calculator that could be used with Homestar v3.

Homestar v4

When evaluating Homestar v4 using the schedule method, the standard Building Code-compliant design was again used as a baseline, and then this design was modified until it met the schedule method requirements. In all instances, the layout floor plans were held constant, with only the construction systems, glazing and glazing sizes being modified to achieve thermal performance requirements.

The details of the changes required for each dwelling are listed in Appendix A. These designs were then inputted into both the EHC-6 calculation and ALF online to determine the kWh/yr/m^2 that the schedule method compliant design would use.

When analysing the Homestar v4 calculation method, the Building Code-compliant design was again taken and then modified in ALF online until the space heating allowance (using the Homestar v4 20°C set point) was achieved. The set point was then converted to 18°C to determine the appropriate kWh/yr usage at this heating level as well.

3.5.2 7-Homestar

Homestar v2 and 3

In Homestar v2 and v3, the approach was relatively simple for 7-Homestar, and a dwelling merely needed to demonstrate that it achieved a space heating load efficiency of 17 kWh/yr/m^2 for the Auckland climate zone. This was demonstrated through the use of the EHC-6 Excel calculator in Homestar v2 or ALF online for Homestar v3.

When approaching the thermal analysis for 7-Homestar in Homestar v2 and v3, the researcher has again first modelled the Building Code-compliant design in the EHC-6 calculator. This has then been translated into ALF online. The design of each dwelling was then modified until the EHC-6 calculator indicated that the modelled dwelling was compliant with the 7-Homestar mandatory minimum requirement. This compliant design was then replicated in ALF online.

Homestar v4

Schedule method

Homestar v4 also has a schedule method for demonstrating 7-Homestar thermal compliance. The 7-Homestar schedule method compliance differs from that of 6-Homestar in that there are three ways to achieve the mandatory minimum required points of 14. Thirteen points can be achieved by meeting the requirements of Table 88. A further point must then be achieved by meeting two of the cooling energy requirements below:

- The solar aperture of each façade of the dwelling is less than 20%.
- For each habitable space, the net openable window area is greater than 5% of the conditioned floor area of that space. Furthermore, at least 30% of the total required openable window area (refer to EHC-2) of the dwelling is located on an opposite/adjacent façade (or dwelling level).
- At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow passive ventilation of at least 10 mm along one edge.

In the schedule method analysis, the researcher has assumed that the most cost-effective way of achieving the points is to target the 5% net openable window area in addition to the window restrictors.

Calculation method

A dwelling can achieve 14 points using the calculation method in three different ways as shown in Table 7.

Table 7. 7-Homestar calculation method options for climate zone 1 (Auckland).

	Heating demand*	Cooling demand
Option 1	35 kWh/m²/yr – 12 points	All of the cooling features from the bullets above – 2 points
Option 2	27 kWh/m²/yr – 13 points	Two of the cooling features from the bullets above – 1 point
Option 3	20 kWh/m²/yr – 14 points	0 points

* From Homestar v4 technical manual Table 6.

Option 1 from Table 7 is basically the 6-Homestar calculation method analysis that was done previously combined with all of the cooling features listed earlier.

Option 2 from Table 7 was not covered previously, and the researcher therefore modified the designs of the case study dwellings in ALF online until they were compliant with the reduced heating energy demand figure of 27 kWh/m²/yr. The exact design changes that were made are listed in Appendix A. This was then combined with the most effective way of achieving the additional cooling point by providing lockable stays or restrictors to one window in each habitable space and meeting the net openable window area of greater than 5%.

When reviewing option 3 from Table 7, the researcher tried to modify the design of each dwelling using ALF online to achieve the required heating demand requirement. This was possible for some dwellings (mostly the terraced dwellings), but in most cases it was not possible to modify the basic design sufficiently to enable this to be achieved. Design changes attempted were aluminium thermally broken with low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5, R6 ceiling insulation and exposed concrete floor to ground floor, which only managed to allow this dwelling to achieve 23.3 kWh/yr/m².

The researcher therefore determined that, in most cases, it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar using this option.

3.5.3 8-Homestar

There is no thermal performance mandatory minimum requirement to achieve higher than 7-Homestar in Homestar v2 or v3. However, Homestar v4 has introduced a new mandatory minimum requirement where a dwelling has to achieve ≤56 kWh/yr/m^2 in climate zone 1 or ≤61 kWh/yr/m^2 in the remaining climate zones for heating and cooling demand. This can be demonstrated using a modelling protocol acceptable to be Homestar such as the Passive House Planning Package (PHPP).

When evaluating 8-Homestar in Homestar v4, the researcher has therefore modelled the Building Code-compliant design of the case study dwellings in PHPP as the base case and then attempted to make modifications to achieve the required thermal performance benchmark. When doing this, the researcher followed the same approach that has been taken previously in the study – in all instances, the layout floor plans were held constant with only the construction systems, glazing and glazing sizes being modified to achieve thermal performance requirements.

3.5.4 Thermal performance benchmark summary

As previously discussed, the situation in relation to mandatory minimums for thermal performance was relatively straight forward in Homestar v2 and v3. The release of Homestar v4 with its schedule, calculation and energy modelling methods is more complex, with more compliance options to choose from, as demonstrated in Table 8.

Table 8. Summary of the different thermal performance benchmarks across the different versions of Homestar.

	Heating temperature set point (°C)	Heating demand kWh/m²/yr	Cooling demand kWh/m²/yr	Combined heating and cooling demand kWh/m²/yr
6-Homestar				
Homestar v2	18	≤26	Not considered	Not considered
Homestar v3	18	≤26	Not considered	Not considered
Homestar v4 schedule method	20	Benchmark not set	Not considered	Not considered
Homestar v4 calculation method	20	≤35	Not considered	Not considered
7-Homestar				
Homestar v2	18	≤17	Not considered	Not considered
Homestar v3	18	17	Not considered	Not considered
Homestar v4 schedule method	20	Benchmark not set	2 cooling home features	Not considered
Homestar v4 calculation method – option 1	20	≤35	3 cooling home features	Not quantifiable
Homestar v4 calculation method – option 2	20	≤27	2 cooling home features	Not quantifiable
Homestar v4 calculation method – option 3	20	≤20	0 cooling home features	≤20
Homestar v4 energy modelling	20	-	-	≤76
8-Homestar				
Homestar v4 energy modelling	20	-	-	≤56

3.6 Design summary of the case study dwellings

10 dwellings were selected for this desktop study. The dwellings were selected from the large grouping of dwellings that the researcher has reviewed in the Hobsonville Point development for another concurrent BRANZ study. Each dwelling has a different owner and different builder. Some are dwellings that have been developed by large developers, some by group home builders and some by individual homeowners, thus representing a wide cross-section of the general residential construction submarket in Hobsonville.

However, since Hobsonville is a master-planned development, the designs selected for study may lack some of the natural variation that might occur if the dwellings were selected at random from other submarkets in Auckland or around the country.

3.6.1 Summary of dwelling characteristics

Table 9. 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	146 m^2	166 m^2	153 m^2	145 m^2	110 m^2	156 m^2	134 m^2	160 m^2	160 m^2	164 m^2
Building footprint	73 m^2	107 m^2	91.8 m^2	86 m^2	72 m^2	104 m^2	89 m^2	103 m^2	98 m^2	85 m^2
GFA	166 m^2	203 m^2	186 m^2	175 m^2	143 m^2	168 m^2	151 m^2	195 m^2	165 m^2	187 m^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
RAF v2*	1.079	1.016	1.095	1.11	1.126	1.047	1.095	1.047	1.032	1.032
RAF v3*	1.127	1.054	1.084	1.106	1.126	1.040	1.093	1.034	1.038	1.035
Number of storeys	2	2	2	2	2	2	2	2	3	2
Type	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Terraced	Stand-alone	Stand-alone	Stand-alone	Terraced	Stand-alone
Total wall area	195 m^2	349 m^2	256 m^2	240 m^2	156 m^2	255 m^2	260 m^2	320 m^2	166 m^2	234 m^2
Total window area	66 m^2	99 m^2	64 m^2	50 m^2	45 m^2	65 m^2	76 m^2	76 m^2	45 m^2	89 m^2
Roof area	73 m^2	109 m^2	89.4 m^2	83 m^2	71 m^2	111.2 m^2	90 m^2	103 m^2	67 m^2	85 m^2
Average ceiling height	2.55 m	2.72 m	2.68 m	2.68 m	2.66 m	2.72 m	2.7 m	2.72 m	2.62 m	2.7 m
Area of carpet	77 m^2	113 m^2	82 m^2	65 m^2	54 m^2	80 m^2	74 m^2	78 m^2	87 m^2	41 m^2
Wall	133 mm Scyon Axon panel & 150 mm Scyon Linea board; insulation R2.2; overall R-value 1.9	Bevel-back & vertical w/board; plaster finish on brick veneer; insulation R1.9; overall R-value 1.75–1.85	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.0	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.13	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.13; south elevation attached to adjacent dwelling – no glazing	Bevel-back & vertical w/board; insulation R2.8; overall R-value 2.2	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.1	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.1	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.1	Bevel-back & vertical w/board; insulation R2.2; overall R-value 2.1
Ceiling	Long-run roof; insulation R3.2; overall R-value 3.1	Long-run roof; insulation R2.9; overall R-value 2.8	Asphalt shingle on 15 mm T&G plywood; insulation R3.2; overall R-value 3.59	Long-run roof; insulation R3.2; overall R-value 3.2	Long-run roof; insulation R3.2; overall R-value 3.2	Long-run roof; insulation R3.6; overall R-value 3.4	Asphalt shingle on 15 mm T&G plywood; insulation R3.2; overall R-value 3.59	Long-run roof; insulation R3.2; overall R-value 3.2	Long-run roof; insulation R3.2; overall R-value 3.2	Long-run roof; insulation R3.2; overall R-value 3.2
Floor	Waffle pod; area/perimeter ratio <2.5, R1.1	Waffle pod; area/perimeter ratio 1.2, R0.98	Waffle pod; area/perimeter ratio 1.94; R1.2	Waffle pod; area/perimeter ratio 1.84; R1.15	Waffle pod; area/perimeter ratio 1.84; R1.2	Waffle pod; area/perimeter ratio 1.36; R0.91	Waffle pod; area/perimeter ratio 1.25; R0.91	Waffle pod; area/perimeter ratio 1.34; R0.91	Waffle pod; area/perimeter ratio 2.0; R1.25	Waffle pod; area/perimeter ratio 2.0; R1.25
Glazing	Aluminium frames; no thermal break; double glazed									

*Refer to Appendix B for details on how the resource adjustment factor (RAF) works.

4. Results and discussion

4.1 Thermal analysis

Thermal performance is an important aspect of the Homestar rating tool, and with the various modifications to the tool, it is worth taking the time to compare and contrast the different iterations of the tool against each other. Of particular interest is whether the Homestar v4 schedule method achieves its stated aim of reducing the cost of compliance whilst still maintaining an acceptable level of thermal performance.

4.1.1 6-Homestar across Homestar v2, v3 and v4

Figure 2 and Figure 3 illustrate how the different case study dwellings perform under each version of the rating tool, using the different thermal analysis methods available.

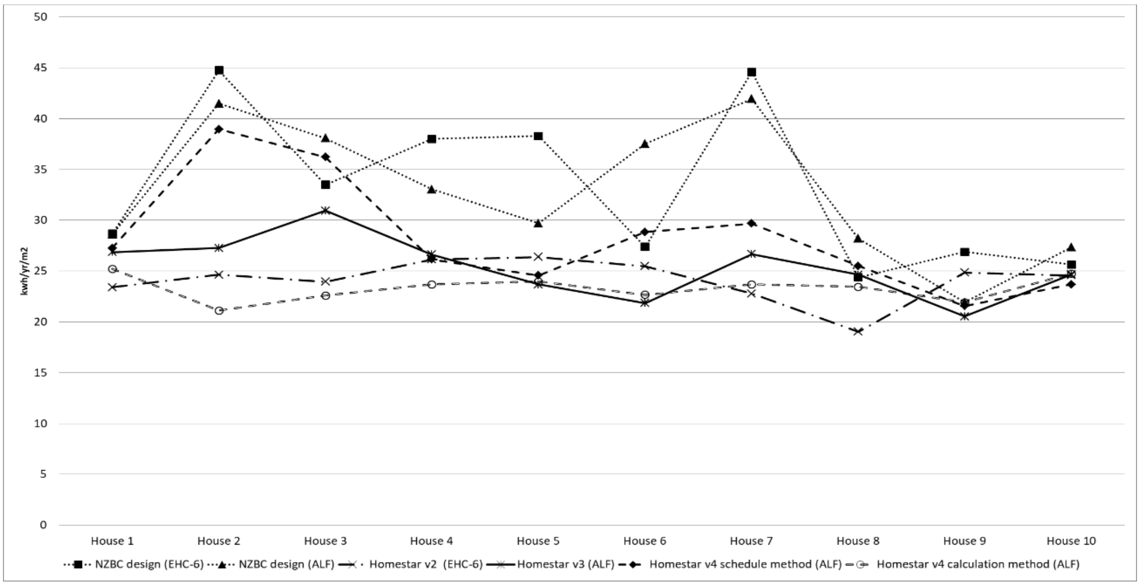


Figure 2. Comparison of thermal performance of the case study dwellings when achieving the 6-Homestar mandatory minimum using an 18°C set point.

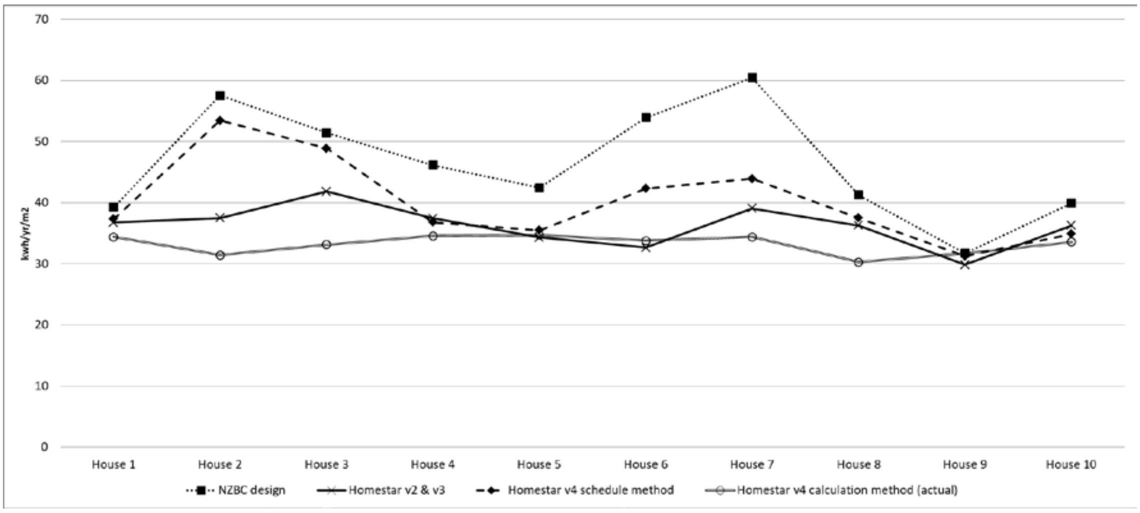


Figure 3. Comparison of thermal performance of the case study dwellings when achieving the 6-Homestar mandatory minimum using a 20°C set point.

These figures show that, in all instances where the same Building Code-compliant design is assessed using the EHC-6 calculator and ALF online, a different kWh/yr figure is being obtained.

This indicates that, even though the same algorithm is being used, there are some differences in the analysis methods, with the EHC-6 calculator producing lower kWh/yr figures in just over half the cases.

In particular, Figure 2 indicates there is a lot of conflict occurring between the different thermal analysis methods in the different rating tool versions. It appears as though the different thermal analysis methods are not consistently measuring performance of a dwelling, as the lines for each analysis method cross over each other at various points in time. (If they were consistently measuring the differences between the dwellings, the lines should theoretically not cross.)

Points of particular concern:

- The constant differences between the EHC-6 calculator and ALF online when evaluating the same designs, particularly since the difference is not always in the same direction.
- The wide disparity of results for certain dwellings (Dwellings 2 –7).

Removing the EHC-6-Homestar v2 calculator from consideration and using only ALF online at a 20°C set point provides a more consistent approach to the measuring of thermal performance as demonstrated in Figure 3. This is to be expected, as in all instances, ALF online has been used to measure the thermal performance of each dwelling. The lines now no longer cross frequently, and it is possible to discern certain trends.

Again, the same dwellings appear to experience disparities between the different method of analysis (Dwellings 2–7), indicating that these dwellings would need to carefully select the best thermal analysis approach they use, as different approaches appear to have different performance outcomes.

It is challenging to determine a trend from the line graphs in Figure 2 and Figure 3, and therefore this information has been translated into table format. Table 10 and Table 11 provide a summary of the results of modelling the 10 case study dwellings.

These tables show the different levels of space heating demand that each dwelling requires for each of the different thermal assessment methods under the different versions of Homestar.

- The cells with the black backgrounds represent the thermal assessment method and rating tool version combination that results in the highest space heating demand.
- The cells highlighted in light grey illustrate the lowest space heating demand.

It is not possible to use the EHC-6 calculator with a 20°C set point, and therefore in Table 11, the researcher has combined Homestar v2 and v3 into the same line. ALF online had to be used for both versions of the tool, and the results are therefore the same for both versions.

Table 10. kWh/yr/m² of space heating requirements with an 18°C set point for 6-Homestar.

18°C set point	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Building Code-compliant design (EHC-6)	29	45	33	38	38	27	45	24	27	26
Building Code-compliant design (ALF)	29	41	38	33	30	38	42	28	22	27
Homestar v2 (EHC-6)	23	25	24	26	26	25	23	19	25	25
Homestar v3 (ALF) *(allowance = 26)*	**<u>27</u>**	**<u>27</u>**	**<u>31</u>**	**<u>27</u>**	24	22	**<u>27</u>**	25	21	25
Homestar v4 schedule method (ALF)	27	39	36	26	25	29	30	26	22	24
Homestar v4 calculation method (ALF)	25	21	23	24	24	23	24	23	22	25

It is most interesting to note than in five instances (**<u>bold underlined</u>** in Table 10), that the design that was compliant in the EHC-6 calculator did not achieve compliance in ALF online and that technically further design alterations would be required. Since Homestar v3 allows the use of either an EHC-6 calculator or ALF online, the researcher has not further modified the designs of the dwellings to allow compliance in ALF online to be achieved. This difference should however be noted by Homestar assessors and practitioners, as it would tend to suggest that the EHC-6 calculator is a more cost-effective way of demonstrating compliance with the 6-Homestar mandatory minimum for EHC-6 for Homestar v2 and v3, as fewer features are required to be included to achieve the required space heating demand target.

Table 11. kWh/yr/m² of space heating requirements with a 20°C set point for 6-Homestar.

20°C set point	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Building Code-compliant design (ALF)	39	58	51	46	42	54	60	41	32	40
Homestar v2 and v3 (ALF)	37	37	42	37	34	33	39	36	30	36
Homestar v4 schedule method (ALF)	37	53	49	37	35	42	44	37	31	35
Homestar v4 calculation method (ALF) *(allowance = 35)*	34	31	33	35	35	34	34	30	32	34

It can be seen from these tables that, as expected, in most cases, the Building Code-compliant designs require the highest space heating load on a per annum basis. However, this is to be expected and therefore it would be worthwhile removing the Building Code from the equation to determine which iteration of Homestar provides the best and worst thermal performance.

Due to the inherent differences that appear to be present between the EHC-6 calculator and the ALF online tool, from this point on, when comparing the different versions of Homestar, ALF online and a 20°C set point will be used to allow consistency. Table 12 quite clearly shows that, in the majority of cases, using the schedule method will result in the highest heating demand.

Table 12. kWh/yr/m^2 of space heating requirements with a 20°C set point and ALF online for 6-Homestar.

20°C set point	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar v2 and v3 (ALF)	37	37	42	37	34	33	39	36	30	36
Homestar v4 schedule method (ALF)	37	53	49	37	35	42	44	37	31	35
Homestar v4 calculation method (ALF) *(allowance=35)*	34	31	33	35	35	34	34	30	32	34

4.1.2 7-Homestar across Homestar v2, v3 and v4

Table 13 provides a summary of the results of modelling the 10 case study dwellings in the different methods required by the iterations of the Homestar rating tool using a 20°C set point and ALF online. Using the same coding as was applied for 6-Homestar, Table 13 demonstrates that, if it was cost-effectively achievable in all instances, that the Homestar v4 calculation method – option 3 would produce dwellings with the lowest space heating demand while the schedule method and calculation method – option 1 produce dwellings with the highest space heating demand, in some instances, doubling the demand from that of the Homestar v4 calculation method – option 3.

Table 13. kWh/yr of space heating required using a 20°C set point and ALF online for 7-Homestar.

20°C set point	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar v2 and v3 (ALF)	28	24	27	24	26	25	30	21	17	25
Homestar v4 schedule method (ALF)	37	53	49	37	35	42	44	37	31	35
Homestar v4 calculation method – option 1 (ALF) *(allowance=35)*	34	31	33	35	35	34	34	30	32	34
Homestar v4 calculation method – option 2 (ALF) *(allowance=27)*	27	25	26	27	26	27	25	26	25	24
Homestar v4 calculation method – option 3 (ALF) *(allowance=20)*					19				20	19

Homestar v4 also has the option for dwellings to be energy modelled to demonstrate compliance with the EHC-1 mandatory minimum requirement. Using PHPP, the researcher determined the results shown in Table 14. This table shows in the first row the annual heating demand as estimated or predicted by ALF online for the Building

Code-compliant design, with the second row showing the annual heating demand as estimated or predicted by PHPP. Of particular interest is the third row, where the factor of difference between the first and second row is shown. It can be seen from this row that, in most instances, PHPP is measuring or estimating double the heating demand of ALF online. The researcher has deliberately separated the energy modelling results from Table 13 above for this reason.

Table 14. kWh/yr/m² of space heating required using a 20°C set point and PHPP for 7-Homestar.

20°C set point	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Building Code (ALF)	39	58	51	46	42	54	60	41	32	40
Building Code (PHPP – heating demand only)	109	109	93	102	101	88	115	78	85	65
Factor of difference	2.8	1.9	1.8	2.2	2.4	1.6	1.9	1.9	2.7	1.6

4.1.3 8-Homestar across Homestar v2, v3 and v4

In Homestar v2 and v3, there are no additional thermal performance requirements to achieve 8-Homestar. Homestar v4, however, has introduced a new mandatory minimum requirement where a dwelling that wishes to achieve 8-Homestar or higher must demonstrate compliance via energy modelling (rather than the schedule or calculation methods). Different kWh/m² benchmarks are set for achieving the required 16 EHC-1 points. An additional difference is that this benchmark takes into account heating and cooling and is therefore higher than the space heating benchmark alone.

4.1.4 Thermal analysis summary

Table 15 shows the kWh/yr savings from the Building Code-compliant design for 6, 7 and 8-Homestar across the various versions of Homestar. In this analysis, we have looked (where possible), at the energy budget allowances that Homestar gives. This table shows that the greatest savings in space heating can be achieved with the 7-Homestar calculation method – option 3, while the 6-Homestar schedule method mostly provides the lowest-performing designs in terms of space heating efficiency. Homestar v4 appears to have relaxed the requirements for 6 and 7-Homestar when compared to Homestar v2 and v3 in terms of the thermal performance mandatory minimums through the use of the schedule method whilst concurrently increasing the requirements when the Homestar v4 calculation method is used.

It can be seen from Table 15 that the increases in Homestar rating level bring with them an increase in thermal efficiency and subsequent reduction in required space heating demand. However, is the additional capital investment to get from 6-Homestar to 7-Homestar a good investment? The researcher explored this further in the following cost analysis section.

From a first glance, it appears that 7-Homestar using the energy modelling method will provide the worst-performing dwellings. However, this assumes that ALF online and PHPP are directly comparable, when this is not the case. As shown in Appendix A and Table 14, when the same Building Code-compliant design is modelled in ALF and PHPP, the heating demand in kWh/m²/yr from PHPP is roughly double that of ALF online. PHPP is therefore analysing and measuring the thermal performance of the dwellings in a very different manner from ALF, and the results from each program cannot be directly compared in this way.

Table 15. Space heating (and cooling demand, where appropriate) in kWh/yr/m^2 for 6, 7 and 8-Homestar across the different Homestar versions using a 20°C set point, ALF online and PHPP.

KWh/yr	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
6-Homestar										
Homestar v2 and v3 (ALF – actual)	37	37	42	37	34	33	39	36	30	36
Homestar v4 schedule method (ALF – actual)	37	53	49	37	35	42	44	37	31	35
Homestar v4 calculation method (ALF – allowance)	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*
7-Homestar										
Homestar v2 and v3 (ALF – actual)	28	24	27	24	26	25	30	21	17	25
Homestar v4 schedule method (ALF – actual)	37	53	49	37	35	42	44	37	31	35
Homestar v4 calculation method – option 1 (ALF – allowance)	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*	*35*
Homestar v4 calculation method – option 2 (ALF – allowance)	*27*	*27*	*27*	*27*	*27*	*27*	*27*	*27*	*27*	*27*
Homestar v4 calculation method – option 3 (ALF – allowance)	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*
Homestar v4 (PHPP allowance – heating and cooling)	*76*	*76*	*76*	*76*	*76*	*76*	*76*	*76*	*76*	*76*
8-Homestar										
Homestar v4 (PHPP – heating and cooling)	*56*	*56*	*56*	*56*	*56*	*56*	*56*	*56*	*56*	*56*

It is interesting to note that, for 6-Homestar for Homestar v4, the heating energy budget is mildly lower than what compliant houses were achieving in Homestar v2 and v3. However for 7-Homestar, the opposite is true, and houses in Homestar v2 and v3 were using much less heating energy when compared to what would be used by compliant dwellings under Homestar v4.

4.2 Cost analysis

4.2.1 Thermal performance cost analysis

As discussed earlier, Homestar v2 and v3 were relatively straightforward in their approach towards thermal analysis, and therefore the options available around costs were also relatively straightforward. However, Homestar v4 appears to have somewhat 'put the cat amongst the pigeons', allowing a plethora of options for analysing the thermal performance mandatory minimums. Figure 4 and Figure 5 graphically show the differences between the different rating tools across the case study dwellings.

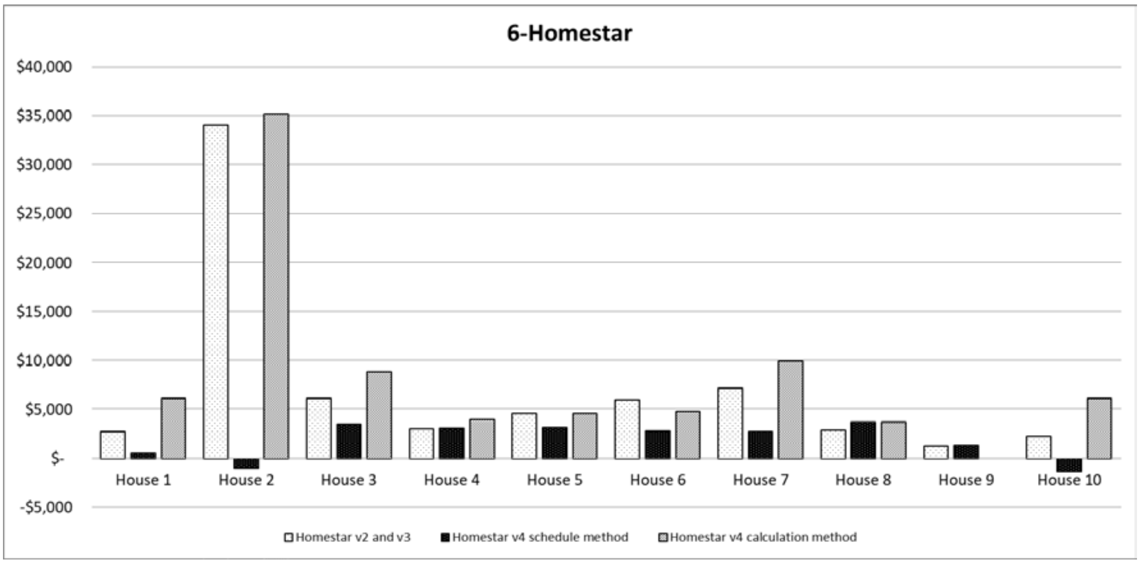


Figure 4. Cost to achieve the 6-Homestar thermal performance mandatory minimum across the different versions of Homestar from the Building Code.

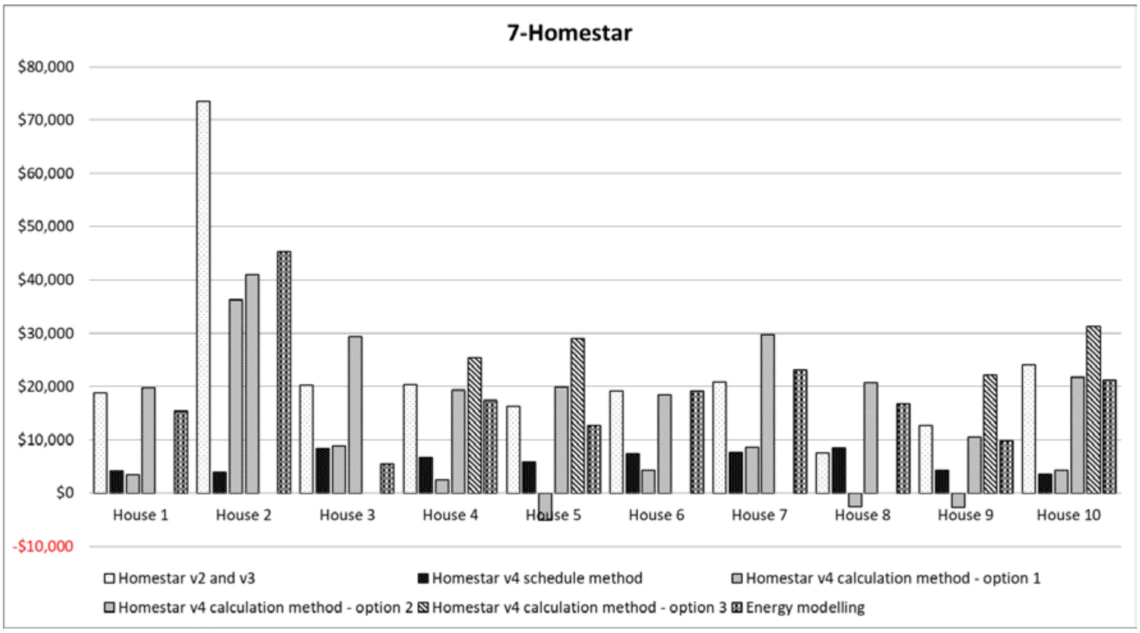


Figure 5. Cost to achieve the 7-Homestar thermal performance mandatory minimum across the different versions of Homestar from the Building Code.

Figure 4 shows there is actually not a lot of variation in cost for achieving the 6-Homestar thermal performance mandatory minimum across the different versions of Homestar with all dwellings, except Dwelling 2, able to achieve compliance for less than $10,000. As discussed elsewhere in this report, Dwelling 2 is a special case with a non-favourable orientation that requires it to work harder to achieve compliance.

Unlike 6-Homestar, achieving the thermal performance mandatory minimum for 7-Homestar is not as straightforward. Figure 5 shows a large amount of variation in cost for the various compliance paths, going from nearly $70,000 additional cost to a saving of around $5,000.

All of these options have been thoroughly reviewed and costed as per Appendix A. A summary of these findings is presented in Table 16.

Table 16. Cost implications of the different thermal performance approaches across the different Homestar versions using a 20°C set point and ALF online.

$	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
6-Homestar										
Homestar v2 and v3	$2,791	$34,074	$6,149	$3,076	$4,626	$5,992	$7,179	$2,888	$1,297	$2,250
Homestar v4 schedule method	$515	-$998	$3,546	$3,143	$3,178	$2,817	$2,737	$3,713	$1,349	-$1,302
Homestar v4 calculation method	$6,176	$35,218	$8,877	$3,984	$4,626	$4,877	$9,973	$3,768	$0	$6,131
7-Homestar										
Homestar v2 and v3	$18,793	$73,562	$20,199	$20,306	$16,212	$19,124	$20,843	$7,468	$12,649	$23,983
Homestar v4 schedule method	$4,274	$4,045	$8,378	$6,948	$5,972	$7,605	$7,571	$8,764	$4,419	$3,803
Homestar v4 calculation method – option 1	$3,530	$36,361	$8,913	$2,722	-$5,012	$4,493	$8,776	-$2,431	-$2,590	$4,516
Homestar v4 calculation method – option 2	$19,804	$41,153	$29,310	$19,589	$19,867	$18,616	$29,879	$20,859	$10,682	$21,897
Homestar v4 calculation method – option 3	na	na	Na	$25,351	$29,051	na	na	na	$22,154	$31,426
Energy modelling	$15,319	$45,205	$5,482	$17,443	$12,634	$19,155	$23,117	$16,813	$9,812	$21,201

The table is again shaded to show the worst-performing thermal analysis method in black with the best in light grey. The method with the highest cost of implementing the thermal performance changes is indicated (**bold underlined**) and the lowest cost in *italics*.

It can be seen that, for eight instances for 6-Homestar, the highest cost is paired with the best thermal performance. However in two instances (Dwelling 4 and Dwelling 9), the highest cost is associated with a middle-of-the-road thermal performance in terms of space heating demand reduction. In terms of the lowest cost, this is in all instances linked to the lowest thermal performance in terms of space heating demand reduction. In seven cases, this is associated with the Homestar v4 schedule method.

For 7-Homestar, a similar trend is noticed. In nine instances, the highest cost is paired with the best thermal performance. It is only in the case of Dwelling 2 that the highest cost is paired with middle-of-the-road performance.

The lowest cost is more intriguing for 7-Homestar, with it being linked in only six instances to the worst thermal performance in terms of space heating demand reduction. In the other cases, it is linked in three instances to the option 1 calculation method and in the last case again to the schedule method, but in that case, the option 1 calculation method is the worst-performing thermally.

However, from this analysis, the researcher does not believe that it is possible to make any generalisations around the Homestar v4 rating and there does not appear to be a clear case that the schedule method is the most cost-effective option to use on a project.

Instead. it appears that the Homestar v4 tool is very nuanced and that it is important to undertake a proper analysis on each dwelling proposing to use the tool, as in most cases, the outcomes will differ.

4.2.2 Homestar v2

Incorporating the costs of the thermal analysis in the previous section with the other more holistic costs of Homestar, it is possible to deduce some basic trends. The results of this desktop analysis indicate median increases in cost for moving through the different Homestar rating levels, as shown in Table 17.

Table 17. Summary of median additional costs to achieve 6, 7, 8, 9 and 10-Homestar using Homestar v2 from a Building Code standard.

	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Total cost increase from Building Code ($0)	$18,043	$38,549	$63,102	$75,453	$101,705

Analysing these results for the 10 case study dwellings, the descriptive statistics can be determined, as shown in Table 18.

Table 18. Descriptive statistics for the various ratings levels for Homestar v2.

	Minimum	Maximum	Median	Average	Range
6-Homestar	$15,031	$55,738	$18,043	$22,449	$40,706
7-Homestar	$30,189	$112,237	$38,549	$45,588	$82,048
8-Homestar	$52,398	$162,708	$63,102	$71,593	$110,310
9-Homestar	$67,472	$192,640	$75,453	$89,145	$125,168
10-Homestar	$77,172	$198,960	$101,705	$109,694	$121,787

Using the median prices for each of the star rating levels from Table 18, and the QV costbuilder construction cost of $1,975/m^2 from

Figure 1 (which interviews with various builders have also indicated is an appropriate rate), the different levels of Homestar rating would equate to an additional percentage cost as shown in Table 19.

Table 19. Percentage increase to achieve 6, 7, 8, 9 and 10-Homestar using Homestar v2 from a Building Code standard.

	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Total cost increase from Building Code rate ($1,975/m^2)	5%	12%	19%	24%	28%

Comparing these results with the findings of the 2013 Jasmax study, which provides a more comprehensive set of Homestar v2 costs than the eCubed study, the present study attributes significantly higher costs to 6 and 7-Homestar than the cost premiums determined in the earlier Jasmax study. It is worth noting that the original Homestar cost estimates excluded some key line items that the authors have subsequently added to enable a direct comparison between the present study's estimates and Jasmax's figures. These cost items are a builder's margin, assumed to be 15%, goods and services tax of 15% and the circa 2013 NZGBC Homestar assessment fees of $180 and a Homestar assessor's fee of $900.

Table 20. Comparison of the results of this study to previous studies.

Homestar rating	Jasmax (2013) % increase	This study % increase
6-Homestar	3.3%	5%
7-Homestar	7.7%	12%

Despite Jasmax including line item costs such as a rainwater tank to achieve 6-Homestar, which the present researcher feels is an uneconomical solution to earn points, the Jasmax study contributors have both underestimated several Homestar costs and omitted others. For example, the Jasmax study has omitted the costs associated with ecolabels for applied coatings (paint), plasterboard and floor coverings. The current study has found that the additional costs for ecolabels is approximately $5,000. This equates to 1.3% of median cost increase. There are other more minor omissions such as low-flow water fixtures and fittings, but these do not attract significant additional costs.

Upon review, the Jasmax study also appears to have underestimated line costs associated with EHC-6 (whole-dwelling thermal performance). These omissions and underestimations help explain why the present study has arrived at higher cost premiums between Building Code and Homestar.

Breaking down the calculated additional costs from Table 28 further, the incremental addition of each level of Homestar rating can be determined for each dwelling. It can be seen in Table 21 and Figure 6 that the incremental increase in the different Homestar rating levels is relatively consistent for the majority of dwellings in the study. With the exception of Dwelling 2, the analysed dwellings could achieve 6-Homestar for an investment of around $15,000–20,000, and the majority of the dwellings can achieve a 7-Homestar rating for under $40,000.

Table 21. Incremental increase for each dwelling to achieve 6, 7, 8, 9 and 10-Homestar using Homestar v2 from a Building Code standard.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
6-Homestar	$15,348	$55,738	$25,405	$18,196	$15,031	$19,507	$22,998	$17,890	$16,604	$17,768
7-Homestar	$20,257	$56,499	$24,880	$22,073	$15,738	$18,499	$16,095	$12,299	$17,205	$27,847
8-Homestar	$26,847	$50,471	$24,545	$25,932	$21,628	$25,746	$20,484	$24,156	$20,214	$20,030
9-Homestar	$18,875	$29,932	$32,300	$10,048	$16,579	$13,508	$12,024	$13,127	$20,113	$9,013
10-Homestar	$5,750	$6,319	$23,690	$26,135	$8,195	$34,245	$15,349	$33,555	$31,257	$20,994

These cost increases correlate well to interviews that were undertaken with owners/builders of higher-rated Homestar dwellings in a concurrent Homestar study. Interviewees in one particular development indicated an additional cost premium of around $30,000 or 6% for a 7-Homestar rating. They attributed this additional cost to more insulation, higher-performing windows (thermally broken with low-e film), slab edge insulation, photovoltaics and rainwater tanks.

Dwelling 2 is an obvious outlier in the results. Table 9 shows that Dwelling 2 has a poor orientation, facing due south, and this greatly affects its fundamental ability to perform well under Homestar without significant cost investment. In the analysis, the researcher has retained the poor orientation of this dwelling, as this was fixed at the resource consent phase, and determined what thermal upgrades would be required to improve its performance to achieve the thermal performance mandatory minimums.

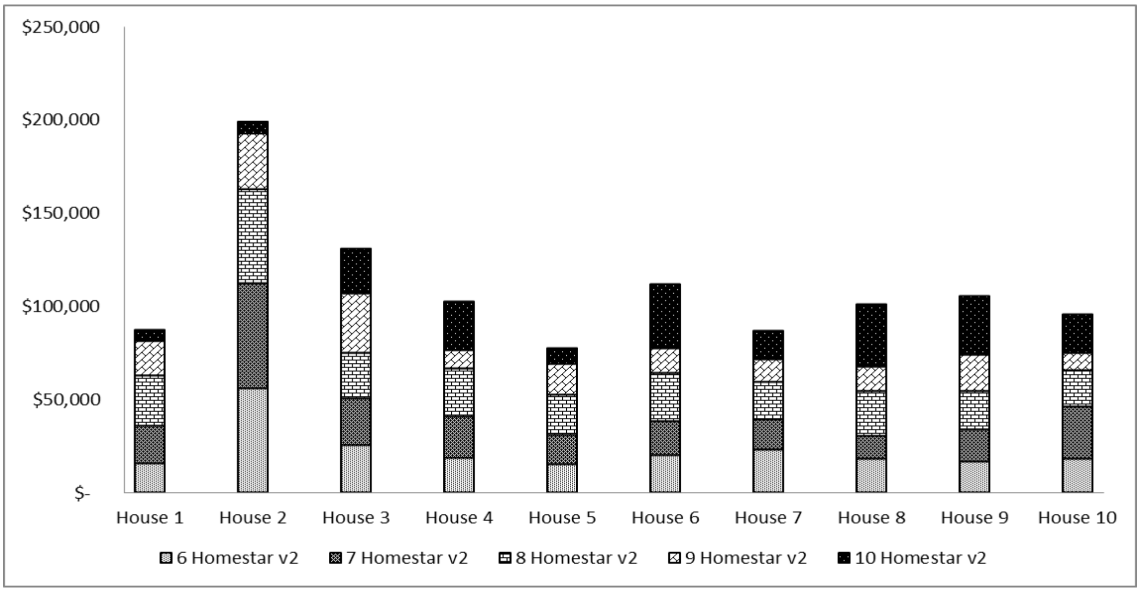


Figure 6. Incremental costs to achieve the different levels of Homestar v2 across the 10 study dwellings.

An intriguing analysis in the 2013 Jasmax study was the conversion of costs to a cost per point interpretation. This type of analysis would be particularly beneficial for builders and developers who are looking to achieve the maximum amount of Homestar impact for every dollar they spend. The researcher has therefore also undertaken a median cost per point analysis for each of the Homestar levels (Table 22). While, in the majority of cases, that cost per point remains steady across the different rating levels, in some instances, that cost varies. This is particularly noticeable in the energy credits such as EHC-5, where the renewable energy system attracts more points for the same capital cost, as other credits contribute to the overall energy efficiency of the dwelling.

Table 22. Cost per point for the various Homestar v2 credits across the different rating levels.

Credit	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Energy, health and comfort					
EHC-1 (space heating)	-	-	-	$957	$957
EHC-2 (hot water)	-	-	-	$804	$804
EHC-3 (lighting)	$88	$88	$88	$88	$88
EHC-4 (whiteware and appliances)	$581	$581	$581	$581	$581
EHC-5 (renewable energy)	-	-	$2,385	$1,428	$1,409
EHC-6 (whole-dwelling thermal performance)	$385	$1,710	$1,710	$1,710	$1,710
EHC-7 (moisture control)	$314	$314	$314	$314	$314
EHC-8 (washing line)	$331	$331	$331	$331	$331
EHC-9 (sound insulation)	-	-	$3,570	$3,704	$3,792
EHC-10 (inclusive design)	-	$225	$315	$165	$165
Water					
WAT-1 (rainwater harvesting)	-	-	$905	$905	$1,384
WAT-2 (internal potable water)	$75	$88	$967	$967	$967
WAT-3 (greywater reuse)	-	-	-	-	$5,527

Credit	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Waste					
WST-1 (construction waste management)	$115	$115	$115	$115	$115
WST-2 (construction waste reduction)	-	$333	$333	$333	$333
WST-3 (recycling facilities)	-	-	-	-	-
WST-4 (composting facilities)	$53	$53	$53	$53	$53
Management					
MAN-1 (miscellaneous – unwanted features)	-	-	-	-	-
MAN-2 (safety and Security)	$43	$43	$43	$43	$43
MAN-3 (home user guide)	$173	$173	$173	$173	$173
MAN-4 (responsible contracting)	$345	$173	$173	$173	$173
Materials					
MAT-1 (materials selection)	$561	$561	$561	$561	$561
MAT-2 (VOCs and toxic materials)	-	-	-	-	-
Site					
STE-1 (stormwater management)	-	-	-	-	-
STE-2 (native ecology)	-	-	-	-	-
STE-3 (on-site food production)	$327	$327	$327	$327	$327
STE-4 (site selection)	-	-	-	-	-
Total	100				
Innovation					
INN – (electric car charger)	-	-	-	$1,299	$1,299
INN – (shower heat drain recovery)	-	-	$1,200	$1,200	$1,200
INN – (timber framing junction – GIB EzyBrace)	-	-	-	-	-
INN – information sharing	-	$500	$500	$500	$500
INN – bike parks	-	$564	$564	$564	$564

4.2.3 Homestar v3

Homestar v3 does not differ greatly from the widely used Homestar v2 and has now been superseded by Homestar v4. For this reason, the researcher has not analysed the results to the level of detail as with Homestar v2. The results of this desktop analysis indicate median increases in cost when compared to Homestar v2 for moving through the different Homestar Rating levels, as shown in Table 23.

Table 23. Summary of median additional costs to achieve 6, 7, 8, 9 and 10-Homestar using Homestar v3 from a Building Code standard.

	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Total cost increase from Building Code ($0)	$18,813	$39,625	$65,901	$93,639	$110,279

Analysing these results for the 10 case study dwellings the descriptive statistics can be determined, as shown in Table 24.

Table 24. Descriptive statistics for the various ratings levels for Homestar v3.

	Minimum	Maximum	Median	Average	Range
6-Homestar	$14,033	$56,279	$18,813	$22,948	$42,246
7-Homestar	$31,612	$63,545	$39,625	$41,671	$31,933
8-Homestar	$55,482	$73,674	$65,901	$64,962	$18,193
9-Homestar	$72,696	$107,249	$93,639	$91,129	$34,553
10-Homestar	$91,763	$130,249	$110,279	$110,763	$38,486

Using the median cost price increase for each of the star rating levels from Table 23 and the QV costbuilder construction cost of $1,975/m^2 (which interviews with various builders have also indicated is an appropriate rate), the different levels of Homestar rating would equate to an additional percentage cost as shown in Table 25. These percentage increases were determined by taking the $1,975/m^2 rate and applying it to the actual size of each case study dwelling to determine a baseline construction cost for each dwelling. The percentage increase from this baseline cost figure for each dwelling was then calculated. From these figures, the median of the percentages was calculated to determine the figures in Table 25.

Table 25. Median percentage increase to achieve 6, 7, 8, 9 and 10-Homestar from a Building Code standard.

	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Total cost increase from Building Code rate ($1,975/m^2)	6%	12%	19%	26%	32%

4.2.4 Homestar v4

As discussed previously in this report, there are a number of ways that 6 and 7-Homestar can be achieved in Homestar v4.

Table 26. Summary of median additional costs to achieve 6, 7, 8, 9 & 10-Homestar using Homestar v4 from a Building Code standard.

	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Total cost increase from Building Code ($0)	$13,248 (checklist)	$16,210 (schedule method)	$47,372	$67,365	$85,446
	$11,677 (points with schedule method)	$13,896 (calculation method – option 1)			
	$14,618 (points with calculation method)	$30,952 (calculation method – option 2)			
		$37,726 (calculation method – option 3)			
		$28,039 (energy modelling)			

As shown in Table 23 for 6-Homestar, a checklist method has been implemented that is meant to provide the most cost-effective approach to 6-Homestar. However, as shown in Figure 7, the analysis of the researcher has determined that, in every instance, this checklist will cost more to implement when compared to the use of the schedule method combined with a points approach. Both methods use the schedule method to determine compliance with the EHC-1 mandatory minimum, so the difference in cost is experienced in the other credits in the tool.

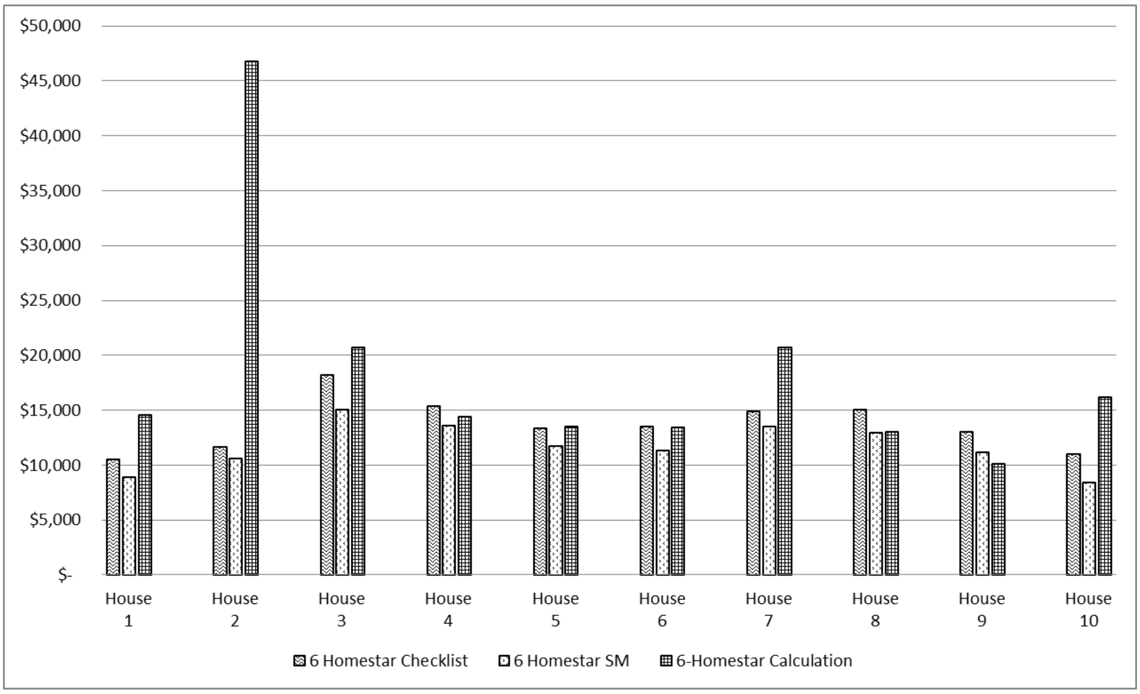


Figure 7. Options for achieving 6-Homestar in Homestar v4.

7-Homestar is even more complicated, with five potential methods to achieve a 7-Homestar rating (with a sixth – a checklist – also being discussed). Figure 8 shows the different options for achieving 7-Homestar in Homestar v4. It can be seen that there is a large variation in the cost associated with each of the options. In this case, all of this variation is to be with the cost of achieving the EHC-1 mandatory minimum, as all other credits have been kept constant in this analysis.

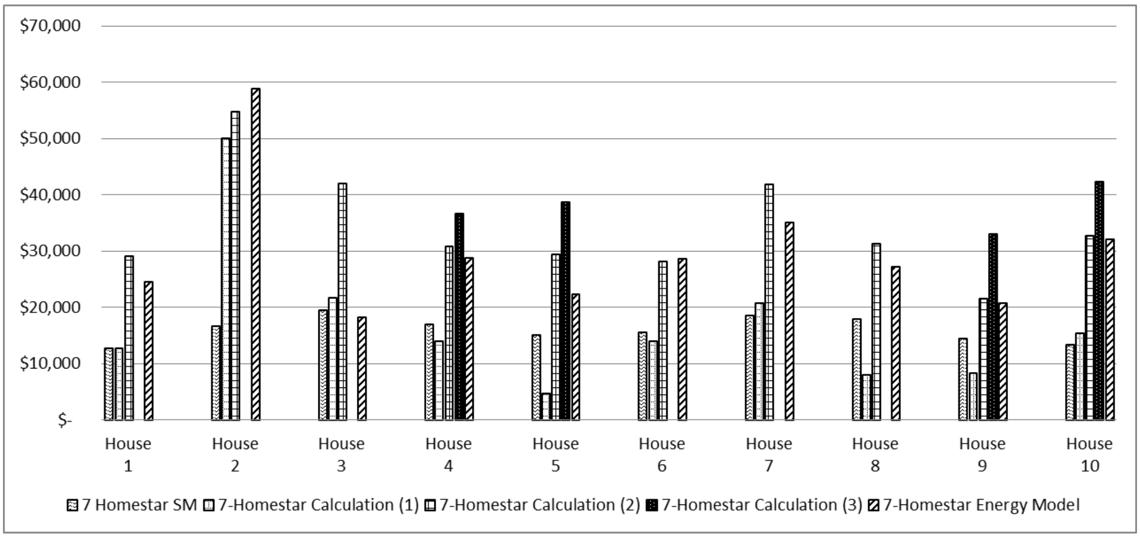


Figure 8. Options for achieving 7-Homestar in Homestar v4.

From these analyses, it appears that the most cost-effective method of targeting 6-Homestar in Homestar v4 is by using the schedule method in conjunction with a points approach, whilst for 7-Homestar, the most cost-effective approach varies between the schedule method and the calculation method – option 1, depending on the dwelling. Therefore, as discussed earlier in this report, the researcher does not believe that it is appropriate to generalise in this manner, as the results for individual dwellings can vary greatly.

Analysing these results for the 10 case study dwellings, the descriptive statistics can be determined, as shown in Table 27.

Table 27. Descriptive statistics for the various ratings levels for Homestar v4.

	Minimum	Maximum	Median	Average	Range
6-Homestar (checklist)	$10,358	$18,160	$13,248	$13,481	$7,802
6-Homestar (schedule method)	$8,590	$15,201	$11,677	$11,868	$6,611
6-Homestar (calculation method)	$10,267	$46,939	$14,618	$18,493	$36,672
7-Homestar (schedule method)	$12,803	$19,584	$16,210	$16,165	$6,780
7-Homestar (calculation method – option 1)	$4,623	$49,965	$13,896	$16,893	$45,342
7-Homestar (calculation method – option 2)	$21,549	$54,758	$30,952	$34,131	$33,208
7-Homestar (calculation method – option 3)	$33,168	$42,176	$37,726	$37,699	$9,008
7-Homestar (energy modelling)	$18,319	$59,002	$28,039	$29,748	$40,683
8-Homestar	$32,912	$75,672	$47,372	$49,863	$42,760
9-Homestar	$58,219	$95,005	$67,365	$72,487	$36,787
10-Homestar	$72,385	$104,174	$85,446	$86,734	$31,789

4.2.5 Overall cost summary

The results of this desktop analysis indicate median increases in cost for moving through the different Homestar rating levels for Homestar v4, as shown in Table 28.

Table 28. Summary of median additional costs to achieve 6, 7, 8, 9 and 10-Homestar from a Building Code standard using the most cost-effective option..

Total cost increase from Building Code	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Homestar v2	$18,043	$38,549	$63,102	$75,453	$101,705
Homestar v3	$18,813	$39,625	$65,901	$93,639	$110,279
Homestar v4	$11,677 (points with schedule method)	$13,896 (calculation method – option 1)	$47,372	$67,365	$85,446

From Table 28, it can be seen that Homestar v4 has greatly reduced the construction cost to achieve Homestar ratings, in particular, for the higher levels of Homestar. A reduction in cost often corresponds with a reduction in quality, and it is therefore of interest if the changes to Homestar v4 that have allowed the construction cost to be reduced have also resulted in a change in performance of the dwellings. The researcher has therefore also undertaken a simple benefit analysis.

4.3 Benefit analysis

When green building rating tools are promoted, benefits that are generally attributed to them include:

- increased sales price
- increased rental rates
- reduced time on the market
- reduced rental vacancy
- improved indoor environmental quality leading to improved occupant health and comfort
- reduced operating costs
- increased societal benefits such as lower healthcare costs, lower costs of carbon and reduced landfill waste.

A concurrent and as yet unpublished BRANZ study is researching whether Homestar-rated dwellings experience any increase in sales price. Due to the ongoing nature of this research, it is not possible to discuss any increased sales price benefits at this time. Rental rates, vacancy rates and time on the market are as yet unstudied for Homestar dwellings in the New Zealand market and therefore cannot be discussed at this time either. In this desktop study, it is however possible to calculate the theoretical benefit of the required Homestar improvements in terms of reduced operating costs.

Something similar was undertaken previously when the 2013 study by eCubed expanded on the 2013 Jasmax study, undertaking cost-benefit analysis and investigating payback periods for 5, 6 and 7-Homestar. The study focused solely on the energy and water credits. This researcher has followed a similar methodology, also focusing on the energy and water credits where it is possible to calculate potential energy and water savings. The main Homestar credits of EHC-1, EHC-, EHC-5, EHC-6 and WAT-1 were reviewed. For all energy credits, the payback period has been estimated using the median electrical usage rate of $0.28, which was determined through a survey of the rates of all of the energy companies in New Zealand.

The eCubed study reviewed the space heating, water heating and lighting savings that could be achieved to determine an overall energy saving. Water saving was determined on the basis of water-efficient fixtures and fittings and the inclusion of rainwater storage.

The results of the eCubed study can be seen in Table 29. The current researcher has adjusted the eCubed results, removing the impact of lighting from consideration as the market has moved on since 2013 and it is now standard to install efficient LED lights in all new dwellings. The current researcher has used the other eCubed figures as they are stated in their report.

Table 29. Energy cost-benefit analysis from eCubed (2013).

	Space heating savings (kWh/yr)	Water heating savings (kWh/yr)	Total energy savings (kWh/yr)	Water and wastewater (m^3/yr)	Annual savings	Cost	Payback (yrs)
6-Homestar	829	615	1,444	89.56	$539	$2,200	4
7-Homestar	471	5,170	5,641	89.56	$877	$11,174	12.7

Unfortunately, it is not possible to easily isolate the rainwater tank L/yr savings from the overall water savings calculations in the eCubed analysis, as their report does not state the occupant usage rates that were used in their calculations. However, the current researcher does note that the Building Code dwelling baseline that they have used assumes a use of 400 L/person/day, which is much higher than the NZGBC Homestar v2 assumed daily water use of 200 L/person/day.

4.3.1 Space heating

A space heating heat pump is a minimum of three times as efficient as a plug-in wall heater according to www.level.org.nz. Taking a basic assumption that installing a heat pump would reduce the kWh/yr required for space heating by two-thirds, the researcher then calculated the payback period for this Homestar improvement. Table 30 shows that, while a heat pump is definitively more efficient than other forms of heating, it would still take a long time to pay off the initial capital cost of installing the heat pump.

Table 30. Payback period for the inclusion of a heat pump for space heating.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Cost increase	$4,500	$4,500	na	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500
KWh/yr saving	1536	955	na	813	621	859	763	907	891	778
Savings ($/yr)	430	267	na	228	174	241	214	254	249	218
Payback	10	17	na	20	26	19	21	18	18	21

It needs to be noted that, while simple payback calculations are an interesting analysis, they can oversimplify financial evaluation to the point that the best-performing alternatives are not properly quantified and identified. Life cycle cost analyses, in comparison, include a comprehensive examination of all of the costs and savings attributable to the investment and should be considered when reviewing technologies.

4.3.2 Hot water heating

A similar analysis was undertaken for the inclusion of a hot water heat pump. The kWh/yr were estimated using the Homestar EHC-5 calculator, which calculates a $kgCO_2$/yr for hot water heating. The Homestar-referenced 0.18 $kgCO_2$/kWh for electricity and 0.22 $kgCO_2$/kWh for LPG gas were used to convert these figures from $kgCO_2$ to kWh/yr. Table 31 replicates the anecdotal evidence from industry that hot water heat pumps are one of the better investments to make in a dwelling as the paybacks are relatively small and are likely to be experienced within the timeframe of the initial owners.

Table 31. Payback period for the inclusion of a hot water heat pump.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Cost increase	$3,295	$3,295	na	$2,195	$3,295	$3,295	$3,295	$3,295	$3,295	$3,295
KWh/yr saving	2,067	2,250	na	4,423	2,217	2,217	2,189	2,283	2,211	3,727
Savings ($/yr)	579	630	na	1,238	621	621	613	639	619	1,044
Payback	6	5	na	2	5	5	5	5	5	3

4.3.3 Appliances

For EHC-4, the HEEP study (Isaacs et al., 2010) was used to determine the average yearly energy use of fridges and dishwashers in New Zealand. This study states these to be 621 kwh/yr and 211 kwh/yr respectively for fridges and dishwashers. The Westinghouse WRM2400WD that has been costed for use is stated as being 237 kwh/yr, while the Imprasio IDW14STS is stated as consuming 260 kwh/yr. This would result in a saving of 384 kwh/yr for the fridge but an increase in energy use for the dishwasher of 49 kwh/yr. Assuming the same electricity usage rate of $0.28/kWh, this would result in a saving of $94/year. The additional capital cost of these two items is $1,104, and this would therefore result in a basic payback period of 12 years for these two items combined.

4.3.4 Renewable energy

For all of the case study dwellings, Homestar estimates that the provided system would generate approximately 3,498 kWh/yr of electricity. Assuming the same electricity usage rate of $0.28/kWh and using the installed system cost of $10,495, this system would have a payback period of 11 years. However, this assumes that all electricity generated on site is used on site. Without storage facilities, this may not be the case.

Assuming that 50% of the electricity was used on site and 50% was exported back to the grid at 8 c/kWh, the payback period would be 17 years. This correlates well with the EnergyWise Solar Calculator (www.energywise.govt.nz/tools/solar-calculator), which also calculated a 17-year payback for the case study dwellings.

4.3.5 Thermal performance

6-Homestar

It is worthwhile knowing which tool and heating calculation method provides the best outcome in terms of space heating load. However, the kWh/yr should not be evaluated in isolation. Therefore, while it is worthwhile trying to design and construct dwellings that are more efficient in terms of space heating load, this needs to be kept in balance with the cost to implement the required energy-saving features.

Table 16 (presented again as Table 32 below) shows the costs associated with the different thermal comfort analysis methods.

Table 32. Cost implications of 6-Homestar for the different thermal performance approaches across the different Homestar versions using a 20°C set point and ALF online.

$	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
6-Homestar										
Homestar v2 and v3	$2,791	$34,074	$6,149	*$3,076*	**$4,626**	**$5,992**	$7,179	*$2,888*	$1,297	$2,250
Homestar v4 schedule method	*$515*	*-$998*	*$3,546*	**$3,143**	*$3,178*	*$2,817*	*$2,737*	$3,713	**$1,349**	*-$1,302*
Homestar v4 calculation method	**$6,176**	**$35,218**	**$8,877**	$3,984	**$4,626**	$4,877	**$9,973**	**$3,768**	*$0*	**$6,131**

The table is again shaded to show the worst-performing thermal analysis method in black, with the best in light grey. The method with the highest cost of implementing the thermal performance changes is indicated (**<u>bold underlined)</u>** and the lowest cost in *italics*.

Table 32 shows that, overall, the schedule method is the most cost-effective method of achieving the 6-Homestar thermal performance mandatory minimum. However, it is important to note that this is not always the case and that, for certain dwellings, alternative compliance paths might be better targeted.

Furthermore, Table 32 shows that, in many instances, implementing the schedule method on the dwellings results in a cost saving. This is due to the fact that these dwellings need to reduce their window area to be able to comply with the schedule method, and it is cheaper to build solid walls rather than windows. Windows are also one of the largest areas of heat loss in a dwelling. Therefore, reducing the window size not only saves capital cost, it also improves operating costs.

However, Table 32 also illustrates that the schedule method provides dwellings with the highest space heating requirements when compared to the other options. It is therefore important to analyse whether the reduced capital costs are negated by the reduced space heating savings.

Figure 9 shows the additional cost to achieve the space heating load requirements for 6-Homestar.

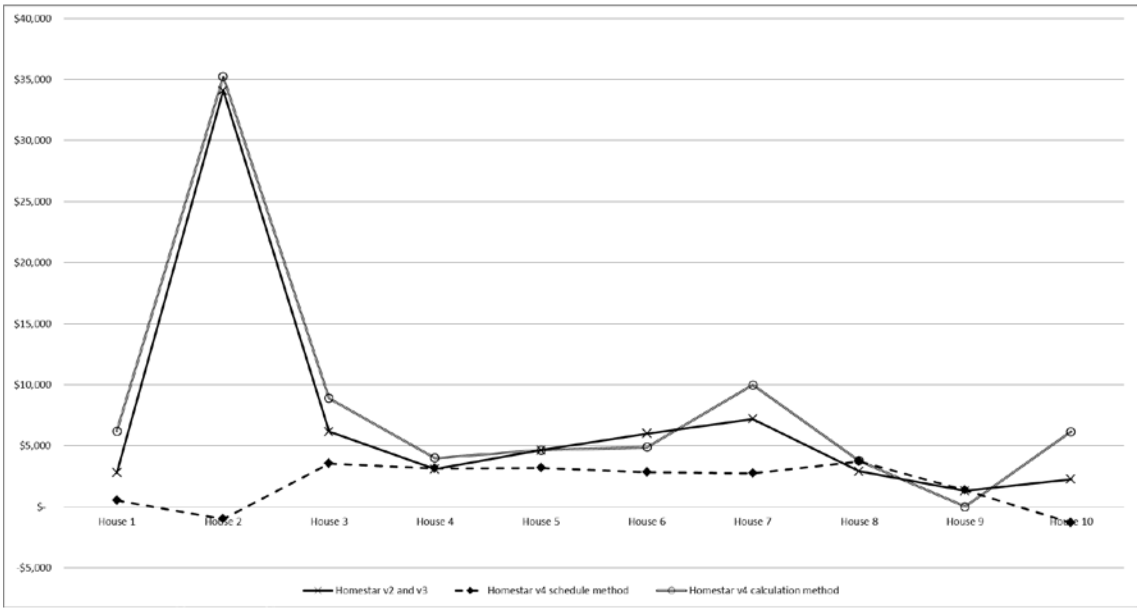


Figure 9. Additional cost to achieve the 6-Homestar space heating load requirements.

Using the information in Table 11 and Table 32, it is possible to analyse the payback period for the different thermal analysis methods used in the different iterations of the Homestar rating tool. For this analysis, a payback period has been estimated using the median electrical usage rate of $0.28 that was determined through a survey of the rates of all of the energy companies in New Zealand. The 20°C set point was used in the analysis as this enabled all the space heating loads to be measured using the same analysis method, namely ALF.

Table 33. Thermal performance upgrade costs and estimated payback period for 6-Homestar using a 20°C set point and ALF online.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar v2 and v3										
Cost increase 6-Homestar	$2,791	$34,074	$6,149	$3,076	$4,626	$5,992	$7,179	$2,888	$1,297	$2,250
Annual 6-Homestar savings ($/yr)	101	941	413	356	252	940	806	225	85	170
Payback (yrs)	28	36	15	9	18	6	9	13	15	13
Homestar schedule method										
Cost increase 6-Homestar	$515	-$998	$3,546	$3,143	$3,178	$2,817	$2,737	$3,713	$1,349	-$1,302
Annual 6-Homestar savings ($/yr)	79	194	109	382	215	514	624	170	23	234
Payback (yrs)	7	No payback period – initial cost saving and then reduced energy costs	33	8	15	5	4	22	60	No payback period – initial cost saving and then reduced energy costs
Homestar v4 heating load calculations using the online BRANZ ALF calculator										
Cost increase 6-Homestar	$6,176	$35,218	$8,877	$3,984	$4,626	$4,877	$9,973	$3,768	-	$6,131
Annual 6-Homestar savings ($/yr)	200	1,226	788	473	240	890	948	494	-	295
Payback (yrs)	31	29	11	8	19	5	10	8	0	21

The results are somewhat surprising to the researcher as our initial assumption was that one version of the tool would trump all of the others. However, this appears to not be the case, and someone who is providing advice on Homestar would need to carefully consider all the different options that are available as each dwelling design is unique and performs differently in each iteration of the rating.

Therefore, while the schedule method may be the best approach for one dwelling, the heating load calculations using the online BRANZ ALF calculator may be a better approach for another dwelling. However, in all instances for the dwellings analysed, Homestar v4 was the best tool for them to use.

7-Homestar

Again and as with 6-Homestar, while it is worthwhile knowing which tool and heating calculation method provides the best outcome in terms of space heating load, the kWh/yr should not be evaluated in isolation. Table 34 shows the additional capital cost that is required to be invested to achieve 7-Homestar from a Building Code baseline. As with 6-Homestar, it is important to analyse whether the reduced capital costs are negated by the reduced space heating savings.

Using the information in Table 13 and Table 34, it is possible to analyse the payback period for the different thermal analysis methods used in the different iterations of the Homestar rating tool.

Table 34. Additional cost to achieve 7-Homestar space heating load requirements.

$	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
7-Homestar										
Homestar v2 and v3	$18,793	**$73,562**	$20,199	$20,306	$16,212	$19,124	$20,843	$7,468	$12,649	$23,983
Homestar v4 schedule method	$4,274	*$4,045*	$8,378	$6,948	*$5,972*	$7,605	*$7,571*	$8,764	$4,419	*$3,803*
Homestar v4 calculation method – option 1	*$3,530*	$36,361	$8,913	*$2,722*	-$5,012	*$4,493*	$8,776	*-$2,431*	*-$2,590*	$4,516
Homestar v4 calculation method – option 2	**$19,804**	$41,153	**$29,310**	$19,589	$19,867	$18,616	**$29,879**	**$20,859**	$10,682	$21,897
Homestar v4 calculation method – option 3	na	na	Na	**$25,351**	**$29,051**	na	na	na	**$22,154**	**$31,426**
Energy modelling	$15,319	$45,205	*$5,482*	$17,443	$12,634	**$19,155**	$23,117	$16,813	$9,812	$21,201

Again, for this analysis, a payback period has been estimated using the median electrical usage rate of $0.28, and the 20°C set point was used in the analysis as this enabled all the space heating loads to be measured using the same analysis method, namely ALF.

At a first glance, Table 35 would appear to indicate that it is not generally worthwhile to target 7-Homestar if you are looking for space heating savings in isolation. However, when the Homestar v4 calculation method – option 1 is used, some of the case study dwellings would experience a good payback period for their initial investment in the 7-Homestar EHC-1 mandatory minimum.

In particular, Dwellings 4, 6 and 7 would experience reasonable payback periods of less than 10 years, as their initial capital investment would then have reduced space heating energy costs from that point on. However, this is largely due to the fact that, in order to follow this compliance path, these dwellings would have had to delete large areas of glazing from their design, which, as discussed in Appendix A, is likely not desirable.

The researcher has not included the energy modelling method in the analysis in Table 36 as it is not possible to directly compare the results achieved in ALF to those achieved in PHPP. Any such attempted analysis would therefore be invalid.

Table 35. Thermal performance upgrade costs and estimated payback period for 7-Homestar using the 20°C set point and ALF online.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar v2 and v3										
Cost increase 7-Homestar	$18,793	$73,562	$20,199	$20,306	$16,212	$19,124	$20,843	$7,468	$12,649	$23,983
Annual 7-Homestar savings ($/yr)	$482	$1,570	$991	$890	$499	$1,292	$1,154	$552	$474	$743
Payback (yrs)	39	47	20	23	32	15	18	14	27	32
Homestar schedule method										
Cost increase 7-Homestar	$4,274	$4,045	$8,378	$6,948	$5,972	$7,605	$7,571	$8,764	$4,419	$3,803
Annual 7-Homestar savings ($/yr)	$79	$194	$109	$382	$215	$514	$624	$170	$23	$234
Payback (yrs)	54	21	77	18	28	15	12	52	196	16

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar calculation method – option 1										
Cost increase 7-Homestar	$3,530	$36,361	$8,913	$2,722	-$5,012	$4,493	$8,776	-$2,431	-$2,590	$4,516
Annual 7-Homestar savings ($/yr)	$200	$1,226	$788	$473	$240	$890	$982	$494	-	$295
Payback (yrs)	18	30	11	6	No payback period – initial cost saving and then reduced energy costs	5	9	No payback period – initial cost saving and then reduced energy costs	No payback – additional cost for no energy savings	15
Homestar calculation method – option 2										
Cost increase 7-Homestar	$19,804	$41,153	$29,310	$19,589	$19,867	$18,616	$29,879	$20,859	$10,682	$21,897
Annual 7-Homestar savings ($/yr)	$504	$1,520	$1,085	$798	$506	$1,191	$1,322	$696	$320	$725
Payback (yrs)	39	27	27	25	39	16	23	30	33	30
Homestar calculation method – option 3										
Cost increase 7-Homestar				$25,351	$29,051				$22,154	$31,426
Annual 7-Homestar savings ($/yr)				$1,884	$714				$535	$956
Payback (yrs)				13	41				41	33

Jump from 6-Homestar to 7-Homestar (Homestar v2 and v3)

When trying to determine whether or not it is worthwhile for a dwelling to attempt a higher level of Homestar rating, it is important to consider the effect of the different thermal analysis methods of the outcomes. Previously, the researcher has been using the 20°C set point and ALF online models to summarise results, as this enables comparisons with Homestar v4. It is important to remember that ALF online has been analysing the same designs more stringently. Therefore, if an assessment is being undertaken on whether or not a higher level of rating should be targeted in Homestar v2 or v3, it would instead be worth reviewing the EHC-6 calculator results that use the 18°C set point.

Table 36 gives the costs of the required design changes to move from 6-Homestar to 7-Homestar and the additional energy savings that would be experienced by each dwelling as well as the estimated payback period.

Table 36. Simplified payback period analysis to move from 6 to 7-Homestar.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar v2 and v3										
Cost increase from 6 to 7-Homestar	$16,001	$39,488	$14,049	$17,230	$11,585	$13,132	$13,663	$4,580	$11,352	$21,733
Annual additional energy savings ($/yr)	$380	$629	$577	$535	$247	$352	$349	$327	$389	$572
Calculated payback (yrs)	42	63	24	32	47	37	39	14	29	38
Difference between 6 and 7-Homestar paybacks in years	11	11	6	14	14	8	9	1	11	19

It can be seen from this table that there is a large payback period associated with moving from 6 to 7-Homestar in Homestar v2 and v3. The analysis appears to demonstrate that the majority of the energy savings are 'banked' at the 6-Homestar stage, with the requisite additional cost required to achieve 7-Homestar resulting in large payback periods.

It is worthwhile remembering that this large cost investment in increased passive thermal efficiency only brings a 1.5 point increase in EHC-6, with a resultant 0.5 point increase in EHC-1. Each dwelling therefore needs to find a further 8 points elsewhere in the rating tool to achieve the 70 point benchmark that is required for 7-Homestar (ignoring any impacts from the RAF). Figure 10 demonstrates how, in most cases, nearly half the cost to achieve 7-Homestar for the case study dwellings is from the increased passive thermal performance requirements.

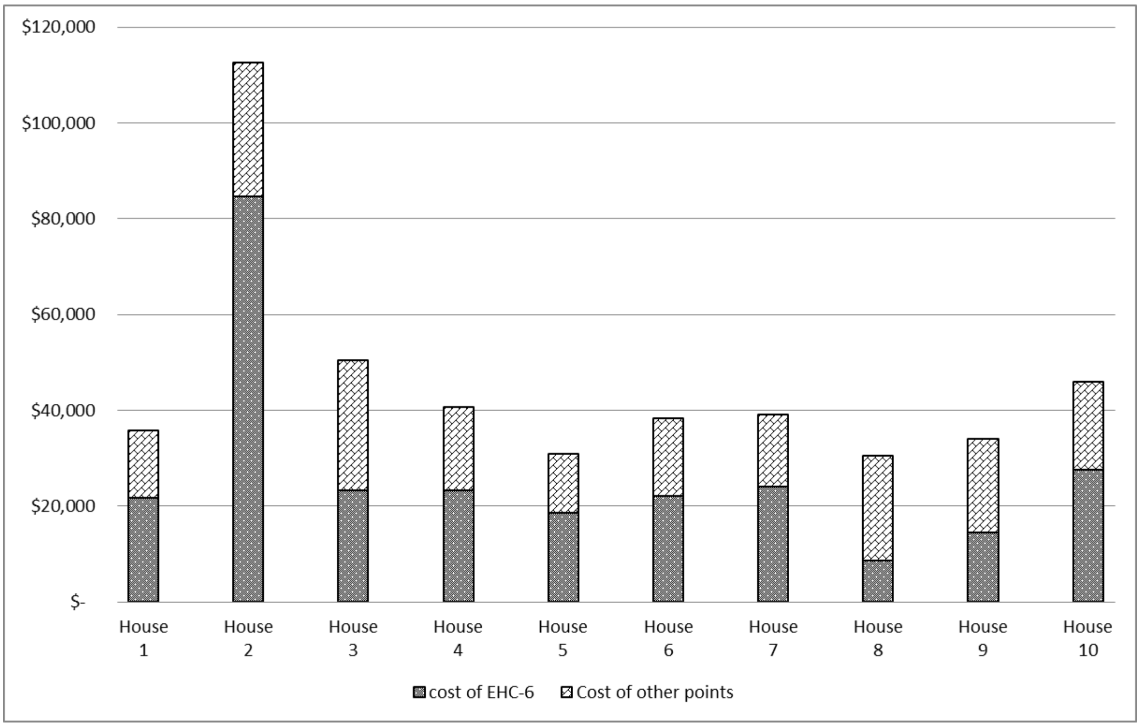


Figure 10. Additional costs associated with EHC-6 (thermal performance) versus other 7-Homestar credits.

Based on the cost-benefit analysis undertaken above, it needs to be seriously considered whether this investment is of benefit to these dwellings. The remaining points and their associated costs to achieve 7-Homestar can be seen in Appendix B.

Slab edge insulation

The researcher[1] is aware that slab edge insulation is a contentious discussion point in the context of Homestar and is frequently highlighted by industry as an area that attracts additional cost for minimal practical benefit for the homeowner. Certainly, each builder the researcher has interviewed in a complementary BRANZ study has listed slab edge insulation as an additional cost item when compared to a standard Building Code dwelling.

[1] Disclaimer: the researcher is married to a manufacturer of slab edge insulation.

It is worth noting that slab edge insulation typically is required by a dwelling to achieve the EHC-7 mandatory minimum, rather than the EHC-6 mandatory minimum, although in many cases, the slab edge insulation often helps the dwelling perform in EHC-6. Critics of slab edge insulation in the market often do not believe that dwellings in the Auckland climate zone require the installation of slab edge insulation, stating verbally to the researcher that the R1.5 mandatory minimum requirement is not an appropriate measure for evaluating the risk of condensation forming on the slab. These critics believe that the Auckland climate is temperate enough that a standard waffle pod foundation's temperature will never drop low enough to warrant the use of slab edge insulation. An analysis of the impact of slab edge insulation in terms of additional cost and payback periods is therefore warranted given the interest the market has shown in this particular product.

Reviewing the results of the study dwellings, initially, the researcher assumed that the dwellings with the largest EHC-6 payback periods (Dwellings 2, 3, 6, 8 and 10) would only require the installation of slab edge insulation to achieve the EHC-7 mandatory minimum of R1.5 for the floor structure and did not require the slab edge insulation to help improve the thermal performance and meet the EHC-6 criteria. A review of Appendix A proves that this was mostly the case. Dwelling 10 required no other thermal improvements other than slab edge insulation, while Dwellings 3 and 8 required slab edge insulation as well as an insulated garage wall and ceiling. Dwelling 6 required slab edge insulation, an insulated garage wall and ceiling as well as low-e glazing. As discussed earlier, Dwelling 2 is a special case and its payback period is large for a different reason.

The dwellings with the EHC-6 large payback period therefore appear to be dwellings that are installing slab edge insulation to achieve the EHC-7 mandatory minimum rather than improve EHC-6 performance. To test this, the researcher removed the slab edge insulation from the EHC-6 thermal analysis to see its impact. It can be seen from Table 37 that the slab edge insulation was in fact required to enable the majority of the dwellings to achieve the EHC-6 mandatory minimum. However, it should also be noted that this compliance could potentially also be achieved in other potentially less costly mechanisms, such as increased wall or ceiling insulation, reduced shading of windows and exposed concrete floors for thermal mass.

Table 37. Thermal performance upgrade costs without slab edge insulation costs and estimated payback period.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Achieve EHC-6 mandatory minimum	N	N	N	N	N	N	Y	Y	N	Y
KWh/yr savings for slab edge insulation	179	522	223	334	200	350	392	251	418	242
Payback (yrs)	39	50	42	26	39	25	27	39	11	33

Since Dwellings 7, 8 and 10 could have achieved the EHC-6 mandatory minimum without the inclusion of slab edge insulation, the researcher removed the cost of the slab edge insulation from the thermal improvements and re-analysed the payback period based on the EHC-6-only required changes for these dwellings.

Table 38 gives the results of this analysis. Dwelling 7 reduces its overall payback period from 9 to 6 years without the slab edge insulation and can make significant heating cost savings once its thermal performance upgrades have been paid off, likely due to the inclusion of the low-e glazing in its design. Dwelling 8 only has a slight increase in insulation R-values, and therefore its heating energy savings are much lower. Dwelling 10 achieves no savings from a Building Code-compliant building without the slab edge insulation and therefore has no cost or payback.

Table 38. Thermal performance upgrade payback without slab edge insulation costs and estimated payback period.

	Dwelling 7	Dwelling 8	Dwelling 10
KWh/yr difference from Building Code	2,520	169	0
Payback (yrs)	6	5	-
10-year savings	$2,562	$261	0

Jump from 6-Homestar to 7-Homestar (Homestar v4)

Initially it appears as though Homestar v4 has been carefully crafted by the NZGBC to reduce or eliminate the requirement for slab edge insulation in the Auckland climate zone. The previous EHC-7 mandatory minimum in Homestar v2 and v3 required a floor R-value of R1.5, and this has been eliminated in its entirety. Somewhat taking its place is the new schedule method that instead requires a Building Code-consistent R-value of R1.3 for the floor of a dwelling in climate zone 1. However, it is the experience of the researcher that a typical waffle pod foundation, without slab edge insulation, will only achieve an R-value of R0.9–1.2 when determined using the BRANZ *House Insulation Guide* (BRANZ, 2014), which is currently the only analysis method acceptable to the NZGBC, with the exception of R-values derived from modelling in 3D heat analysis software.

Certainly, most dwellings analysed for this study still required slab edge insulation to enable the Building Code and Homestar v4 schedule method R1.3 requirement to be achieved. This is due to the fact that the area/perimeter ratios of the dwellings were too low to achieve >R1.3 when the waffle pod R-value tables in the BRANZ *House Insulation Guide* were used.

It is interesting to note that slab edge insulation is not a standard feature of Building Code-compliant dwellings, even though waffle pod slabs do not typically achieve R1.3. However, Building Code clause H1 *Energy efficiency* Acceptable Solution H1/AS1 amends NZS 4218:2009 *Thermal insulation – Housing and small buildings* so that concrete slab-on-ground floors (which have an R-value very close to waffle pods) are deemed to achieve a construction R-value of R1.3 (www.level.org.nz/passive-design/insulation/options-for-floor-insulation).

The Homestar Technical Manual references H1/AS1 on page 34, stating that Homestar requires all slab-on-ground constructions to demonstrate that they have met the R1.3 requirements and that slab-on-ground construction is not deemed to comply. This research therefore highlights that, even though the floor R-value has been reduced from R1.5 to R1.3, the majority of dwellings will still likely require slab edge insulation in climate zone 1 if attempting 6-Homestar and targeting basic schedule method compliance. Dwellings could potentially use the NZS 4218:2009 approach to the schedule method or undertake an ALF calculation to demonstrate 6-Homestar compliance without requiring slab edge insulation, as the ALF calculation method is not prescriptive and therefore items like wall and ceiling insulation could be increased to achieve compliance in preference to slab edge insulation.

From Table 39, it can be seen that only the schedule method appears to be a candidate for use if a dwelling wishes to move from 6 to 7-Homestar, with the rest of the thermal comfort analysis options having much larger payback periods. This appears to contrast with the analysis provided earlier where it appeared that the Homestar v4 calculation method – option 1 was the best way to achieve 7-Homestar. However, the findings are consistent with each other when one remembers that the calculation method – option 1 is just the 6-Homestar calculation method with three home cooling features appended to it. Therefore, additional cost is attracted for these additional features when moving from 6 to 7-Homestar with no additional annual energy saving. Therefore, all of the energy savings for the Homestar v4 calculation method – option 1 are banked at the 6-Homestar level, resulting in no additional benefits (and a large payback period) when moving to 7-Homestar.

Table 39. Payback period for the thermal performance upgrades required to move from 6 to 7-Homestar using a 20°C set point and ALF online.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Homestar schedule method										
Cost increase from 6 to 7-Homestar	$3,759	$5,042	$4,832	$3,805	$2,794	$4,788	$4,833	$5,051	$3,070	$5,105
Annual additional energy savings ($/yr)	$187	$475	$324	$455	$329	$798	$830	$388	$202	$459
Payback (yrs)	20	11	15	8	9	6	6	13	15	11
Homestar calculation method – option 1										
Cost increase 7-Homestar	-$2,646	$1,142	$36	-$1,262	-$9,638	-$384	-$1,198	-$6,200	-$2,590	-$1,616
Annual 7-Homestar savings ($/yr)	-	-	-	-	-	-	-	-	-	-
Payback (yrs)	No payback period – initial cost saving	No payback – initial extra cost with no energy saving	No payback – initial extra cost with no energy saving	No payback period – initial cost saving	No payback period – initial cost saving	No payback period – initial cost saving	No payback period – initial cost saving	No payback period – initial cost saving	No payback – initial extra cost with no energy saving	No payback period – initial cost saving
Homestar calculation method – option 2										
Cost increase 7-Homestar	$13,628	$5,935	$20,434	$15,605	$15,241	$13,739	$19,905	$17,091	$10,682	$15,765
Annual 7-Homestar savings ($/yr)	$304	$294	$297	$324	$267	$301	$340	$202	$320	$430
Payback (yrs)	45	20	69	48	57	46	58	85	33	37
Homestar calculation method – option 3										
Cost increase 7-Homestar				$21,367	$24,425				$22,154	$25,294
Annual 7-Homestar savings ($/yr)				$1,429	$484				$683	$727
Payback (yrs)				15	50				32	35

The Homestar v4 schedule method on the other hand requires the inclusion of low-e film for glazing, thus improving one of the weakest elements of the thermal envelope when moving from 6 to 7-Homestar and thus providing additional energy savings. This is verified through the schedule method having the best payback period in this analysis.

However, the Homestar v4 calculation method – options 2 and 3 have large payback periods, and therefore, while 7-Homestar in these instances delivers an increased benefit in terms of reduced heating costs when compared to a Building Code benchmark, Table 36 indicates that the payback period for this benefit is in every instance so large that it is likely not worthwhile to invest in it.

4.3.6 Rainwater harvesting

With the exception of Dwelling 2, which requires a rainwater tank to achieve 7-Homestar, in every instance, to reach the 8-Homestar level or higher, the researcher has included a rainwater tank, with the majority of dwellings only requiring the rainwater tank for 9-Homestar or higher. The tanks have been sized as 3,500 L tanks. Unfortunately, Homestar v2 just provides blanket points for the provision of a tank rather than an analysis of points based on how much potable water the dwelling would save. Homestar v3, however, has a calculator that does undertake this analysis. The researcher has therefore used the rainwater calculator from Homestar v3 to estimate the water savings and payback period for the provision of rainwater tanks to these dwellings.

According to Heinrich and Roberti (2008, Table 2, p. 4), the average Auckland household uses around 150,000 litres of water a year and typically buys all of that from Watercare at a cost of $2.454 per 1,000 litres (or $368 per year for 150,000 L). The Homestar v3 calculator uses a benchmark of 200 L per person per day and variously estimates the water use of a 4-bedroom home as 365,000 L/yr and a 5-bedroom home as 465,000 L/yr. A press release from Watercare on 23 May 2016 stated that the price of water was to be $1.444 per 1,000 (including GST). Using the figures from the Homestar v3 rainwater calculator in conjunction with the recent Watercare pricing figures, it can be seen that the payback periods on the inclusion of water tanks for each of these dwellings are large (Table 40).

Table 40. Payback period for the inclusion of rainwater tanks.

	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Yearly usage (L)	365,000	365,000	438,000	438,000	365,000	365,000	365,000	365,000	365,000	365,000
Rainwater contribution (L)	83,950	120,450	188,340	91,980	80,300	98,550	98,550	120,450	120,450	120,450
Rainwater tank cost	$3,620	$4,220	$3,620	$3,620	$3,620	$3,620	$3,620	$3,620	$3,620	$3,620
Payback (yrs)	30	24	13	27	31	25	25	21	21	21

It needs to be noted that, for some dwellings to achieve 9 and 10-Homestar, the researcher has had to increase the size of the rainwater tanks to enable additional points to be activated in the WAT-1 credit. This is detailed in Appendix B.

It can be seen from Table 40 that, in the majority of cases, the payback period for the inclusion of a 3,500 L rainwater tank is large and is therefore likely not warranted on a reduction of operating cost basis alone. However, it should also be noted that reduced operating costs are not the only reason for including a rainwater tank in a project. Flexibility of use during watering/hose pipe bans, resilience in case of emergency and stormwater attenuation are some other valid reasons for including a rainwater tank on a project, and these benefits are not highlighted in a review of operating costs alone.

4.3.7 Internal potable water use

For this study, it was not possible to know the actual base case usage and flow rates in the case study dwellings. Therefore, the Water End-use and Efficiency Project (WEEP) study (Heinrich, 2007) as shown in

Table 41 was used as a reference for the baseline water usage rates that could be expected in a dwelling that is not considering Homestar. These figures were used to establish a base Building Code-equivalent water usage in litres per year.

Table 41. WEEP water use figures.

	% of total use	Litres/ person/ day	Average flow rate (L/min)	Volume (L/flush)	Usage time (mins)	Number of uses (person/day)
Tap	13.5	22.7	3.8		0.46	11.9
Shower	26.7	44.9	11.8		7.7	1.35
Toilet	18.6	31.3		12.9		4.7
Washing machine	23.7	39.9				0.75
Dishwasher	Not separately identified in the study. NZGBC estimate dishwasher water use as 1% of total in their potable water calculator in the Homestar tool.					

However, when undertaking the costing exercise for this credit, it was determined that the cheapest shower available from the Bunnings website was already compliant with the required WELS 3-star rating (9 L/min). The cheapest toilet suite listed on the website was also already compliant with the WELS 3- star requirement.

Therefore, for accuracy of the study, operational savings are only calculated for items where an additional cost had to be incurred to achieve Homestar points (Table 42). In this study, this would be for the basin mixer taps, kitchen tap, WELS 4-star toilet suite and washing machine. However, an overview of what the savings would be when compared to the WEEP benchmarks has also been included as the savings that are possible for low-flow showers when compared to higher-flow showers are stark, and it can still be common in the market for high-flow showers to be installed in Building Code-compliant dwellings.

Table 42. Water savings for reduced-flow taps and low flush toilets.

Savings	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
L/yr	25,144	25,144	30,173	30,173	25,144	25,144	25,144	25,144	25,144	25,144
$/yr*	$62	$62	$74	$74	$62	$62	$62	$62	$62	$62
Cost	$234	$234	$311	$311	$234	$234	$234	$311	$234	$311
Payback (yrs)	3.8	3.8	4.2	4.2	3.8	3.8	3.8	3.8	3.8	3.8

* Watercare cost of water of $2.454 per 1,000 litres.

The flow and flush rates were then modified to reflect the low-flow fixtures and fittings rates that were allocated in the Homestar ratings. The resultant water and cost savings are shown in Table 43. Due to the cost associated with higher WELS-rated dishwasher and washing machine, points for these items were typically not targeted until 9-Homestar. The taps, showers and toilets will therefore be reviewed separately from the dishwasher and washing machine.

Table 43. Water savings from WEEP benchmarks for reduced-flow rate showers, taps and low-flush toilets.

Savings	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
L/yr	55,384	55,384	66,461	66,461	55,384	55,384	55,384	55,384	55,384	55,384
$/yr*	$136	$136	$163	$163	$136	$136	$136	$136	$136	$136

* Watercare cost of water of $2.454 per 1,000 litres.

However, the inclusion of low-flow showers will not only have an effect on overall water usage, it will also impact that amount of hot water that is used in the dwelling. Using the Homestar v2 EHC-2 hot water calculator, it is possible to change the flow rate of the shower from 11.8 L/min to 9 L/min, which is the 6-Homestar requirement, and determine the resultant $kgCO_2$ savings, which can then be converted to kwh/yr as shown in Table 44.

Table 44. Hot water savings from reduced-flow rate showers.

Savings	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
Kwh/yr	889	1,217	389	1,706	889	889	889	883	889	1,444
$/yr	$249	$341	$109	$478	$249	$249	$249	$247	$249	$404

Incorporating this information into the payback summary greatly alters the figures, as shown in Table 45, demonstrating that the inclusion of low-flow taps and showers and toilets can pay back almost immediately.

Table 45. Water savings from WEEP benchmarks for reduced-flow rate showers, taps and low-flush toilets.

Savings	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
L/yr	71,999	71,999	86,398	86,398	71,999	71,999	71,999	71,999	71,999	71,999
Kwh/yr	889	1,217	389	1,706	889	889	889	883	889	1,444
$/yr	$426	$518	$321	$690	$426	$426	$426	$424	$426	$581
Cost	$234	$234	$311	$311	$234	$234	$234	$311	$234	$311
Payback (yrs)	0.5	0.5	1	0.5	0.5	0.5	0.5	0.7	0.5	0.5

The Imprasio dishwasher IDW14STS (WELS 4.5-star rating) is stated as having a water usage of 12.1 L per wash, while the benchmark Vogue WMVG.6KG, which holds a WELS 3-star rating, uses 60 L per load and the WELS 5-star Miele WMV960WPS uses 54 L per load. Since dishwashers only account for such a small percentage of water use, only the washing machine will be evaluated (Table 46). The WEEP study identifies that each person in the dwelling will use the washing machine 0.75/day and the average water usage for a load was 134 L (top loader). For this analysis, the WEEP L/load figure has been used.

Table 46. Water savings and payback period for water-efficient washing machine.

Savings	Dwelling 1	Dwelling 2	Dwelling 3	Dwelling 4	Dwelling 5	Dwelling 6	Dwelling 7	Dwelling 8	Dwelling 9	Dwelling 10
L/yr	109,500	109,500	131,400	131,400	109,500	109,500	109,500	109,500	109,500	109,500
$/yr	$269	$269	$322	$322	$269	$269	$269	$269	$269	$269
Cost	$4,149	$4,149	$4,149	$4,149	$4,149	$4,149	$4,149	$4,149	$4,149	$4,149
Payback (yrs)	15	15	12	12	15	15	15	15	15	15

However, it must be noted that the analysis in Table 47 does not include the potential hot water savings that would be experienced from using less water in each load. The WEEP study does not indicated the percentage of hot water that is used in each load, and therefore it is not possible to easily calculate this additional savings benefit, which is why it has not been included here.

4.3.8 Payback summary

It is very difficult to analyse and discuss the remainder of the credits in the Homestar rating tool in terms of cost versus benefit, as many of the credits address items where it is not easily possible to estimate the economic benefit to the household, for example, WST-3 (recycling facilities) and WST-4 (composting facilities). The researcher therefore undertook no further cost-benefit comparisons on the remaining credits in the rating tool.

The analysis indicates that there are several items that Homestar encourages the use of that have significant and almost immediate benefits for homeowners and occupants. Items such as hot water heat pumps and low-flow showers have very short payback periods and therefore their inclusion in designs would greatly benefit dwelling occupants. Items such as space heating heat pumps have slightly longer paybacks but are also likely to be able to pay themselves back over the duration of the initial owner's occupancy.

Whilst other items have much longer paybacks, it is worthwhile noting that the capital cost of these items could be covered immediately if the dwelling achieved a premium price in the market, reflecting the desire of long-term owners to eventually achieve energy and water savings for this investment. For example, if a 6-Homestar rating attracts an additional 5–6% cost premium in the market, all of the capital cost investment has paid itself off and the operational savings are an extra bonus.

To complete this analysis, the researcher has also performed an analysis of the overall median cost to achieve the different Homestar credits that would result in the operational savings that each of these levels attracts (EHC-1, EHC-2, EHC-4, EHC-5, EHC-6, WAT-1 and WAT-2). The resulting payback periods for the different Homestar rating levels are shown in Table 47.

Table 47. Payback period for the different levels of Homestar v2 and v3 ratings based on the capital cost of the EHC and WAT credits and their resultant operational savings.

	Median capital cost	Annual savings	Payback (yrs)
6-Homestar	$4,675	$459	11
7-Homestar	$20,769	$863	27
8-Homestar	$36,053	$2,113	16
9-Homestar	$49,799	$3,080	14
10-Homestar	$49,799	$3,080	14

In this analysis, as previously stated, the researcher has targeted the most cost-effective credits ($/point) for approaching this study. This has meant that the inclusion of some of the energy efficiency options such as space heating and hot water heat pumps are not activated until the 9-Homestar level. Therefore for 6 and 7-Homestar in particular, the only operational savings that will be experienced by the dwellings are in space heating savings due to increased passive thermal performance. 8-Homestar typically includes renewable energy generation, and therefore the payback period demonstrated in Table 47 drops because of this. The space heating and hot water heat pumps are included into the designs at the 9-Homestar level in most instances as well as the rainwater tank. The payback efficiency of the hot water heat pump appears to offset the rainwater tank and the larger payback period of the space heating heat pump.

It needs to be noted that, for rating levels higher than 7-Homestar, the researcher has included technologies such as electric vehicle (EV) charging points and hot water heat drain recovery. The impacts of these items on energy use and potential savings for the case study dwellings have not been addressed in this study at this time in terms of benefits and payback. However, it should be noted that EECA has calculated that the fuel running cost of an EV is the equivalent of paying approximately 15% of the cost of running an equivalent-sized petrol vehicle (www.energywise.govt.nz/on-the-road/electric-vehicles/advantages-and-challenges-of-evs/ev-running-costs/). In addition, in 2016, Concept Consulting found that lifetime cost to the consumer for electric cars is similar to conventional cars, and in some cases, electric cars are expected to save money over their lifetime. However, the report also found that electric cars currently suffer from higher upfront costs than conventional vehicles and have lower ranges in the case of pure electric vehicles (Concept Consulting, 2016).

It should be noted that these paybacks are not being calculated for the overall cost of achieving each level of Homestar rating. Instead, the payback calculations have been targeted to be focused solely on the credits that result in operational energy savings. In addition, only a simple payback has been calculated, with discounting and future increases in electricity not accounted for. Table 48 shows the payback period for the different levels of Homestar v4 ratings based on operational savings.

Table 48. Payback period for the different levels of Homestar v4 ratings based on their operational savings.

	Median total capital cost	Annual savings	Payback (yrs)
6-Homestar (schedule method with points)	$2,834	$266	6
7-Homestar (calculation method – option 1)	$4,057	$548	7
8-Homestar	$35,396	$809	51
9-Homestar	$53,630	$2,806	20
10-Homestar	$53,630	$2,806	20

It is important to note that analysing the benefits of Homestar only in terms of its operational savings does not allow consideration of the additional potential benefits of a Homestar rating, which could include:

- increased sales price
- increased rental rates
- reduced time on the market
- reduced rental vacancy
- improved indoor environmental quality leading to improved occupant health, comfort and satisfaction.
- the cost of carbon
- reduced healthcare costs
- reduced sick days.

It is therefore highly important that the benefits of a green building rating tool be discussed within a wider context and that one particular element is not discussed in isolation, as this would lead to an erroneous conclusion.

5. Conclusion

The results of this desktop analysis have indicated that there is an additional cost to achieve not only 6-Homestar but also the higher levels of Homestar in all of the versions of the rating tool (Table 49). This is to be expected, as the quality of the dwelling is being increased from a Building Code baseline.

The expected additional costs determined in this study differ from those of previous studies, with this analysis estimating the expected costs as higher than the previous studies. For a 6-Homestar rating, the researcher has determined a median additional cost of 3–5% depending on the version of the rating tool that is used, with 7-Homestar attracting an additional cost of 12% for Homestar v2 and v3 but only 4% for Homestar v4.

Initial findings appear to indicate that Homestar v4 has reduced the cost of compliance for all levels of Homestar ratings when compared to previous versions of the tool. The new schedule method for 6 and 7-Homestar is frequently the most cost-effective method of compliance with the EHC-1 mandatory minimum requirement, especially for 6-Homestar.

However, after undertaking this research, the researcher does believe that perhaps there are too many compliance options for thermal performance for 7-Homestar, with the costs associated with the 7-Homestar calculation method – option 2 and 3 and energy modelling option being cost prohibitive when compared to other options and that perhaps these should be removed from the tool.

Table 49. Summary of median additional costs and percentage increase to achieve 6, 7, 8, 9 and 10-Homestar from a Building Code standard.

Total cost increase from Building Code	6-Homestar	7-Homestar	8-Homestar	9-Homestar	10-Homestar
Homestar v2					
$ increase	$18,009	$38,514	$63,068	$75,419	$101,671
% increase	5%	12%	19%	24%	28%
Homestar v3					
$ increase	$18,813	$39,625	$65,951	$93,639	$110,279
% increase	6%	12%	19%	26%	32%
Homestar v4					
$ increase	$11,575	$13,794	$47,270	$67,263	$92,127
% increase	3%	4%	13%	21%	26%

It should be noted at this point again that this research has been completed on stand-alone and terraced housing for single house designs. The certification costs of Homestar as calculated in section 3.2 are $3,800 and therefore make up a significant portion of the total cost of achieving 6 and 7-Homestar.

Therefore, if a single dwelling design is repeated numerous times, the overall cost of the Homestar rating dwelling will decrease (see Table 50).

Table 50. Cost per dwelling to achieve 6 and 7-Homestar from a Building Code standard in a multiple dwellings typology approach.

	Number of homes in development			
	1 dwelling	10 dwellings	50 dwellings	100 dwellings
Homestar v2				
6-Homestar	$18,351 (5%)	$14,076 (4%)	$13,726 (4%)	$13,682 (4%)
7-Homestar	$38,757 (12%)	$34,514 (11%)	$34,231 (10%)	$34,188 (10%)
Homestar v3				
6-Homestar	$18,813 (5%)	$14,880 (4%)	$14,530 (4%)	$14,487 (4%)
7-Homestar	$39,625 (11%)	$39,625 (11%)	$35,342 (10%)	$35,299 (10%)
Homestar v4				
6-Homestar	$11,521 (3%)	$7,642 (2%)	$7,292 (2%)	$7,249 (2%)
7-Homestar	$13,979 (4%)	$9,861 (3%)	$9,511 (3%)	$9,468 (3%)

The cost increases shown in Table 49 correlate well to interviews that were undertaken with owners/builders of higher-rated Homestar dwellings in a concurrent, as yet unpublished, Homestar study. In particular, the additional 7-Homestar v2 and v3 cost correlates very well with the data gathered from builders who have undertaken 7-Homestar dwellings. These interviewees indicated an additional cost premium of around $30,000 or 10% for a 7-Homestar rating. However, the market appears to attribute the additional cost for 6 and 7-Homestar to items that the researcher did not include for these rating levels in this study, indicating a potential misunderstanding and misalignment between the market understanding of what is required to achieve various Homestar rating levels and the reality of what needs to be done.

When analysing the case study dwellings, the researcher noticed that, when the design of the dwelling was properly oriented on the site (with living areas and bedrooms facing north) and the floor plan layout was efficient (with a high area to perimeter ratio), the dwellings performed very well using the basic Building Code schedule method R-values, and few changes were required to allow the dwellings to achieve 6-Homestar. However, when the orientation and layout were poor, the dwellings performed poorly. This indicates that one place where the Building Code falls down is in not requiring any analysis of site orientation or floor plate efficiency. This approach has now been replicated in Homestar v4, which, once the window to wall ratio (WWR) eligibility test has been passed, also does not consider orientation or floor plate efficiency.

In this vein, it is also important to note that Homestar is a comprehensive rating tool that addresses many more issues than the Building Code. It is therefore somewhat erroneous to attempt to directly compare the Building Code to Homestar without providing context. In particular, comments such as a Building Code-compliant dwelling is the equivalent to 3 or 4-Homestar' is often interpreted by the market as 'a 6-Homestar rated dwelling will be greatly more energy efficient than a Building Code-compliant dwelling'. However, this may not be the case, as shown by this piece of research, with some of the case study dwellings able to perform at the 6-Homestar thermal performance level with minimal changes to the Building Code compliant-design.

It is therefore important that the market be educated to the nuance that Homestar is a comprehensive rating tool that addresses many areas of environmental concerns that the Building Code does not. That is why, when directly compared, a Building Code-compliant dwelling may not achieve highly on the Homestar rating scale at first glance (although the levels of insulation, site orientation and floor plate design may already be compliant with 6-Homestar).

The researcher believes that an additional piece of research should be undertaken directly comparing and contrasting the requirements of Homestar v4 with the Building Code highlighting where Homestar and the Building Code cover the same issues (such as heating energy demand, ventilation and so on) and where Homestar covers elements that the Building Code does not (such as water efficiency) and what the differences are. This research should also seek to determine which elements of Homestar would benefit from being included in the base Building Code as a minimum requirement for all dwellings.

Whilst addressing items of potential further research, the researcher is very aware that this study was born out of an ongoing study focusing on the Auckland housing submarket. The case study houses were therefore all selected from the Hobsonville suburb of Auckland, which is a large master-planned development. Therefore, certain amounts of natural variability in design will not have been picked up in this study, and this research would greatly benefit from being extended to cover all of New Zealand, picking up houses that are being designed to the Building Code in other cities and regional towns in different climate zones and analysing them against Homestar v4 to determine if there are any differences from what has been discovered in this research. This is specifically in terms of what these dwellings would need to do to meet the thermal performance (heating energy budget) mandatory minimum requirements.

Following the completion of this study, the researcher believes that there is a large disconnect between the general understanding of what is required to achieve a Homestar rating on a dwelling and what is actually required. In addition, the researcher has determined that many of the items that the market erroneously believes need to be included for 6 and 7-Homestar are items and technologies that have significant capital cost and long payback periods and that therefore should be avoided wherever possible in the lower Homestar rating levels to maintain affordability. The exception to this is hot water heat pumps, which have a short payback period and would therefore benefit homeowners when included in the lower rating levels. In relation to paybacks, it should be again noted that only a simple payback period has been calculated, with discounting and future increases in electricity not accounted for. It would therefore be interesting for future studies to undertake a more detailed analysis of payback periods accounting for these factors.

In summary, the progression of the Homestar rating tool is positive, with Homestar v4 appearing to have greatly reduced compliance costs when compared to previous versions of the tool. Homestar v4 (using the schedule method for EHC-1 compliance) can in many cases be implemented for only a few hundred dollars. However, this is dependent upon homeowners being willing and able to modify key elements of the building design such as floor area and the window to wall ratio.

References

BRANZ. (2014). *House insulation guide.* Judgeford, New Zealand: BRANZ Ltd.

Burgess, J., Camilleri, M. & Saville-Smith, K. (2009). EC1505A *The Home Lighting Survey*. BRANZ Ltd report for the Electricity Commission.

Concept Consulting. (2016) *Electric care, solar panels, and batteries in New Zealand – Vol 2: The benefits and costs to consumers and society*. Retrieved from http://www.concept.co.nz/uploads/2/5/5/4/25542442/new_technologies_economic_report_v2.0.pdf

Davis Langdon. (2010). *The road to 'green property': Your handbook for energy efficiency and sustainability in property*. Retrieved from http://www.gbca.org.au/uploads/1/2817/Davis%20Langdon.pdf

eCubed Building Workshop. (2013). *Homestar case study: Cost benefit analysis*. Retrieved from http://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=480

Heinrich, M. (2007). *Water-end use and efficiency project (WEEP) – a case study.* Retrieved from https://www.branz.co.nz/cms_show_download.php?id=6467cda48bfb9e97d599da7ef68d1be3a6872ff9

Heinrich, M. & Roberti, H. (2008). *Auckland water use study: Monitoring of residential water end uses*. Retrieved from https://www.branz.co.nz/cms_show_download.php?id=fd1b4c6fd498564cefe2084a7e99c7b0265b4607

Isaacs, N., Camilleri, M., French, L., Pollard, A., Saville-Smith, K., Fraser, R., … & Jowett, J. (2006). *Energy use in New Zealand households: Report on the Year 10 analysis for the Household Energy End-use Project (HEEP)*. BRANZ Study Report SR155. Judgeford, New Zealand: BRANZ Ltd.

Jasmax. (2013). *Homestar cost-scoring appraisal for Auckland Council*. Retrieved from http://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=481

Matthiessen, L. & Morris, P. (2004). *Costing green: A comprehensive cost database and budgeting methodology*. Retrieved from https://www.usgbc.org/sites/default/files/Costing%20Green_A%20Comprehensive%20Cost%20Database%20and%20Budgeting%20Methodology.pdf

Matthiessen, L. & Morris, P. (2007). *Cost of green revisited: Reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption*. Retrieved from http://sustainability.ucr.edu/docs/leed-cost-of-green.pdf

Appendix A: Case Study dwellings

A.1 Costing assumptions

In the below analysis, the following assumptions have been made for costings. These costs have been verified by Shanika Ekanayake BSc (QS) using QV costbuilder.

Foundations

- Traditional waffle pod slab per m^2 rate including labour is \$160/m^2.
- Standard 250 TC1 MAXRaft slab with sand blinding, polythene vapour barrier, edge formwork, mesh and edge steel, 100 mm wide ribs, 300 mm wide edge beams, 25 MPa concrete, pumping per m^2 including labour is \$135/m^2.

Slab insulation

- R1 edge insulation is typically around \$49/lineal metre supplied and installed with a \$50 delivery fee and \$30 cost per external corner.
- Climafoam 50 x 1200 x 600 mm XPS \$25.91 each.

Wall insulation

- Installation labour \$65/hour.

	Material Code	R-Value (m² K/W)	Thickness (mm)	Width (mm)	Length (mm)	Pieces per Pack	Area per pack (m²)	Packs per MasterBag	MasterBags per Supakube	\$/m² (Excl GST)
Wall	471038	2.2	90	580	1160	29	19.51	4	4	5.23
	471039	2.4	90	580	1160	20	13.46	4	4	7.40
	471070	2.6	90	430	1160	14	6.98	5	5	9.57
	471071	2.6	90	580	1160	14	9.42	4	4	9.57
	471040	2.8	90	430	1160	10	4.99	5	5	14.66
	471041	2.8	90	580	1160	10	6.73	4	4	14.66
	471042	3.2	140	580	1160	22	14.80	4	4	6.97
	470319	3.6	140	580	1160	15	10.1	4	4	10.84
	505604	4.1	140	580	1160	9	6.1	4	4	16.95

Retrieved from www.knaufinsulation.co.nz.

Ceiling insulation

	Material Code	R-Value (m² K/W)	Thickness (mm)	Width (mm)	Length (mm)	Pieces per Pack	Area per pack (m²)	Packs per MasterBag	MasterBags per Supakube	\$/m² (Excl GST)
Ceiling	583498	2.9	130	430	1160	24	12	5	5	6.14
	583500	3.3	155	430	1160	21	10.47	5	5	6.77
	471072	3.6	175	430	1160	21	10.47	5	5	7.24
	471073	4.1	195	430	1160	18	8.98	5	5	7.97
	471054	5.2	210	430	1160	11	5.49	5	5	11.58
	471055	6.3	275	430	1160	11	5.49	5	5	13.65
Skillion	470320	3.2	105	430	1160	11	5.49	5	5	15.40

Retrieved from www.knaufinsulation.co.nz.

Glazing

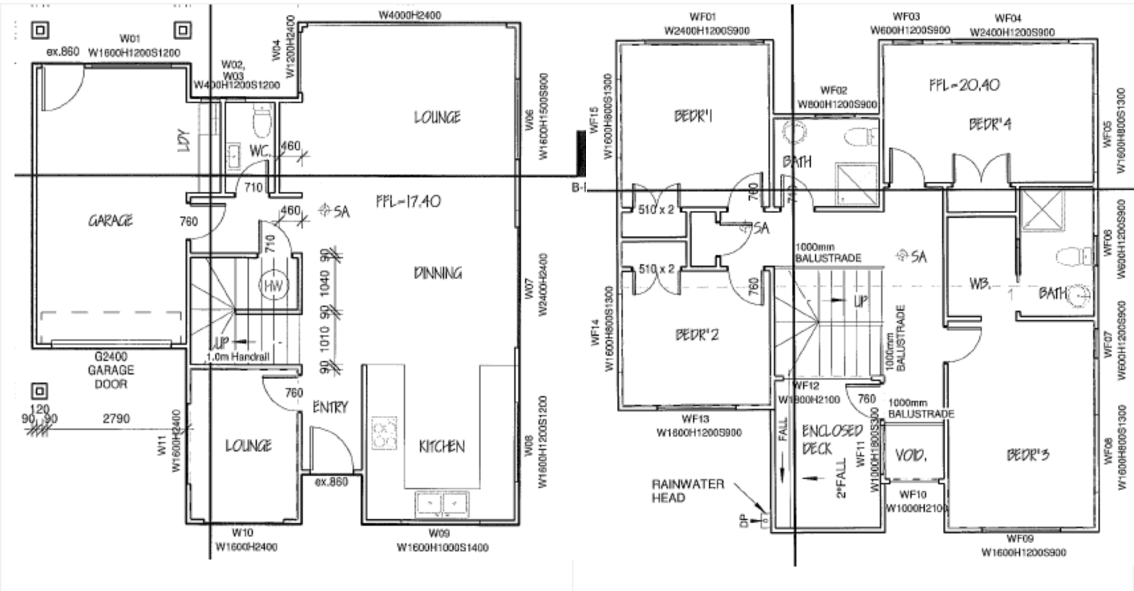
- Double glazing = \$530/m^2.
- Double glazing with low-e film= 580/m^2.
- Thermally broken double glazing with low-e argon = 750/m^2 (www.vinylcladding.co.nz/about/cost).

Weatherboard

- Standard fibre-cement weatherboard rate of \$209/m^2.
- Window stays (bronze) (\$18.65 each).
- Installation half an hour at an hourly rate of \$65/hour.
- Carpet/timber flooring installed rate of \$45 m^2.
- Concrete sealing and polishing rate of \$55 m^2.

A.2 Dwelling 1

A.2.1 Design



A.2.2 Summary

Figure 11 provides an interesting summary of the cost of the different thermal performance options for Dwelling 1.

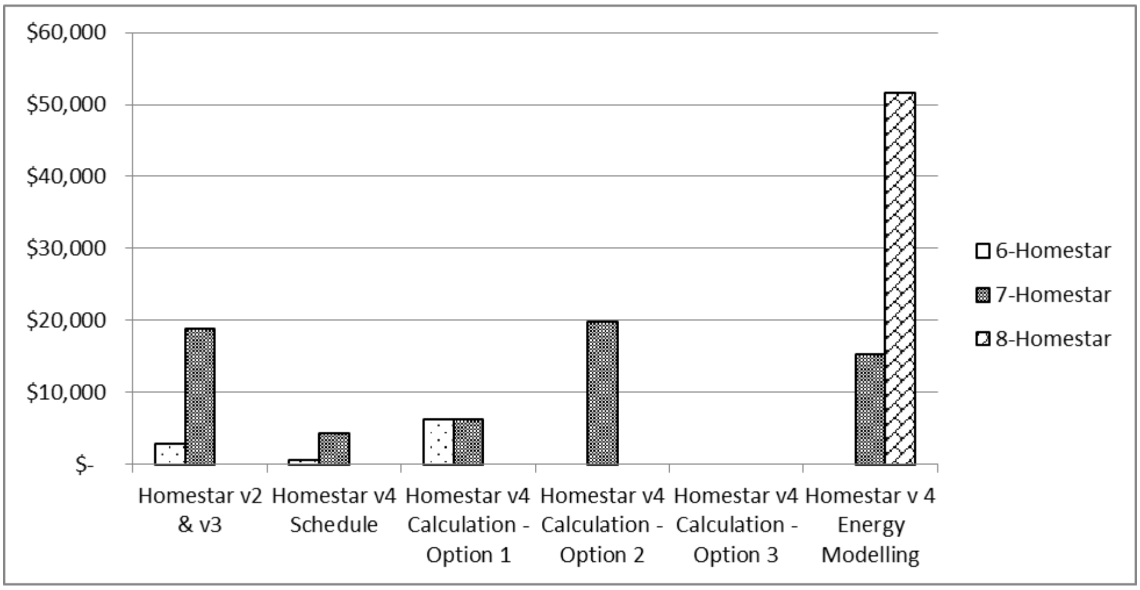


Figure 11. Cost of each thermal performance option for Dwelling 1 for 6, 7 and 8-Homestar mandatory minimum.

It can be seen from Figure 11 that the most cost-effective mechanism for this dwelling to achieve the 6 and 7-Homestar mandatory minimums is the new schedule method. However, for 6-Homestar, this also provides the worst thermal performance in terms of annual heating demand as shown in Table 51. For 7-Homestar, this is not the case, and the energy modelling method would actually result in both the lowest cost and the highest annual heating and& cooling demand.

Table 51 gives a summary of how Dwelling 1 performs across the different versions of Homestar.

Table 51. Dwelling 1 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,185	na	na	na
Building Code-compliant design	ALF online	4,175	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,416	2,304	na
Homestar v3	ALF online *allowance*	na	3,923 *(3,796)*	2,714 *(2,482)*	na
20°C set point					
Building Code-compliant design	ALF online	5,728	na	na	
Homestar v2 and v3	ALF online	na	5,368	2,304	na
Homestar v4 schedule method	ALF online	na	5,449	3,702	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,020 *(5,110)*	5,020* *(5,110)**	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	3,940* *(3,942)**	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(2,920)*	na
Energy modelling	PHPP *allowance*	17,067	na	11,096 *(11,096)***	8,147 *(8,232)****

* Home cooling features also to be considered. ** 56 kWh/m²/yr. ** 76 kWh/m²/yr.

Table 52. Dwelling 1 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (42.5 m)	$2,371	$2,371	$2,371	$2,371	$2,371	$2,371	$2,371			$2,371
Insulated garage ceiling below conditioned space (23.6 m^2)	$224	$224	$224	$224	$224	$224	$224		$224	$224
R1.2 insulation under slab										$3,408
Walls										
Insulated internal garage wall (13.6 m^2)	$197	$197	$197	$197	$197	$197	$197		$197	$197
Increased wall insulation – R2.2 to R2.8 (128 m^2)		$1,327			$1,521	$1,521	$1,521		$1,521	
140 mm wall framing and R4.2 insulation										$7,916
Windows										
Removal of glazing – delete 7.4 m^2 windows to reach 30% WWR			-$2,375	-$2,375						
Removal of glazing (solar aperture) – delete 10.78 m^2 windows to reach 31% WWR on NW and NE						-$3,462				
Window restrictors (15 opening windows)				$815		$815	$815			
Low-e film to SW and SE windows only (35.3 m^2)					$1,765	$1,765				
All windows with low-e (58 m^2)				$2,943						
Replace double glazing with low-e and argon gas										
Thermally broken windows with low-e and argon (66 m^2)		$14,575					$12,812		$12,812	$12,812
Ceilings										
Increased ceiling insulation – R3.2 to R3.8 (can only purchase R4.1) (109.5 m^2)		$99	$99		$99	$99	$99			
Increased ceiling insulation – R3.2 to R6.3 (109.5 m^2)									$566	$566
Ventilation										
Mechanical heat recovery ventilation system (allowance)										$15,000
Total	**$2,791**	**$18,793**	**$515**	**$4,274**	**$6,176**	**$3,530**	**$19,804**	**na**	**$15,319**	**$42,494**

A.2.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 4,185 kWh/yr for heating. Homestar v2 would award this dwelling 9.75 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 52. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.2.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 1 performs against them, are shown in Table 53.

Table 53. Schedule method analysis – Building Code-compliant design – Dwelling 1.

Schedule method – heating energy			Dwelling 1	6-Homestar	7-Homestar
Glazing area is 30% or less of the total wall area.			34%	N	N
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			30%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.1	N	N
Wall	2.1	2.1	R2.13 & R0.4	N	N
Floor	1.3	1.5	R1.1	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NE=61% NW=33%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 1 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised for 6 or 7-Homestar ratings. The changes it would require, as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 52. One fundamental change that is required is for 7.4 m^2 of glazing to be deleted.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 39 kWh/m^2/yr, which is close but not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 would result in a thermal performance of 36 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 52 would be required to achieve a 34.4 kWh/m^2 performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 53, Dwelling 1 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from it NW and NE elevations. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher modified the current design of Dwelling 1 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes required to achieve the required heating demand benchmark are shown in Table 52.

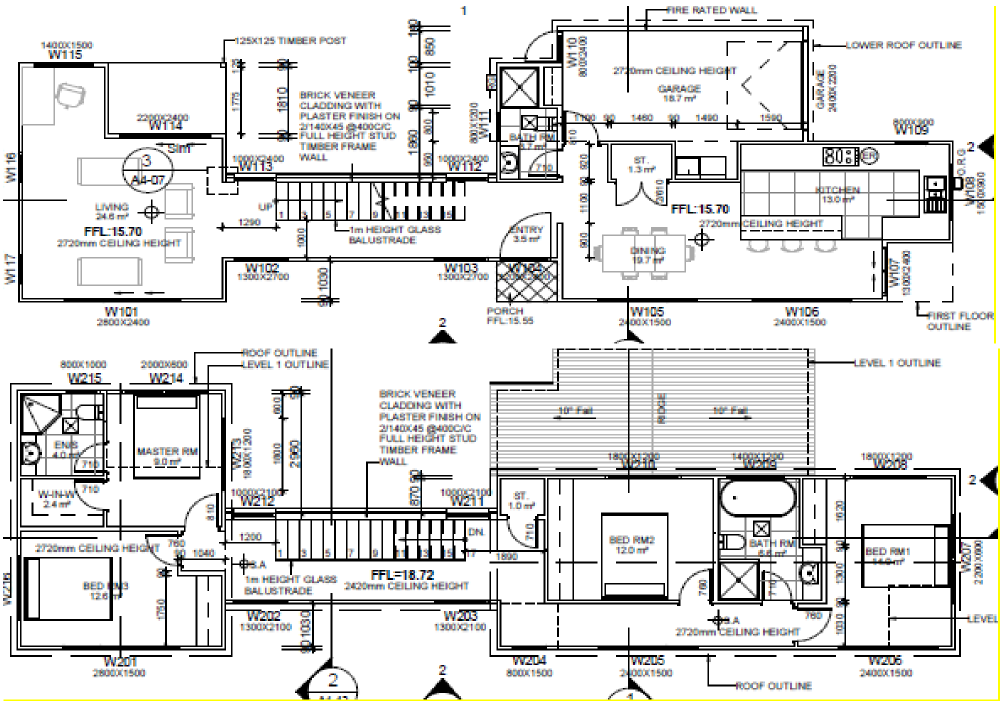
Option 3: The third way would be for the dwelling to have a design that uses no more than 2,920 kWh/yr for space heating, being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design of this dwelling to achieve this level of heating requirement. However, it was not possible to modify the basic design sufficiently to enable this to be achieved. Design changes of aluminium thermally broken low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5, R6 ceiling insulation and exposed concrete floor to ground floor only managed to allow this dwelling to achieve 3,414 kWh/yr. The researcher therefore concluded it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar for this dwelling in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has therefore not completed the modelling or costing for a thermal upgrade to 7-Homestar for this dwelling using the calculation method – option 3 pathway.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used the Passive Dwelling Planning Package (PHPPv9.6) to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.3 Dwelling 2

A.3.1 Design



A.3.2 Summary

Figure 12 provides an interesting summary of the cost of the different thermal performance options for Dwelling 2.

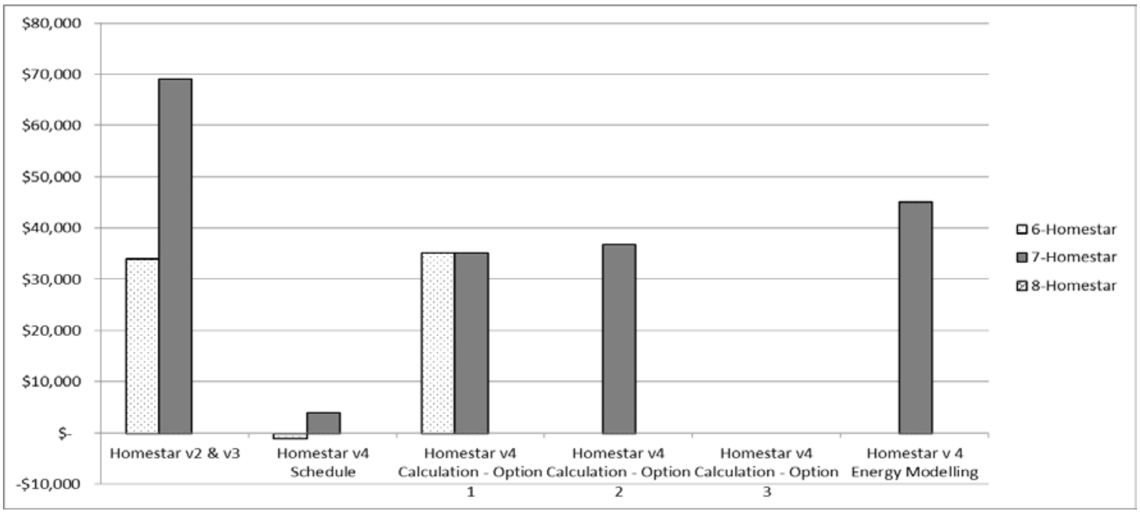


Figure 12. Cost of each thermal performance option for Dwelling 2 for the 6, 7 and 8-Homestar mandatory minimum.

It can be seen from Figure 12 that the most cost-effective mechanism for this dwelling to achieve the 6 and 7-Homestar mandatory minimums is the new schedule method, which provides a cost saving for 6-Homestar. However, this also provides the worst thermal performance in terms of annual heating demand as shown in Table 54.

Table 54 gives a summary of how Dwelling 2 performs across the different versions of Homestar. In relation to Dwelling 2, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4, and this would save the dwelling money. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 54. Dwelling 2 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	7,443	na	na	na
Building Code-compliant design	ALF online	6,902	na	na	na
Homestar v2	EHC-6 Excel calculator	na	4,101	2,864	na
Homestar v3	ALF online	na	4,537	2,626	na
20°C set point					
Building Code-compliant design	ALF online	9,574	na	na	
Homestar v2 and v3	ALF online	na	6,233	4,001	na
Homestar v4 schedule method	ALF online	na	8,887	5,743	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,223 *(5,822)*	5,223* *(5,822)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	4180* *(4,491)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled	na
Energy modelling	PHPP *allowance*	21792	na	12,509 *(12,643)***	Not achievable without complete redesign

* Home cooling features also to be considered. ** 56 kWh/m^2/yr.

Table 55. Dwelling 2 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (71.52 m)			$3,794	$3,794						
Slab edge insulation (71.52 m)+ R1.2 (99 m^2) underneath slab	$8,630				$8,630	$8,630			$8,630	
Thermally broken slab (71.52 m^2)		-$2,601					-$2,601			
Insulated L1 extents (11.1 m^2)	$242	$242	$242	$242	$242	$242	$242		$242	
Exposed concrete slab		$1,144			$1,144	$1,144	$1,144			
Walls										
Increased wall insulation – R2.2 to R2.4 (250 m^2)			$597	$597						
Increased wall insulation – R2.2 to R2.8 (250 m^2)	$2,643				$2,643	$2,643	$2,643			
Insulated internal garage wall (13.6 m^2)	$701		$701	$701	$701	$701	$701		$701	
Increased wall framing and insulation 140 mm		$11,701					$11,701		$11,701	
Windows										
Thermally broken windows with low-e and argon	$21,725	$21,725			$21,725	$21,725	$21,725		$21,725	
Removal of glazing – delete 20 m^2 windows to reach 30% WWR			-$6,420	-$6,420						
Windows with low-e (78 m^2)				$3,900						
Window restrictors (21 opening windows)				$1,142		$1,142	$1,142			
Ceilings										
Increased ceiling insulation – R2.6 to R3.6 (109.5 m^2)	$132				$132	$132	$132			
Increased ceiling insulation – R2.6 to R4.1 (109.5 m^2)			$138							
Increased ceiling framing to 140 mm and insulation – R2.6 to R6.0 (109 m^2)		$2,253							$2,253	
Total	**$34,074**	**$69,193**	**-$998**	**$4,045**	**$35,218**	**$36,361**	**$36,784**		**$42,205**	

A.3.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, the Building Code-compliant design for this dwelling would use 7,443 kWh/yr for space heating, which would be awarded 7.5 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 55. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.3.4 Thermal performance analysis (Homestar v4)

Schedule method

The performance of Dwelling 2 against the schedule method requirements is listed in Table 56.

Table 56. Schedule method analysis – Building Code-compliant design – Dwelling 2.

Schedule method – heating energy			Dwelling 2	6-Homestar	7-Homestar
Glazing area is 30% or less of the total wall area.			28%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			34%	N	N
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R2.8	N	N
Wall	2.1	2.1	R1.85 & R0.4	N	N
Floor	1.3	1.5	R0.98	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NE=23% NW=13%	Y	Y
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 2 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised.

The changes it would require, as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 55.

Calculation method (6-Homestar)

The performance of Dwelling 2 against the calculation method is shown in Table 55.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 56, Dwelling 2 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range, partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from it NW and NE elevations. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 2 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 55.

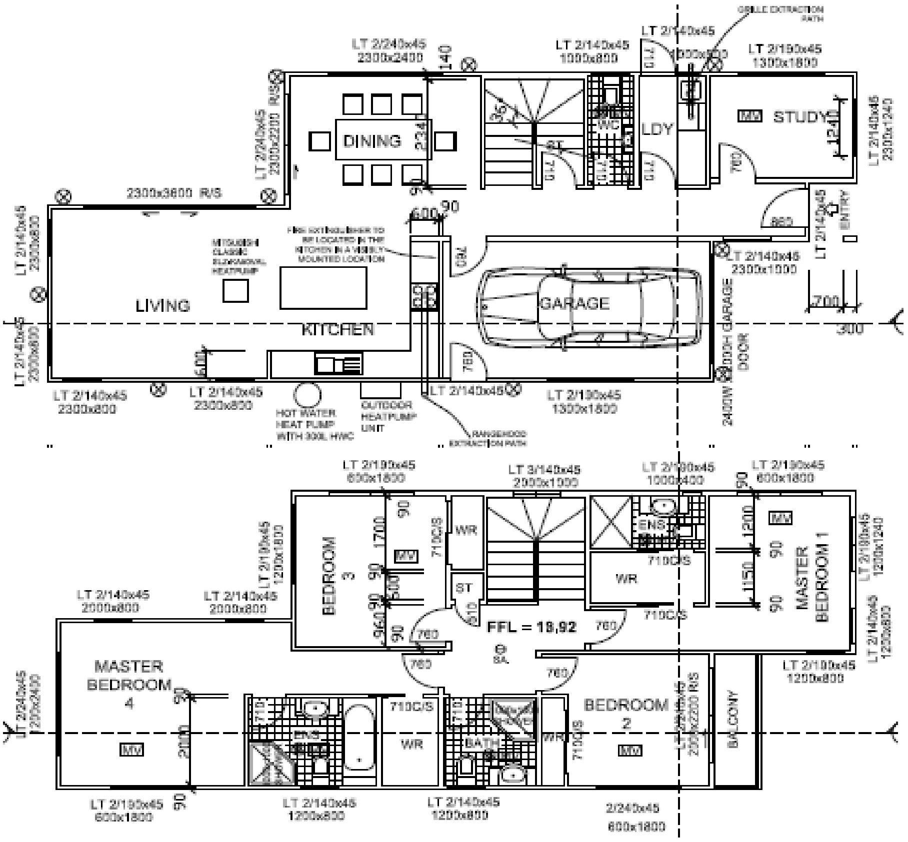
Option 3: The third way would be for the dwelling to have a design that uses no more than 3,327 kWh/yr for space heating, being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design of this dwelling to achieve this level of heating requirement. However, it was not possible to modify the basic design sufficiently to enable this to be achieved. design changes of flipping the dwelling 180 degrees so that it faced north, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5 and R6 ceiling insulation only managed to allow this dwelling to achieve 3,414 kWh/yr. The researcher therefore concluded that it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar for this dwelling in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has therefore not completed the modelling or costing for a thermal upgrade to 7-Homestar for this dwelling using the calculation method –option 3 pathway.

Energy modelling method

The researcher attempted to model this dwelling in the Passive Dwelling Planning Package (PHPPv9.6) for 7 and 8-Homestar compliance. Whilst it was possible to render the basic design of the dwelling compliant with the 7-Homestar energy budget, it was not possible to make the current floor plan and orientation compliant with the 8-Homestar energy budget.

A.4 Dwelling 3

A.4.1 Design



Note that a heat pump was already included in the building consent drawing set for space heating as well as a hot water heat pump before Homestar was considered.

A.4.2 Summary

Figure 13 provides an interesting summary of the cost of the different thermal performance options for Dwelling 3.

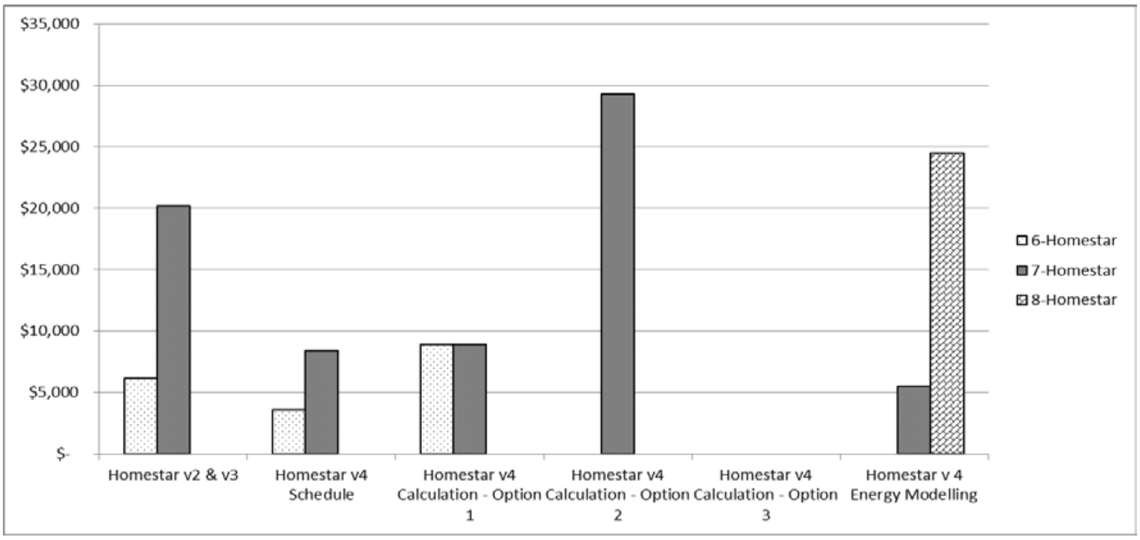


Figure 13. Cost of each thermal performance option for Dwelling 3 for the 6, 7 and 8-Homestar mandatory minimum.

It can be seen from Figure 13 that the most cost-effective mechanism for this dwelling to achieve the 6-Homestar mandatory minimums is the new schedule method. However, this also provides the worst thermal performance in terms of annual heating demand as shown in Table 57. For 7-Homestar, it appears the most cost-effective way for the dwelling to achieve the mandatory minimum would be for it to undertake energy modelling using PHPP.

Table 57 gives a summary of how Dwelling 3 performs across the different versions of Homestar. It appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 57. Dwelling 3 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,467	na	na	na
Building Code-compliant design	ALF online	5,285	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,663	2,260	na
Homestar v3	ALF online *allowance*	na	4,735 *(3,798)*	2,953 *(2,601)*	na
20°C set point					
Building Code-compliant design	ALF online	7,866	na	na	
Homestar v2 and v3	ALF online *allowance 17 kWh/m²/yr*	na	6,399	4,350	na
Homestar v4 schedule method	ALF online	na	7,479	4,981	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,070 *(5,355)*	5,070* *(5,355)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	4,015* *(4,131)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(3,060)*	na
Energy modelling	PHPP *allowance*	14,703	na	*11,367* *(11,628)***	*7,757* *(8,568)****

* Home cooling features also to be considered. ** 56 kWh/m^2/yr. ** 76 kWh/m^2/yr.

Table 58. Dwelling 3 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (48.35 m)	$2,659	$2,659	$2,659	$2,659	$2,659	$2,659	$2,659			
R1.2 under slab insulation							$4,264			$4,264
Insulated L1 extents R2.2 (1.6 m^2)	$18	$18	$18	$18	$18	$18	$18		$18	$18
Exposed concrete slab (63 m^2)		$1,008			$1,008	$1,008	$1,008			
Walls										
Insulated internal garage wall R2.2 (13.6 m^2)	$272	$272			Incl. below	Incl. below	Incl. below		$272	$272
Insulated internal garage wall R2.4 (13.6 m^2)			$379	$379						
Increased wall insulation – R2.2 to R 2.4 (192 m^2)			$597	$647						
Increased wall insulation – R2.4 to R 2.8 (192 m^2)										
Increased wall insulation – R2.2 to R2.8 (192 m^2)		$1,992			$1,992	$1,992	$1,992		$1,992	
140 mm wall framing with R4.2 insulation										$8,750
Windows										
Windows with low-e (64 m^2)	$3,200			$3,200	$3,200	$3,200			$3,200	
Thermally broken windows with low-e and argon (65 m^2)		$11,050					$14,538			$14,538
Window restrictors (30 opening windows)				$1,632		$1,632	$1,632			
Delete 4.3 m^2 windows to reach 31% WWR on NE						-$1,595				
Ceilings										
Increased wall insulation – R2.9 to R 6.3 (192 m^2)										$917
Total	**$6,149**	**$20,199**	**$3,546**	**$8,378**	**$8,877**	**$8,913**	**$29,310**	**na**	**$5,482**	**$24,495**

A.4.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 5,123 kWh/yr for space heating. Homestar v2 would award this dwelling 9 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 58. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.4.4 Thermal performance analysis (Homestar v4)

Schedule method

The performance of Dwelling 3 against the schedule method requirements is shown in Table 59.

Table 59. Schedule method analysis – Building Code-compliant design – Dwelling 3.

Schedule method – heating energy			**Dwelling 3**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			25%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			26%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.6	Y	Y
Wall	2.1	2.1	R2.0 & R0.4	N	N
Floor	1.3	1.5	R1.2	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW=29% NE=39%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 3 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require, as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 58.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 53 kWh/m^2/yr, which is not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Following calculations in ALF, it was determined that the upgrades shown in Table 58 would be required to achieve a 35 kWh/m^2/yr performance.

Calculation method (7-Homestar)

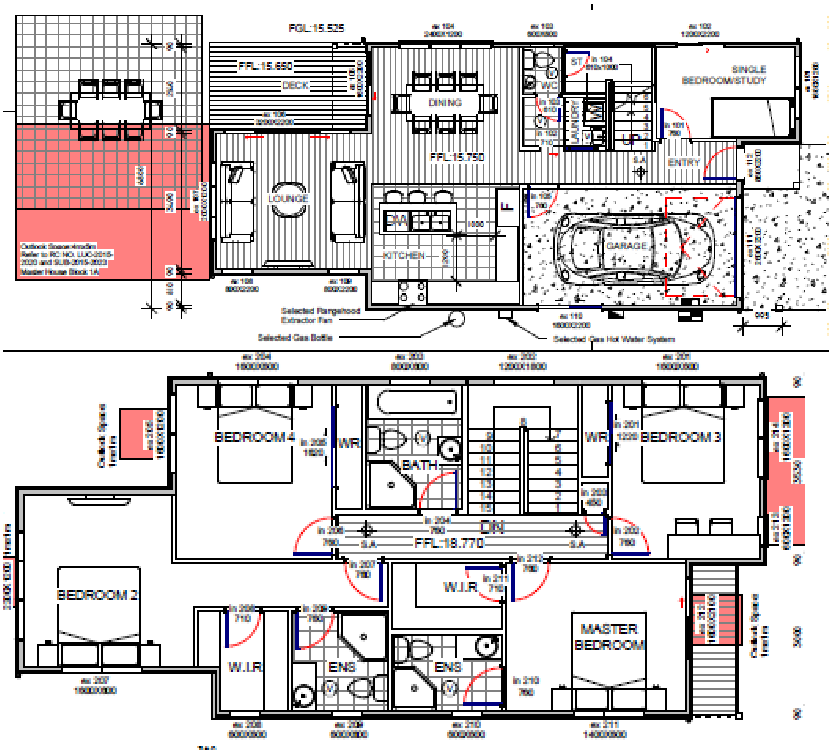
Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 59, Dwelling 3 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its NE elevation. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 3 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 58.

Option 3: The third way would be for the dwelling to have a design that uses no more than 3,060 kWh/yr, being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design of this dwelling to achieve this level of heating requirement. However, it was not possible to modify the basic design sufficiently to enable this to be achieved. Design changes of aluminium thermally broken low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5, R6 ceiling insulation and exposed concrete floor to ground floor could still not allow this dwelling to achieve compliance. The researcher therefore concluded that it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar for this dwelling in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has therefore not completed the modelling or costing for a thermal upgrade to 7-Homestar for this dwelling using the calculation method – option 3 pathway.

A.5 Dwelling 4

A.5.1 Design



For EHC-2 (hot water), consent drawings show an instantaneous gas hot water system.

A.5.2 Summary

Figure 14 provides an interesting summary of the cost of the different thermal performance options for Dwelling 4. It can be seen that the Homestar v4 schedule method and calculation method are equivalent in terms of costs for this dwelling for 6-Homestar as is the Homestar v2 and v3 approach.

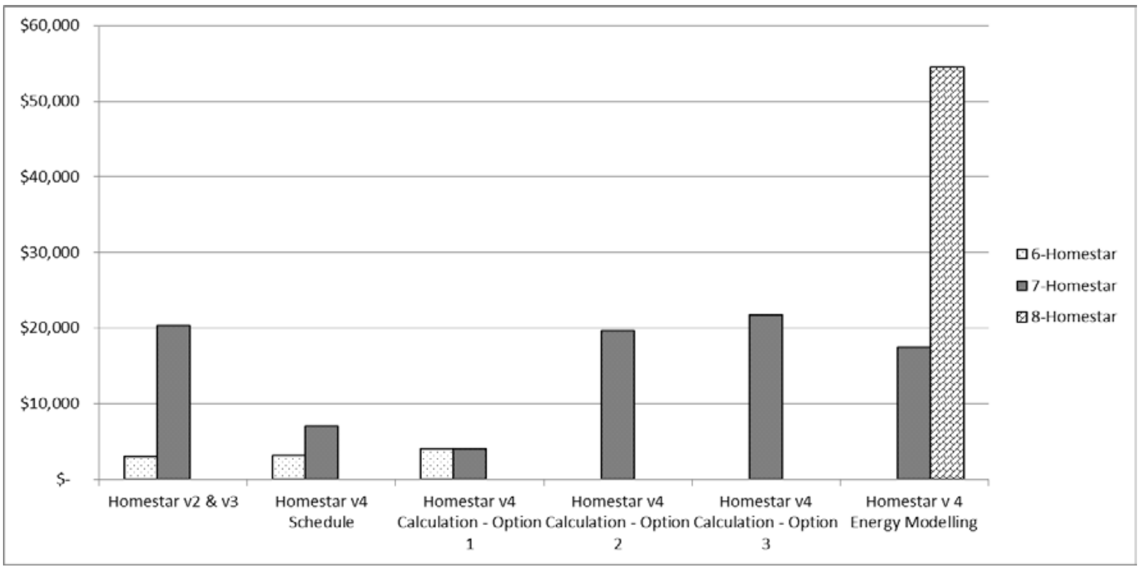


Figure 14. Cost of each thermal performance option for Dwelling 4 for the 6, 7 and 8-Homestar mandatory minimum.

Table 60 gives a summary of how Dwelling 4 performs across the different versions of Homestar. In relation to Dwelling 4, it appears that, for a 6-Homestar rating, it is easiest and most cost-effective for this dwelling to comply with the calculation method of Homestar v4. This also provides the best result in terms of thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 60. Dwelling 4 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	5,504	na	na	na
Building Code-compliant design	ALF online	4,785	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,786	2,438	na
Homestar v3	ALF online *allowance*	na	3,858 *(3,767)*	2,362 *(2,463)*	na
20°C set point					
Building Code-compliant design	ALF online	6,687	na	na	
Homestar v2 and v3	ALF online *allowance 17 kWh/m²/yr*	na	5,242	3,527	na
Homestar v4 schedule method	ALF online	na	3,787	3,603	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,007* *(5,071)**	5,007* *(5,071)**	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	3,856* *(3,911)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(2,898)*	na
Energy modelling	PHPP *allowance*	15,676	na	*10,981 (11,011)***	*8,113 (8,113)****

* Home cooling features also to be considered. ** 56 kWh/m^2/yr. ** 76 kWh/m^2/yr.

It is interesting to note that, when this dwelling was modelled in ALF online (20°C set point), its predicted annual heating demand was 6,687 kWh/yr or 46.2 kWh/m^2/yr. However, when the same design was modelled in PHPP, the predicted annual heating demand was 15,676 kWh/yr or 89 kWh/m^2/yr, which is more than double. 7-Homestar offers an interesting comparison as the costs vary wildly for each of the different thermal performance compliance options. Homestar v4 is more cost-effective when compared to Homestar v2 and v3. However, the calculation method is less expensive to implement for this dwelling when compared to the schedule method. This will be due to the requirement in the schedule for the glazing to have a minimum R-value of 0.31.

Table 61. Dwelling 4 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (43.8 m)	$2,440	$2,440	$2,440	$2,440	$2,440	$2,440	$2,440		$2,440	$2,440
Insulated L1 extents and garage ceiling below conditioned space R2.4 (20.4 m^2)	$281	$281	$281	$281	$281	$281	$281	$281	$281	$281
Insulated internal garage wall R2.4 (24.4 m^2)	$355	$355	$355	$355	$355	$355	$355	$355	$355	$355
Thermally broken slab								-$2,150		
Exposed concrete slab (54 m^2)		$907			$907	$907	$907	$907		
R1.2 insulation under slab										$4,006
Walls										
Increased wall insulation R2.2 to R2.8 (192 m^2)		$1,533								
Increased 140 mm wall framing and insulation R4.2								$7,556		$7,556
Windows										
Windows with low-e (50 m^2)				$2,500					$2,500	$2,500
Thermally broken windows with low-e and argon (50 m^2)		$14,300					$14,300	$14,300	$14,300	$14,300
Window restrictors (24 opening windows)				$1,305		$1,305	$1,305			
Delete 6.92 m^2 windows to reach 31% WWR on NE						-$2,567				
Ceilings										
Increased ceiling insulation R2.6 to R3.8 (83 m^2)			$67	$67					$67	$67
Increased ceiling insulation R2.6 to R6.3 (109 m^2)		$900						$900		
Ventilation										
Allowance for MHRV system										$15,000
Total	**$3,076**	**$20,306**	**$3,143**	**$6,948**	**$3,984**	**$2,722**	**$19,589**	**$21,739**	**$17,443**	**$44,494**

A.5.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 5,504 kWh/yr for space heating. Homestar v2 would award this dwelling 8.25 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 61. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.5.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 4 performs against them, are shown in Table 62.

Table 62. Schedule method analysis – Building Code-compliant design – Dwelling 4.

Schedule method – heating energy			**Dwelling 4**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			21%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			21%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.5	N	N
Wall	2.1	2.1	R2.1 & R0.4	N	N
Floor	1.3	1.5	R1.15	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW=24% NE=35%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 4 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require, as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 61.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 38 kWh/m^2/yr, which is close but not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 would result in a thermal performance of 36 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 61 would be required to achieve a 34.6 kWh/m^2/yr performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 62, Dwelling 4 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northeast elevation. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness in Table 61.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 4 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 61.

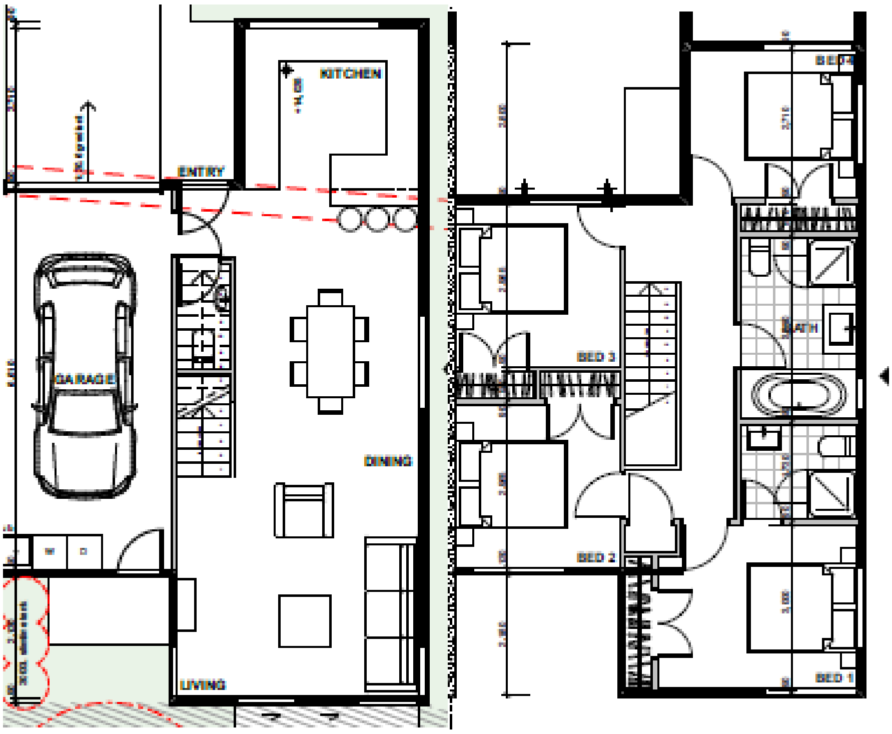
Option 3: Unlike Dwellings 1–3, it would be possible for this dwelling to comply with the third option. The changes that were required to achieve the required heating demand benchmark are shown in Table 61.

Energy modelling method

It was relatively straightforward to modify the design of this dwelling whilst retaining the existing floor plan and orientation to achieve the 7-Homestar energy budget, but it was very challenging to enable this dwelling to achieve the 8-Homestar energy budget. The only way to enable the energy budget to be achieved without completely redesigning the floor plan and cladding systems (which is outside the scope of this project) was through the inclusion of a heat recovery ventilation system.

A.6 Dwelling 5

A.6.1 Design



A.6.2 Summary

Figure 15 provides an interesting summary of the cost of the different thermal performance options for Dwelling 5. It can be seen from Figure 15 that the Homestar v4 schedule method and calculation method are nearly equivalent in terms of costs for this dwelling for 6-Homestar as is the Homestar v2 and v3 approach.

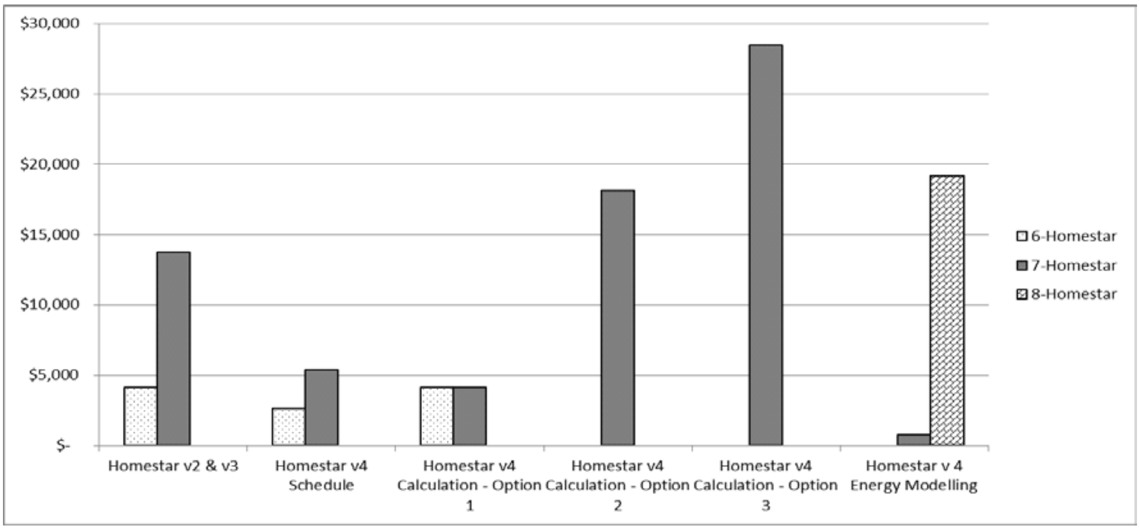


Figure 15. Cost of each thermal performance option for Dwelling 5 for the 6, 7 and 8-Homestar mandatory minimum.

Table 63 gives a summary of how Dwelling 5 performs across the different versions of Homestar. In relation to Dwelling 5, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 63. Dwelling 5 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,223	na	na	na
Building Code-compliant design	ALF online	3,276	na	na	na
Homestar v2	EHC-6 Excel calculator	na	2,909	1,863	na
Homestar v3	ALF online *allowance*	na	2,612 *(2,868)*	1,976 *(1,875)*	na
20°C set point					
Building Code-compliant design	ALF online	4,678	na	na	
Homestar v2 and v3	ALF online *allowance 17 kWh/m²/yr*	na	3,782	2,906	na
Homestar v4 schedule method	ALF online	na	2,710	2,417	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	3,827* *(3,861)**	3,827* *(3,861)**	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	2,881* *(2,978)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	2,144 *(2,206)*	na
Energy modelling	PHPP *allowance*	9,784	na	*8,240 (8,383)***	*6,177 (6,177)****

* Home cooling features also to be considered. ** 56 kWh/m²/yr. ** 76 kWh/m²/yr.

It is interesting to note that, when this dwelling was modelled in ALF online (20°C set point), its predicted annual heating demand was 4,678 kWh/yr or 42.4 kWh/m²/yr. However, when the same design was modelled in PHPP, the predicted annual heating demand was 9,784 kWh/yr or 89 kWh/m²/yr, again over double. 7-Homestar offers an interesting comparison as the costs again vary wildly for each of the different thermal performance compliance options. The energy modelling method is the most cost-effective with the basic Building Code design compliant with the energy budgets. Homestar v4 is more cost-effective for the schedule method when compared to Homestar v2 and v3. However, the calculation method is more expensive to implement for this dwelling. For this dwelling, it more cost-effective to target 7-Homestar using the energy modelling approach than it is to target 6-Homestar under any of the other approaches, again leading to the conclusion that the Homestar v4 energy modelling energy budgets are leading to some perverse outcomes.

Table 64. Dwelling 5 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (38.9 m)	$2,196	$2,196	$2,196	$2,196	$2,196	$2,196	$2,196	$2,196	$2,196	$2,196
Insulated garage ceiling R2.8 (20 m^2)	$471	$471	$471	$471	$471	$471	$471	$471	$471	$471
Exposed concrete slab (44 m^2)		$785								
R1.2 underslab insulation							$3,283	$3,283		$3,283
Walls										
Increased wall insulation – R2.2 to R2.8	$1,514	$1,514		$1,514	$1,514		$1,514	$1,514		
Insulated internal garage wall R2.8 (20.4 m^2)	$444	$444	$444		$444	$444	$444	$444	$444	$444
Increased wall thickness 140 mm and insulation R2.2 to R4.2								$8,283		$8,283
Windows										
Windows with low-e (45 m^2)				$2,250						
Thermally broken windows with low-e and argon (45 m^2)		$9,900					$9,900	$9,900	$9,900	$9,900
Window restrictors (10 opening windows)				$544		$544	$544	$544		
Delete 27 m^2 windows to reach 31% WWR on NE						-$8,667				
Ceilings										
Increased ceiling insulation R3.6 to R4.1 (109 m^2)			$67	$67					$67	
Increased ceiling insulation R3.6 to R6.3 (109 m^2)		$900						$900		$900
Total	**$4,626**	**$16,212**	**$3,178**	**$5,972**	**$4,626**	**-$5,012**	**$19,867**	**$29,051**	**$12,634**	**$21,611**

A.6.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 4,223 kWh/yr for heating. Homestar v2 would award this dwelling 8.25 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 64. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.6.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 5 performs against them, are shown in Table 65.

Table 65. Schedule method analysis – Building Code-compliant design – Dwelling 5.

Schedule method – heating energy			**Dwelling 5**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			29%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			52%	N	N
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.2	N	N
Wall	2.1	2.1	R2.1 & R0.4	N	N
Floor	1.3	1.5	R1.2	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NE=10% NW=34%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 5 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 64.

Even though the dwelling is not compliant with point 2 from the schedule method, this is due to the fact that the dwelling is a terraced dwelling with a co-joined south elevation. This area is therefore not considered in the wall area calculations as it is adiabatic. If this area was included in the schedule method WWR calculation, it would comply with the 30% WWR.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 32.3 kWh/m^2/yr, which is compliant. Therefore, no further upgrades from Table 64 would be required.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 65, Dwelling 5 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northeast elevation. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 5 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 64.

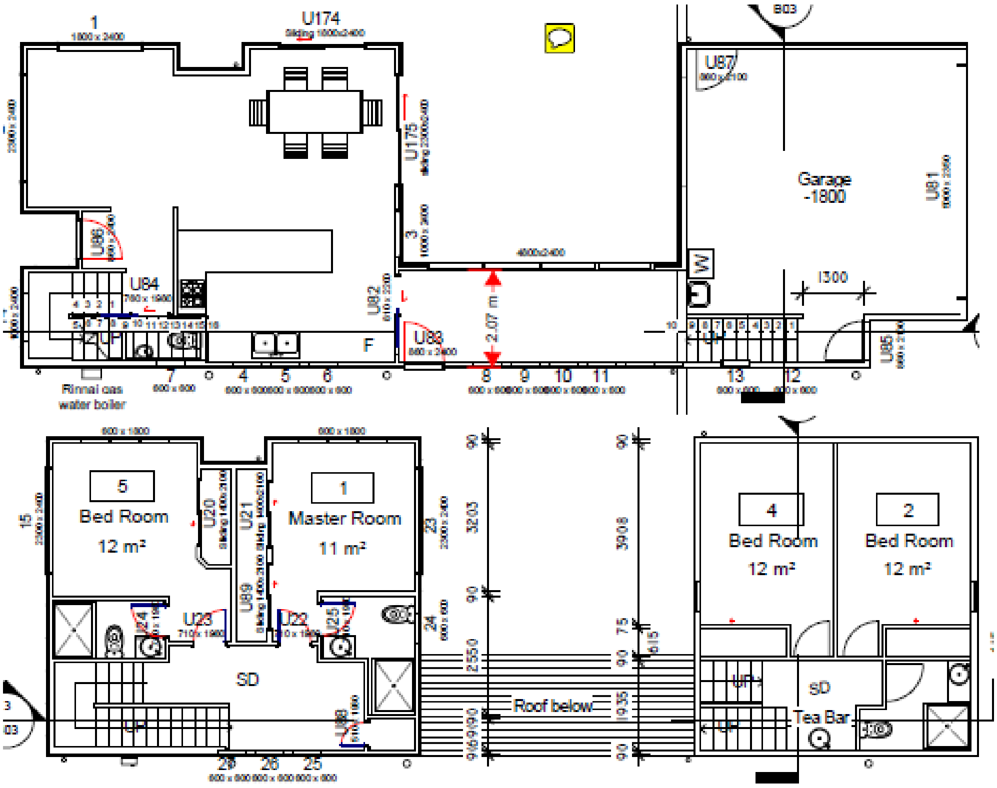
Option 3: The third way would be for the dwelling to have a design that uses no more than 2,206 kWh/yr, this being equivalent to 20 kWh/yr/m^2.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used the Passive Dwelling Planning Package (PHPPv9.6) to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7-Homestar as well as the 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.7 Dwelling 6

A.7.1 Design



Note: Garage is fully insulated with insulated garage door

A.7.2 Summary

Figure 16 provides an interesting summary of the cost of the different thermal performance options for Dwelling 6. It can be seen that Homestar v2 and v3 are much more expensive to implement when compared to Homestar v4. The schedule method is cheaper to implement for 6-Homestar but more expensive for 7-Homestar.

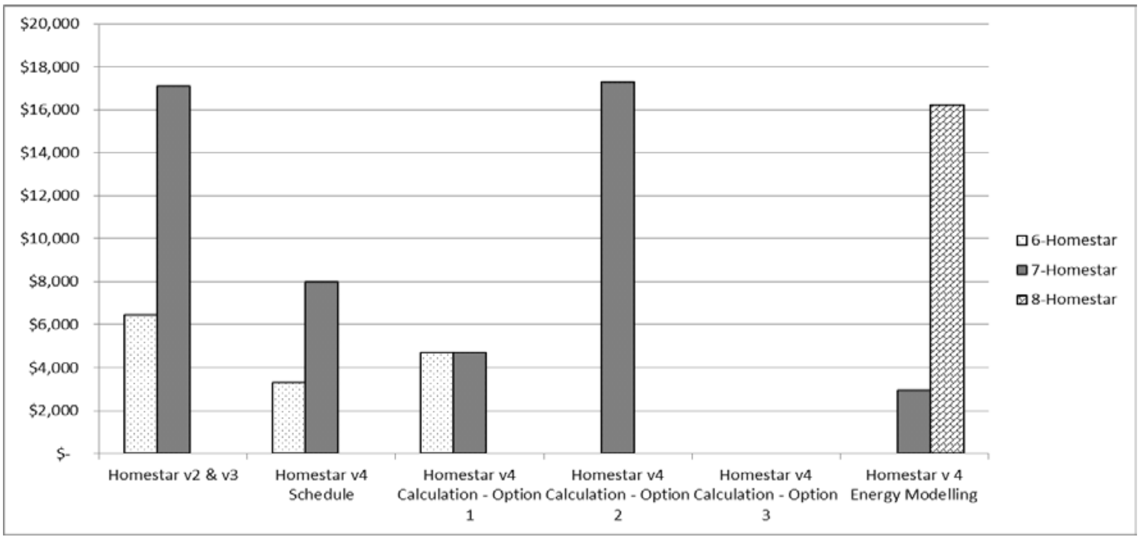


Figure 16. Cost of each thermal performance option for Dwelling 6 for the 6, 7 and 8-Homestar mandatory minimum.

Table 66 gives a summary of how Dwelling 6 performs across the different versions of Homestar. It appears it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 66. Dwelling 6 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,293	na	na	na
Building Code-compliant design	ALF online	5,883	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,994	2,577	na
Homestar v3	ALF online *allowance*	na	3,427 *(4,077)*	2,526 *(2,666)*	na
20°C set point					
Building Code-compliant design	ALF online	8,455	na	na	
Homestar v2 and v3	ALF online	na	5,120	3,870	na
Homestar v4 schedule method	ALF online	na	6,630	5,622	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,298 *(5,488)*	5,298* *(5,488)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	4,230* *(4,233)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(3,136)*	na
Energy modelling	PHPP *allowance*	13,297	na	*11,917* *(11,917)***	*8,044* *(8,781)****

* Home cooling features also to be considered. ** 56 kWh/m²/yr. ** 76 kWh/m²/yr.

It is interesting to note that, when this dwelling was modelled in ALF online (20°C set point), its predicted annual heating demand was 8,455 kWh/yr or 53.9 kWh/m²/yr. However, when the same design was modelled in PHPP, the predicted annual heating demand was 13,297 kWh/yr or 85 kWh/m²/yr, nearly double. 7-Homestar offers an interesting comparison as the costs again vary wildly for each of the different thermal performance compliance options. The energy modelling method is the most cost-effective, with the basic Building Code design nearly compliant with the energy budget. Again for this dwelling, it is more cost-effective to target 7-Homestar using the energy modelling approach than it is to target 6-Homestar under any of the other approaches, again leading to the conclusion that the Homestar v4 energy modelling energy budgets are leading to some perverse outcomes.

Table 67. Dwelling 6 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (44 m)	$2,446	$2,446	$2,446	$2,446	$2,446	$2,446	$2,446		$2,446	$2,446
Insulated garage ceiling R2.8 (20 m^2)	$210	$210	$210	$210	$210	$210	$210		$210	$210
Exposed concrete slab (60 m^2)		$1,114								
R1.2 insulation under slab										$4,784
Walls										
Insulated internal garage wall R2.2 (4.86 m^2)	$71	$71	$71	$71	$71	$71	$71		$71	$71
Increased wall insulation R2.2 to R2.8									$1,973	$1,973
Windows										
Low-e film to all windows (65.3 m^2)	$3,265			$3,265						
Low-e film to S/W/E windows only (43 m^2)					$2,150	$2,150				
Thermally broken windows with low-e and argon (65.3 m^2)		$14,366					$14,366		$14,366	$14,366
Window restrictors (28 opening windows)				$1,523		$1,523	$1,523			
Delete 5.14 m^2 windows to reach 31% WWR on NW and NW						-$1,907				
Ceilings										
Increased ceiling insulation R3.6 to R4.1 (111 m^2)			$89	$89					$89	$
Increased ceiling insulation R3.6 to R6.0 (111 m^2)		$917								
Total	**$5,992**	**$19,124**	**$2,817**	**$7,605**	**$4,877**	**$4,493**	**$18,616**		**$19,155**	**$24,856**

A.7.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 4,293 kWh/yr for heating. Homestar v2 would award this dwelling 9.75 points in EHC-6, below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 67. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.7.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 6 performs against them, are shown in Table 68.

Table 68. Schedule method analysis – Building Code-compliant design – Dwelling 6.

Schedule method – heating energy			**Dwelling 6**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			26%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			25%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.4	N	N
Wall	2.1	2.1	R2.3 & R0.4	N	N
Floor	1.3	1.5	R0.8	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW=30% NE=39%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 6 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 67.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 58 kWh/m^2/yr, which is not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 would result in a thermal performance of 35.3 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 67 would be required to achieve a 34.4 kWh/m^2 performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 68, Dwelling 6 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northwest and northeast elevations. This area of glazing is potentially feasible to remove.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 6 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 67.

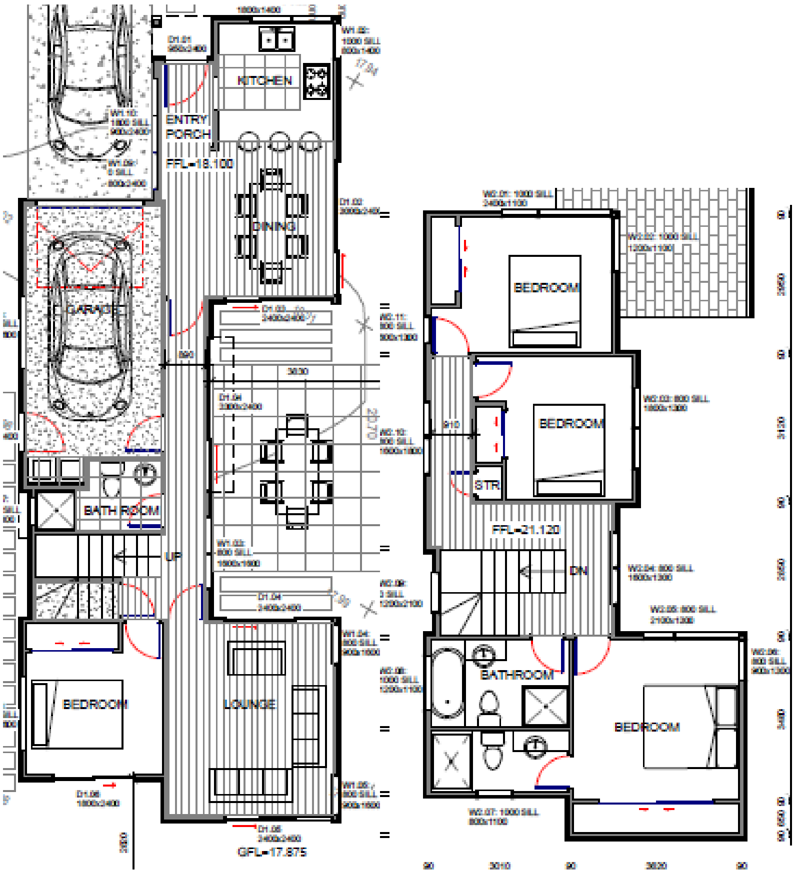
Option 3: The third way would be for the dwelling to have a design that uses no more than 3,136 kWh/yr, being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design of this dwelling to achieve this level, but it was not possible to modify the basic design sufficiently. Design changes of aluminium thermally broken low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5,) R6 ceiling insulation and exposed concrete floor to ground floor only managed to allow this dwelling to achieve 3,280 kWh/yr. The researcher concluded it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar for this dwelling in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has therefore not completed the modelling or costing for a thermal upgrade to 7-Homestar for this dwelling using the calculation method – option 3 pathway.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used PHPPv9.6 to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.8 Dwelling 7

A.8.1 Design



A.8.2 Summary

Figure 17 provides an interesting summary of the cost of the different thermal performance options for Dwelling 7.

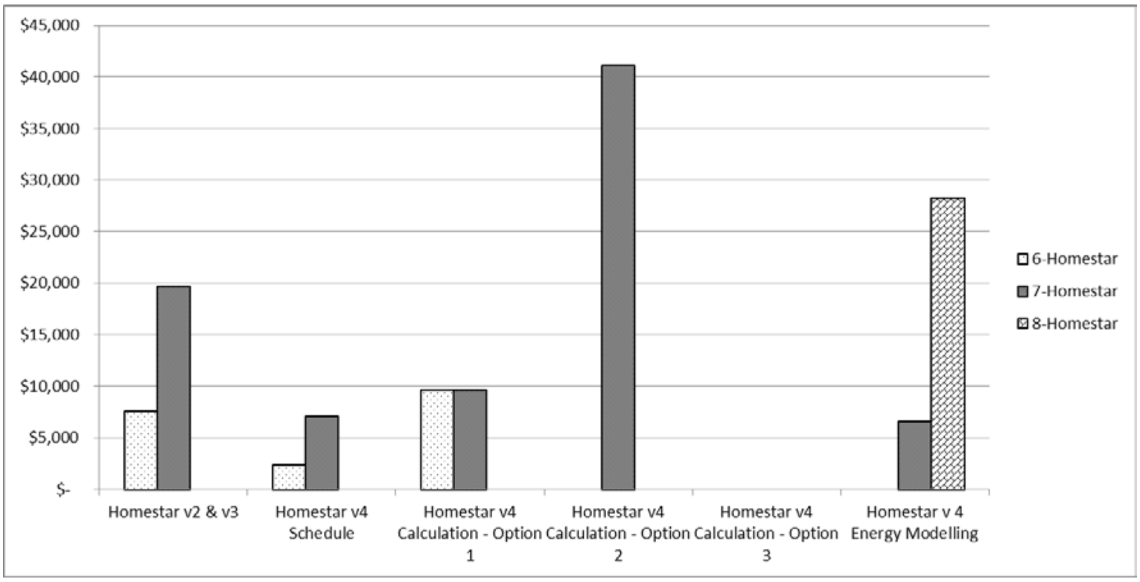


Figure 17. Cost of each thermal performance option for Dwelling 7 for the 6, 7 and 8-Homestar mandatory minimum.

From Figure 17, it can be seen that ...

Table 69 gives a summary of how Dwelling 7 performs across the different versions of Homestar. In relation to Dwelling 7, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 69. Dwelling 7 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	5,955	na	na	na
Building Code-compliant design	ALF online	5,604	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,043	2,290	na
Homestar v3	ALF online *allowance*	na	3,563 *(3,474)*	2,679 *(2,271)*	na
20°C set point					
Building Code-compliant design	ALF online	8,079	na	na	
Homestar v2 and v3	ALF online *allowance*	na	5,220	4,018	na
Homestar v4 schedule method	ALF online	na	5,866	5,064	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	4,595 *(4,676)*	4,595* *(4,676)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	3,387* *(3,607)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(2,672)*	na
Energy modelling	PHPP *allowance*	14,335	na	*9,993 (10,153)***	*414 (7,481)****

* Home cooling features also to be considered. ** 56 kWh/m^2/yr. ** 76 kWh/m^2/yr.

Table 70. Dwelling 7 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (55 m)	$2,985	$2,985	$2,985	$2,985	$2,985	$2,985	$2,985		$2,985	$2,985
Insulated garage ceiling R2.2 (18.3 m^2)	$197	$197	$197	$197	$197	$197	$197		$197	$197
Thermally broken slab										$1,731
Walls										
Insulated internal garage wall R2.2 (25.9 m^2)	$197	$197	$197	$197	$197	$197	$197		$197	$197
Increased wall insulation R2.2 to R2.8 (250 m^2)					$2,593	$2,593	$2,593		$2,593	
Increase wall thickness to 140 mm and increased insulation to R4.2										6,216
Windows										
Low-e film to all windows (76 m^2)	$3,800			$3,800	$3,800	$3,806				
Thermally broken windows with low-e and argon (76 m^2)		$17,141					$17,141		$17,141	$17,141
Delete 2 m^2 windows to reach 30% WWR			-$642	-$642						
Window restrictors (19 opening windows)				$1,033		$1,033	$1,033			
Delete 6.95 m^2 low-e windows to reach 31% WWR on NW and NW						-$2,475				
Ceilings										
Increased ceiling insulation R3.6 to R4.1 (90 m^2)					$201				$201	$201
Increased ceiling insulation R3.6 to R6.3 (90 m^2)		$743								
Total	**$7,179**	**$20,843**	**$2,737**	**$7,571**	**$9,973**	**$8,776**	**$29,879**		**$23,117**	**$31,487**

A.8.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 5,955 kWh/yr for heating. Homestar v2 would award this dwelling 7.5 points in EHC-6, below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 70. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.8.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 7 performs against them, are shown in Table 71.

Table 71. Schedule method analysis – Building Code-compliant design – Dwelling 7.

Schedule method – heating energy			**Dwelling 7**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			29%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			32%	N	N
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.6	R3.6	Y	Y
Wall	2.1	2.1	R2.1 & R0.4	N	N
Floor	1.3	1.5	R0.8	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW=34% NE=43%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 7 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 70.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 56 kWh/m^2/yr, which is not compliant. Therefore certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 would result in a thermal performance of 36 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 70 would be required to achieve a 32.5 kWh/m^2/yr performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 69, Dwelling 7 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northwest and northeast elevations. Deleting this amount of glazing is again potentially feasible.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 7 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 70.

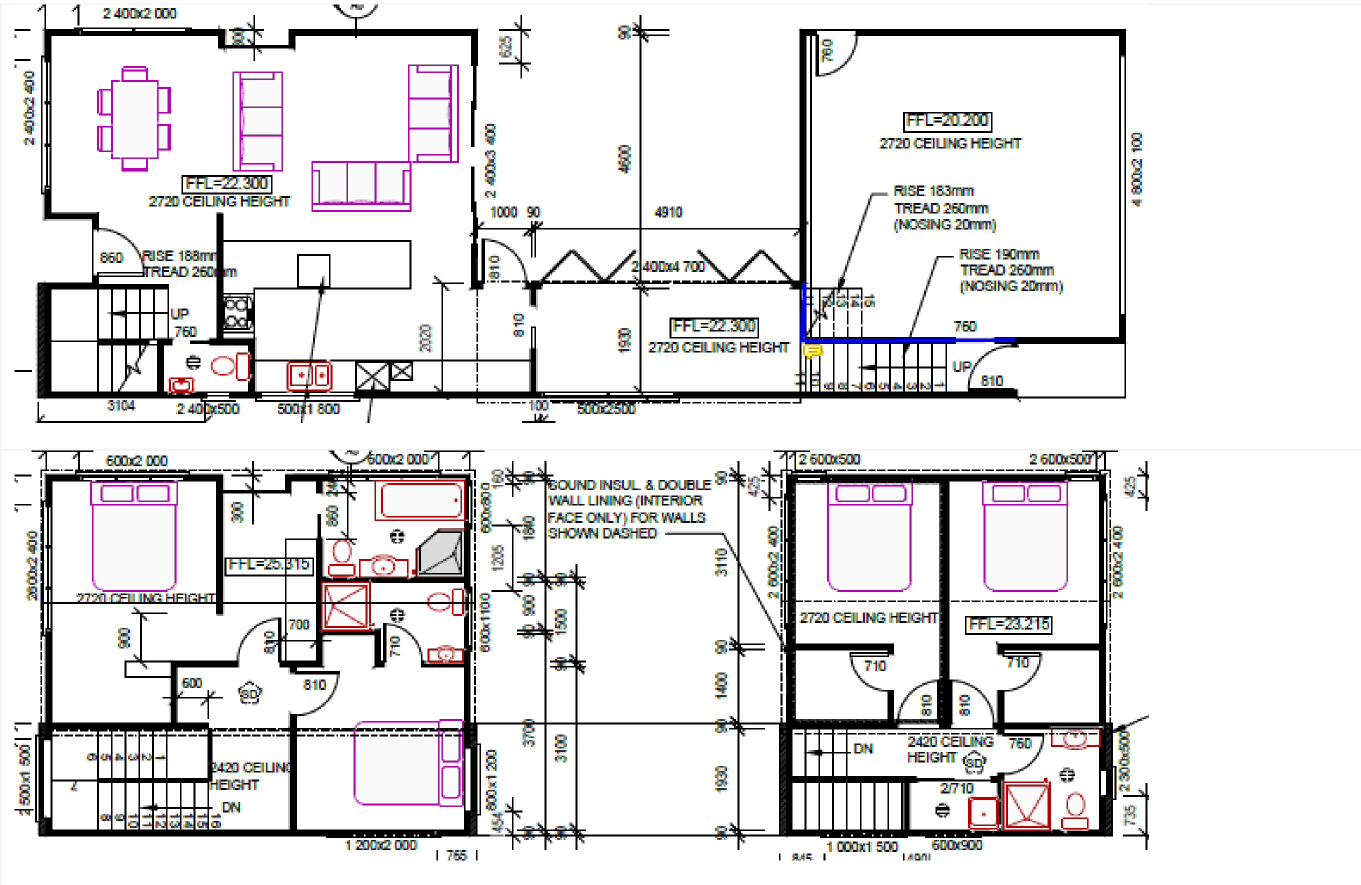
Option 3: The third way would be for the dwelling to have a design that uses no more than 2,672 kWh/yr, this being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design of this dwelling to achieve this, but it was not possible to modify the basic design sufficiently. Design changes of aluminium thermally broken low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5, R6 ceiling insulation and exposed concrete floor to ground floor only managed to allow this dwelling to achieve 2,965 kWh/yr. The researcher concluded it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar for this dwelling in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has therefore not completed the modelling or costing for a thermal upgrade to 7-Homestar for this dwelling using the calculation method – option 3 pathway.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used PHPPv9.6 to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.9 Dwelling 8

A.9.1 Design



A.9.2 Summary

Figure 18 provides an interesting summary of the cost of the different thermal performance options for Dwelling 8.

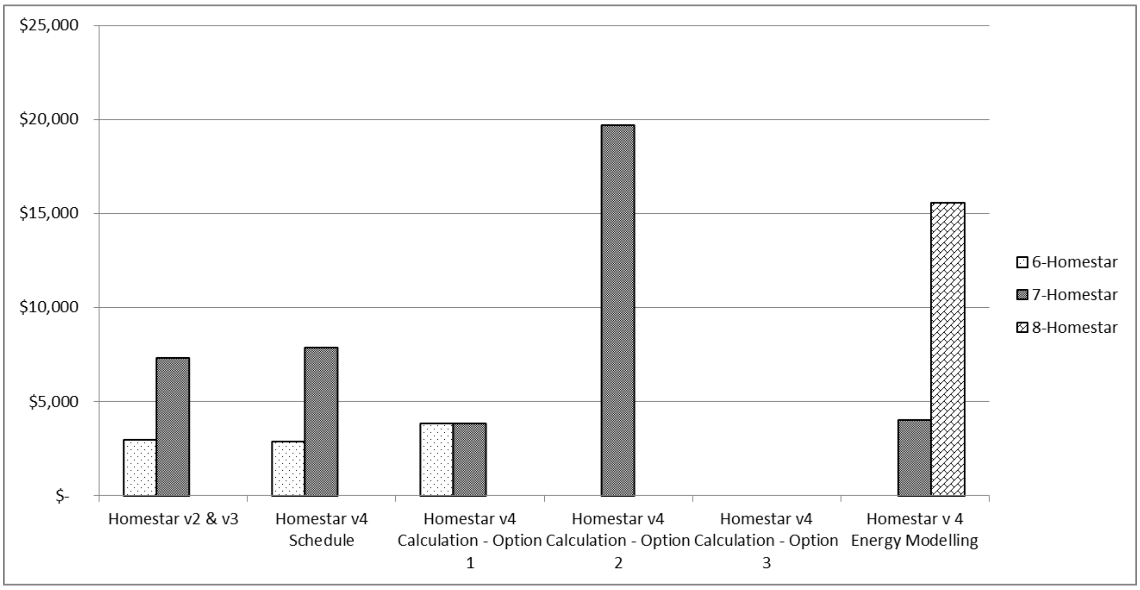


Figure 18. Cost of each thermal performance option for Dwelling 8 for the 6, 7 and 8-Homestar mandatory minimum.

From Figure 18, it can be seen that ...

Table 72 gives a summary of how Dwelling 8 performs across the different versions of Homestar. In relation to Dwelling 8, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 72. Dwelling 8 thermal performance summary across various versions of Homestar for the 6, 7 and 8-Homestar mandatory minimums.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	3,888	na	na	na
Building Code-compliant design	ALF online	4,495	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,033	2,722	na
Homestar v3	ALF online *allowance*	na	3,930 *(4,145)*	3,117 *(2,710)*	na
20°C set point					
Building Code-compliant design	ALF online	6,577	na	na	
Homestar v2 and v3	ALF online *allowance 17 kWh/m²/yr*	na	5,780	4,618	na
Homestar v4 schedule method	ALF online	na	5,975	5,199	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	4,824 *(5,579)*	4,824* *(5,579)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	4,107* *(4,304)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	Not modelled *(3,188)*	na
Energy modelling	PHPP *allowance*	13,310	na	*10,521 (12,115*****	*8,895 (8,926)*******

* Home cooling features also to be considered. ** 56 kWh/m^2/yr. ** 76 kWh/m^2/yr.

Table 73. Dwelling 8 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (50 m)	$2,740	$2,740	$2,740	$2,740	$2,740	$2,740	$2,740			$2,740
Insulated L1 extent R2.2 (2 m^2)	$23	$23	$23	$23	$23	$23	$23		$23	$23
Walls										
Insulated internal garage wall R2.2 (11 m^2)	$125	$125	$125	$125	$125	$125	$125		$125	$125
Increase wall thickness to 140 mm and increased insulation to R4.2										$8,174
Windows										
Low-e film to all windows (76 m^2)		$3,800		$3,800						
Window restrictors (23 opening windows)				$1,251		$1,251	$1,251			
Low-e film to SE windows (17.6 m^2)					$880	$880	$880			
Delete 23.21 m^2 windows to reach 31% WWR on NW						-$7,450				
Thermally broken glazing with low-e and argon gas							$15,840		$15,840	$15,840
Ceilings										
Increased ceiling insulation R3.2 to R4.1 (103 m^2)			$825	$825					$825	$825
Increased ceiling insulation R3.2 to R6.0 (103 m^2)		$780								
Total	**$2,888**	**$7,468**	**$3,713**	**$8,764**	**$3,768**	**-$2,431**	**$20,859**		**$16,813**	**$27,727**

A.9.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 3,888 kWh/yr for heating. Homestar v2 would award this dwelling 10 points in EHC-6, which achieves the mandatory minimum requirement for 6-Homestar but is below the 7-Homestar mandatory minimum requirement of 11.5 points. However, the dwelling would not achieve the EHC-7 mandatory minimum R-value requirement and would therefore still require some thermal upgrades as shown in Table 73.

A.9.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 8 performs against them, are shown in Table 74.

Table 74. Schedule method analysis – Building Code-compliant design – Dwelling 8.

Schedule method – heating energy			**Dwelling 8**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			24%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			22%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.2	R3.6	N	N
Wall	2.1	2.1	R2.1 & R0.4	N	N
Floor	1.3	1.5	R1.06	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW=36% NE=14%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 8 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 73.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 45 kWh/m^2/yr, which is not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 (as detailed earlier) would result in a thermal performance of 39.9 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 73 would be required to achieve a 33.3 kWh/m^2/yr performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 74, Dwelling 8 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%. the dwelling would need to delete some window area from it northwest and northeast elevations. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 8 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 73.

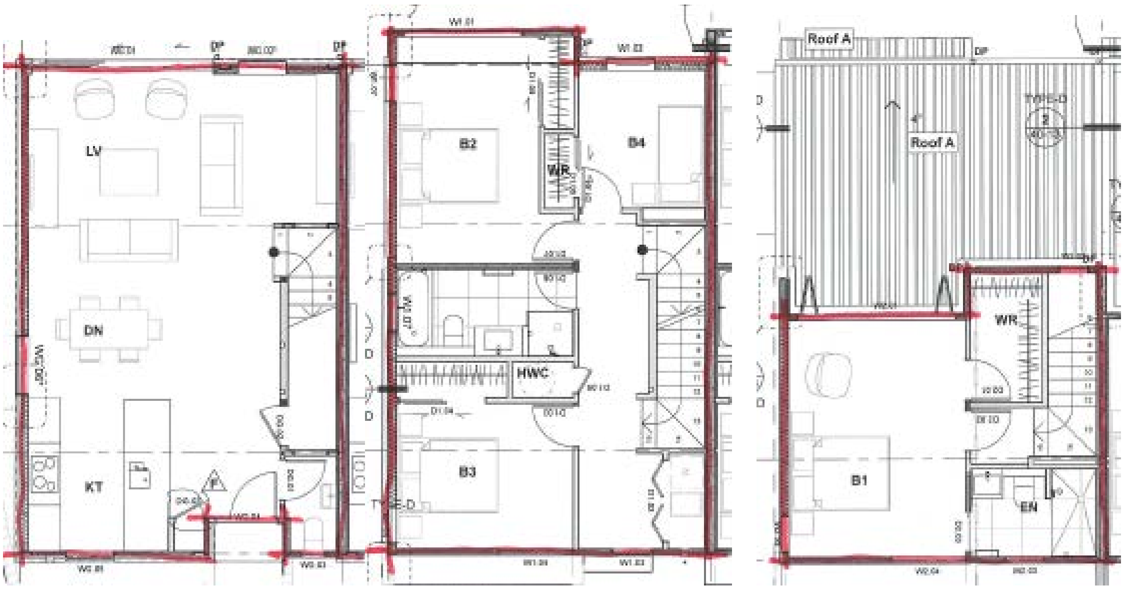
Option 3: The third way is for the dwelling to have a design that uses no more than 3,188 kWh/yr, being equivalent to 20 kWh/yr/m^2. Using ALF, the researcher tried to modify the design to achieve this, but it was not possible to modify the basic design sufficiently. Design changes of aluminium thermally broken low-e glazing, 140 mm timber framing with R4.2 insulation, thermally broken slab with overall construction R-value of R4.5, R6 ceiling insulation and exposed concrete floor to ground floor was not enough to achieve the required benchmark. The researcher concluded it would not be financially feasible to attempt to demonstrate compliance for 7-Homestar in ALF online using this heating demand benchmark, and one of the other compliance paths would be better targeted. The researcher has not completed the modelling or costing for a thermal upgrade to 7-Homestar using the calculation method – option 3 pathway.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used PHPPv9.6 to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.10 Dwelling 9

A.10.1 Design



A.10.2 Summary

Figure 19 provides an interesting summary of the cost of the different thermal performance options for Dwelling 9.

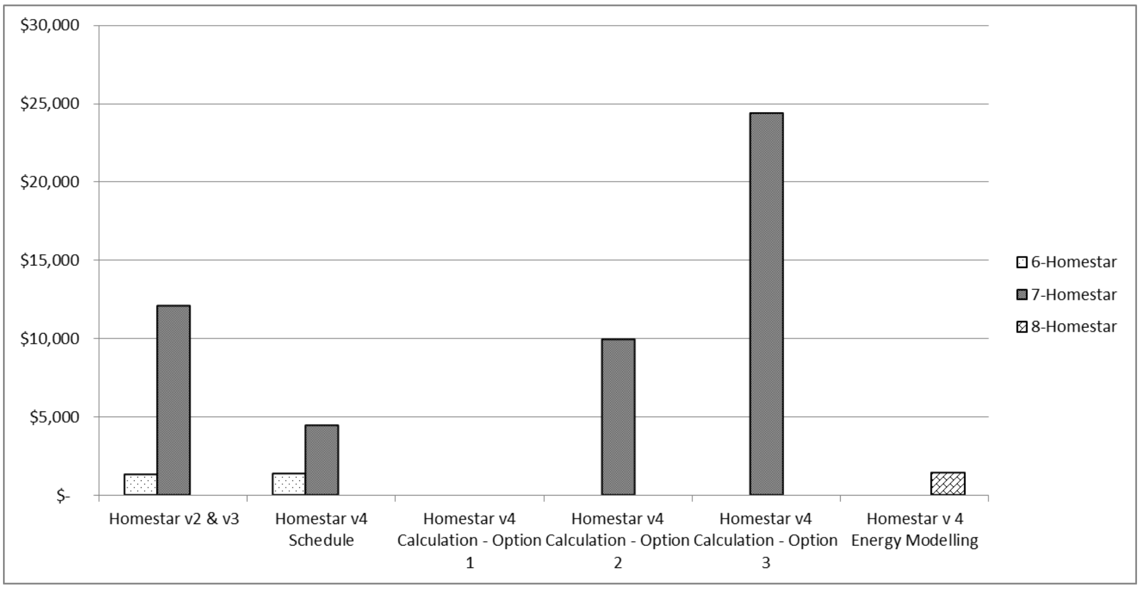


Figure 19. Cost of each thermal performance option for Dwelling 9 for the 6, 7 and 8-Homestar mandatory minimum.

From Figure 19, it can be seen that ...

Table 75 gives a summary of how Dwelling 9 performs across the different versions of Homestar. In relation to Dwelling 9, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. However, the schedule method approach also provides the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 75. Dwelling 9 thermal performance summary across various versions of Homestar.

	Thermal modelling method	Original design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,324	na	na	na
Building Code-compliant design	ALF online	3,527	na	na	na
Homestar v2	EHC-6 Excel calculator	na	3,998	2,753	na
Homestar v3	ALF online *allowance*	na	3,302 *(4,181)*	2,714 *(2,734)*	na
20°C set point					
Building Code-compliant design	ALF online	5,100	na	na	
Homestar v2 and v3	ALF online *allowance*	na	4,797	3,418	na
Homestar v4 schedule method	ALF online	na	5,020	4,384	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,100 *(5,628)*	5,100* *(5,628)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	3,964* *(4,341)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	3,203 *(3,216)*	na
Energy modelling	PHPP *allowance*	11272	na	*11,272 (12,220)***	*8,940 (9,005)****

* Home cooling features also to be considered. ** 56 kWh/m^2/yr. ** 76 kWh/m^2/yr

Table 76. Dwelling 9 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design.

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (23 m)	$1,297	$1,297	$1,297	$1,297						$1,297
Slab edge insulation (23 m)+ R1.2 (98 m^2) underneath slab								$4,307		
Walls										
Increased wall insulation R2.2 to R2.8 (122 m^2)		$1,322								$1,322
Increased wall thickness 140 mm and wall insulation R4.2								$7,685		$7,685
Windows										
Windows with low-e and argon (44 m^2)				$2,200						
Thermally broken windows with low-e and argon (44 m^2)		$9,680					$9,812	$9,812	$9,812	$9,812
Window restrictors (16 opening windows)				$870		$870	$870			
Delete 10.78 m^2 windows to reach 31% WWR on NW and NW						-$3,460				
Ceilings										
Increased ceiling insulation R2.6 to R4.1 (67 m^2)			$52	$52						
Increased ceiling insulation R2.6 to R6.0 (67 m^2)		$350						$350		$350
Total	**$1,297**	**$12,649**	**$1,349**	**$4,419**	No changes	**-$2,590**	**$10,682**	**$22,154**	**$9,812**	**$15,710**

A.10.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 4,324 kWh/yr for heating. Homestar v2 would award this dwelling 9.75 points in EHC-6, which is below the 6-Homestar mandatory minimum requirement of 10 points as well as the 7-Homestar mandatory minimum requirement of 11.5 points. The dwelling would therefore require some thermal upgrades as shown in Table 76. These improvements would also enable this dwelling to meet the EHC-7 mandatory minimum R-value requirements.

A.10.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 9 performs against them, are shown in Table 77.

Table 77. Schedule method analysis – Building Code-compliant design – Dwelling 9.

Schedule method – heating energy			**Dwelling 9**	**6-Homestar**	**7-Homestar**
Glazing area is 30% or less of the total wall area.			27%	Y	Y
The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.			27%	Y	Y
The area of all skylights is less than 1.5% of the roof area.			-	na	na
The thermal performance of each building element (climate zone 1).					
	6-Homestar	**7-Homestar**			
Roof	3.6	3.2	R3.2	N	N
Wall	2.1	2.1	R2.1	Y	Y
Floor	1.3	1.5	R1.25	N	N
Windows	0.26	0.31	R0.26	Y	N
Skylights	0.4	0.4	-	na	
Schedule method – cooling energy					
The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.			NW-na NE=32%	N	N
The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.				Y	Y
At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.				N	N

Dwelling 9 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 76.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 34.4 kWh/m^2/yr, which is compliant with the requirements. Therefore no changes are required to this design to comply with the calculation method.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 77, Dwelling 9 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northeast elevations. Given the small amount of glazing that would be required to be deleted for this dwelling, this is a feasible approach.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 9 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 76.

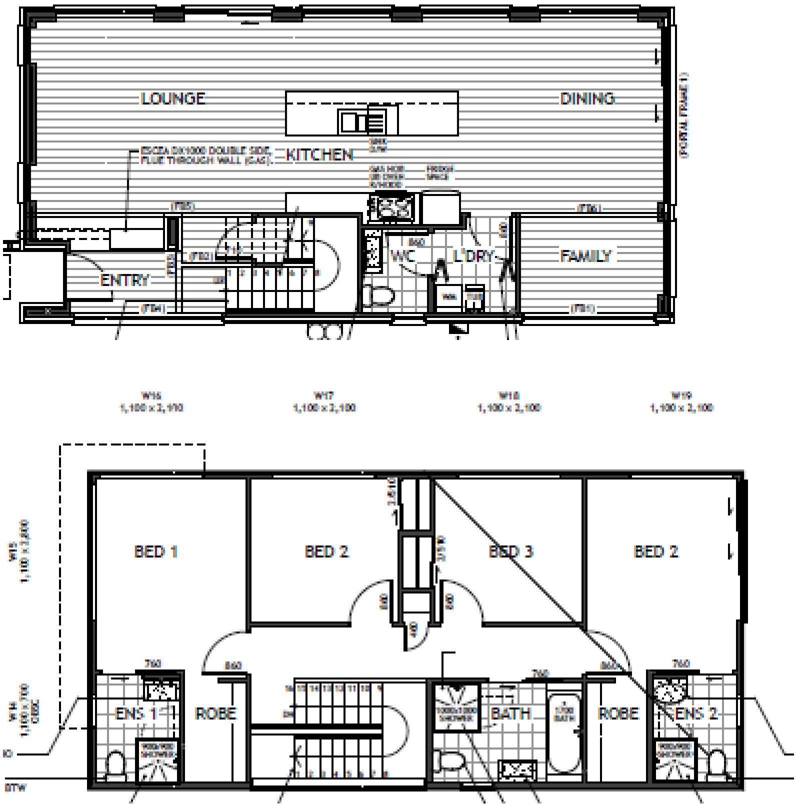
Option 3: The third way would be for the dwelling to have a design that uses no more than 3,216 kWh/yr, this being equivalent to 20 kWh/yr/m^2. It is possible for Dwelling 9 to achieve this using the thermal upgrades shown in Table 76.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used the Passive Dwelling Planning Package (PHPPv9.6) to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

A.11 Dwelling 10

A.11.1 Design



A.11.2 Summary

Figure 20 provides an interesting summary of the cost of the different thermal performance options for Dwelling 10.

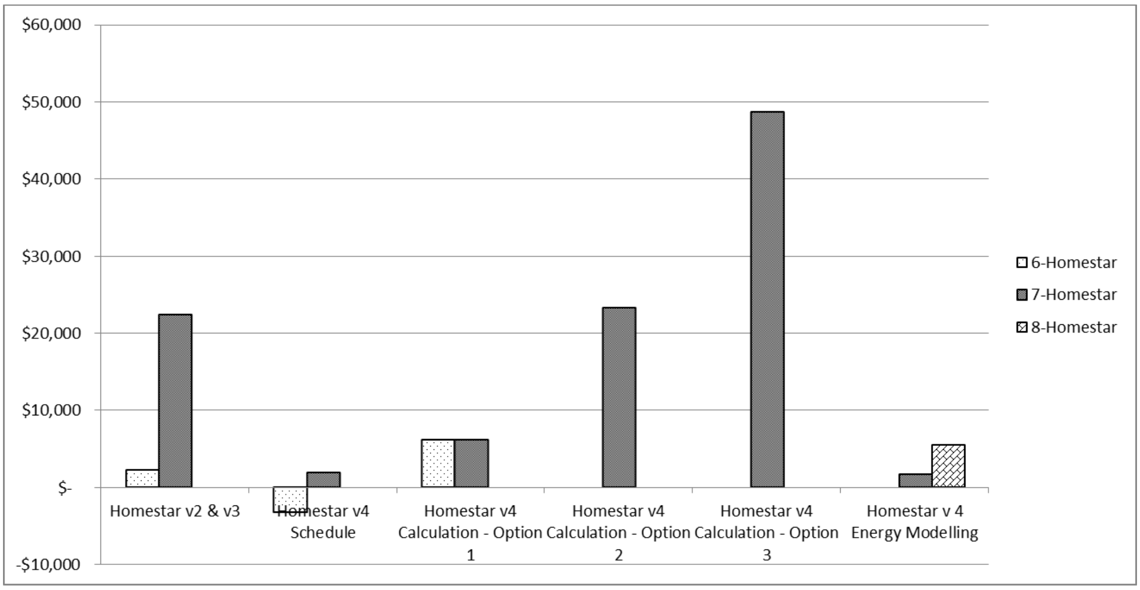


Figure 20. Cost of each thermal performance option for Dwelling 10 for the 6, 7 and 8-Homestar mandatory minimum.

From Figure 20, it can be seen that …

Table 78 gives a summary of how Dwelling 10 performs across the different versions of Homestar. In relation to Dwelling 10, it appears that it is easiest and most cost-effective for this dwelling to comply with the schedule method of Homestar v4. It is however very interesting to note that, for this dwelling, it is Homestar v2 and v3 that provide the worst thermal performance, with the exception of the Building Code-compliant design when modelled in ALF using a 20°C heating set point.

Table 78. Dwelling 10 thermal performance summary across various versions of Homestar.

	Thermal modelling method	Original Design (kWh/yr)	6-Homestar (kWh/yr)	7-Homestar (kWh/yr)	8-Homestar (kWh/yr)
18°C set point					
Building Code-compliant design	EHC-6 Excel calculator	4,210	na	na	na
Building Code-compliant design	ALF online	4,485	na	na	na
Homestar v2	EHC-6 Excel calculator	na	4,032	2,389	na
Homestar v3	ALF online *allowance*	na	4,046 *(4,267)*	2,860 *(2,790)*	na
20°C set point					
Building Code-compliant design	ALF online	6,555	na	na	
Homestar v2 and v3	ALF online *allowance*	na	5,950	4,064	na
Homestar v4 schedule method	ALF online	na	5,723	4,927	na
Homestar v4 calculation method – option 1	ALF online *allowance 35 kWh/m²/yr*	na	5,507 *(5,743)*	5,507* *(5,743)*	na
Homestar v4 calculation method – option 2	ALF online *allowance 27 kWh/m²/yr*	na	na	3,982* *(4,430)*	na
Homestar v4 calculation method – option 3	ALF online *allowance 20 kWh/m²/yr*	na	na	3,162 *(3,282)*	na
Energy modelling	PHPP *allowance*	12,865	na	*12,291 (12,471)***	*9,156 (9,189)****

* Home cooling features also to be considered. * 56 kWh/m²/yr. ** 76 kWh/m²/yr.

Table 79. Dwelling 10 cost summary to achieve the required thermal performance upgrades for each rating tool from a $0 cost for the existing design

Thermal upgrades	Homestar v2 and v3		Homestar v4							
			Schedule method		Calculation method				Energy modelling	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar			7-Homestar	8-Homestar
						Option 1	Option 2	Option 3		
Foundation/floors										
Slab edge insulation (40 m)	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250			
Thermally broken slab								$1,370		$1,370
Walls										
Increased wall insulation R2.2 to R2.4 (146 m^2)			$349	$349						
Increased wall insulation R2.2 to R2.8 (146 m^2)		$1,509			$1,509	$1,509	$1,509		$1,509	
Increased wall framing 140 mm and R4.2 insulation								$7,514		$7,514
Windows										
Windows with low-e on SE and SW only (45.2 m^2)					$2,260	$2,260				
Windows with low-e (89 m^2)				$3,800						
Thermally broken windows with low-e and argon (89 m^2)		$19,580					$19,580	$19,580	$19,580	$19,580
Delete 12.5 m^2 windows to reach 30% WWR			-$4,013	-$4,013						
Delete 9.1 m^2 windows to reach 31% WWR on NW and NW						-$2,921				
Window restrictors (24 opening windows)				$1,305			$1,305			
Ceilings										
Increased ceiling insulation R3.2 to R4.1 (67 m^2)			$112	$112	$112	$112	$112		$112	
Increased ceiling insulation R3.2 to R6.0 (67 m^2)		$644						$644		$644
Total	**$2,250**	**$23,983**	**-$1,302**	**$3,803**	**$6,131**	**$4,516**	**$21,897**	**$35,622**	**$21,201**	**$29,142**

A.11.3 Thermal performance analysis (Homestar v2 and v3)

Using the Homestar v2 EHC-6 calculator, this dwelling would use 4,045 kWh/yr for heating. Homestar v2 would award this dwelling 10 points in EHC-6, which achieves the mandatory minimum requirement for 6-Homestar. However, the dwelling would not achieve the EHC-7 mandatory minimum R-value requirement and would therefore still require some thermal upgrades as shown in Table 79.

A.11.4 Thermal performance analysis (Homestar v4)

Schedule method

The EHC-1 schedule method requirements, along with how Dwelling 10 performs against them, are shown in Table 80.

Table 80. Schedule method analysis – Building Code-compliant design – Dwelling 10.

<table>
<tr><th colspan="3">Schedule method – heating energy</th><th>Dwelling 10</th><th>6-Homestar</th><th>7-Homestar</th></tr>
<tr><td colspan="3">Glazing area is 30% or less of the total wall area.</td><td>38%</td><td>N</td><td>N</td></tr>
<tr><td colspan="3">The combined area of glazing on the east, south and west-facing walls is 30% or less of the combined total area of these walls.</td><td>35%</td><td>N</td><td>N</td></tr>
<tr><td colspan="3">The area of all skylights is less than 1.5% of the roof area.</td><td>-</td><td>na</td><td>na</td></tr>
<tr><td colspan="3">The thermal performance of each building element (climate zone 1).</td><td></td><td></td><td></td></tr>
<tr><td></td><td>6-Homestar</td><td>7-Homestar</td><td></td><td></td><td></td></tr>
<tr><td>Roof</td><td>3.6</td><td>3.2</td><td>R3.2</td><td>N</td><td>N</td></tr>
<tr><td>Wall</td><td>2.1</td><td>2.1</td><td>R1.8</td><td>N</td><td>N</td></tr>
<tr><td>Floor</td><td>1.3</td><td>1.5</td><td>R1.25</td><td>N</td><td>N</td></tr>
<tr><td>Windows</td><td>0.26</td><td>0.31</td><td>R0.26</td><td>Y</td><td>N</td></tr>
<tr><td>Skylights</td><td>0.4</td><td>0.4</td><td>-</td><td>na</td><td></td></tr>
<tr><th colspan="3">Schedule method – cooling energy</th><th></th><th></th><th></th></tr>
<tr><td colspan="3">The solar aperture of each façade of the dwelling is less than 27% for unshaded windows or 31% for windows under shallow eaves.</td><td>NW=54%
NE=30%</td><td>N</td><td>N</td></tr>
<tr><td colspan="3">The openable area of windows in each habitable space is greater than 5% of the conditioned floor area, and at least 30% of the total required openable area for the dwelling as a whole is on an opposite/adjacent façade or on a different floor of the dwelling.</td><td></td><td>Y</td><td>Y</td></tr>
<tr><td colspan="3">At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow secure night-time ventilation. Windows on upper storeys that are not accessible are exempt. Dwellings on upper storeys with no windows accessible from public areas are compliant by default.</td><td></td><td>N</td><td>N</td></tr>
</table>

Dwelling 10 is not currently compliant with the schedule method and would therefore require a few design changes to enable it to be utilised. The changes it would require,

as well as the additional cost to undertake these changes to the dwelling design, have been estimated and are provided in Table 79.

Calculation method (6-Homestar)

The second method of EHC-1 compliance is via a calculation method that uses the annual loss factor (ALF) algorithm from BRANZ. To achieve the 6-Homestar mandatory minimum requirement of 12 EHC-1 points, the dwelling would have to demonstrate in ALF that its total predicted energy demand for space heating is equal to or less than 35 kWh/m^2/yr. Inputting the Building Code-compliant design into ALF delivers a result of 38.3 kWh/m^2/yr, which is not compliant. Therefore, certain thermal upgrades will again be required to allow the dwelling to comply with the calculation method of Homestar v4. Using the same upgrades as were required for Homestar v2 and v3 (as detailed earlier) would result in a thermal performance of 36.3 kWh/m^2/yr, which is closer but still not compliant. Following calculations in ALF, it was determined that the upgrades shown in Table 79 would be required to achieve a 33.6 kWh/m^2/yr performance.

Calculation method (7-Homestar)

Option 1: The first way of complying with the 7-Homestar calculation method is for the design of the dwelling to achieve the 12 point calculation heating energy demand of 35 kWh/m^2/yr and to then achieve 2 points for cooling through the inclusion of all three home features in the cooling list. As shown in Table 80, Dwelling 10 does not currently comply with the solar aperture cooling feature. To achieve compliance with the mid-range partially shaded with eaves of 300 mm requirement of 31%, the dwelling would need to delete some window area from its northwest and northeast elevations. Whilst the researcher does not believe that this is actually feasible, this approach has been costed for completeness.

Option 2: The second way is for the design of the dwelling to achieve the 13 point calculation heating energy demand of 27 kWh/m^2/yr and to then achieve 1 point for cooling through the inclusion of two home features in the cooling list. The researcher therefore modified the current design of Dwelling 10 in ALF online to reduce its heating demand to 27 kWh/m^2/yr. The changes that were required to achieve the required heating demand benchmark are shown in Table 79.

Option: The third way would be for the dwelling to have a design that uses no more than 3,282 kWh/yr, this being equivalent to 20 kWh/yr/m^2. It is possible for Dwelling 10 to achieve this using the thermal upgrades shown in Table 79.

Energy modelling method

Homestar v4 requires the use of energy modelling to demonstrate compliance with the EHC-1 mandatory minimum requirement for 8-Homestar and above. The researcher has used the Passive Dwelling Planning Package (PHPPv9.6) to model the case study dwellings. Energy modelling can be used to demonstrate compliance with the 7 and 8-Homestar mandatory minimum. Both of these have therefore been modelled.

Appendix B: Background to Homestar

Homestar is a comprehensive, national, voluntary environmental rating tool that evaluates the environmental attributes of New Zealand's stand-alone homes, townhouses and apartment dwellings. Homestar allows homeowners and tenants to assess their home, providing a scale that creates value around warm, healthy, sustainable and efficient homes. Homestar rewards and recognises improvements in both the home's comfort as well as the impact that the home has on the environment.

The Homestar rating tool framework allows for self-assessment by the homeowner or tenant using an online tool and also independent assessment of the star rating resulting in the issuing of a formal Homestar certified rating.

B.1 Types of Homestar assessments

Certified Tool

A Homestar Built rating is an official confirmation of how well a home performs or will perform against the Homestar criteria. The Certified Tool comprises of a Homestar Technical Manual, the Homestar Scorecard and Homestar Calculator. There are two checkpoints in the progress of achieving a Homestar Built rating. However, these checkpoints are not compulsory.

Checkpoint 1: Homestar Appraisal

A Homestar Appraisal occurs when a project is at concept phase. It is a marketing opportunity for the developer to confirm intention to achieve a Homestar Built rating.

Checkpoint 2: Homestar Design rating

A Homestar Design rating is a full assessment of a proposed dwelling based on detailed plans, specifications and any other documentation required to fully describe the build. A Homestar Design rating is only a checkpoint on the path to a Homestar Built rating and will expire after 2 years. A Homestar Design rating is often required to be obtained at the same time as building consent as a resource consent condition for dwellings in Special Housing Areas.

Homestar Built rating

A Homestar Built rating involves a physical check of a completed dwelling by the Homestar assessor. It can be conducted on an existing property without a prior Homestar Appraisal or Homestar Design rating. If a Homestar Design rating has been completed, that documentation may be used to streamline the documentation process for a Homestar Built rating. This in-dwelling assessment and resulting Homestar Built rating allows prospective buyers and tenants to understand the likely level of performance for a given dwelling and easily compare it to other certified dwellings. A 6-Homestar Built rating is required as a resource consent condition for a large number of dwellings being developed in the, now defunct, Special Housing Areas in Auckland.

B.2 Star bands

Homestar has been developed to enable existing and newly built homes to undergo assessment. Older homes have not been built to modern Building Code standards, and the Building Code itself does not address all the categories covered by Homestar. The star bands for Homestar have to cater for a variety of standards of housing and their environmental attributes. The Homestar star bands and scores are shown in Table 81.

Table 81. Homestar score required for different star ratings.

Rating	Required score
1-Homestar	0–19.9
2-Homestar	20–29.9
3-Homestar	30–39.9
4-Homestar	40–49.9
5-Homestar	50–59.9
6-Homestar	60–69.9
7-Homestar	70–79.9
8-Homestar	80–89.9
9-Homestar	90–94.9
10-Homestar	95–100

B.3 Homestar v2

B.3.1 Mandatory minimum levels

Some core issues within Homestar are considered so important that a minimum performance level needs to be achieved before progress up the stars can be made. These are referred to as mandatory minimum levels. If the assessed dwelling fails to achieve these mandatory minimum levels, no matter what the performance is in other areas of the tool, the minimum levels will limit the final star rating. In this case, the home's final star rating will be the next lowest rating where the mandatory minimum levels are all met. Mandatory minimum levels are in the energy, health and comfort (EHC) and water categories at the 3, 5, 6 and 7 star bands. Apart from these mandatory minimums, Homestar is flexible – the homeowner or tenant can choose which credit criteria to meet. Details of the minimum levels are provided in Table 82.

Table 82. Homestar mandatory minimum levels.

Level	Requirement	Outcome
3-Homestar or above	In the whole-dwelling thermal credit, the home must achieve at least 7.6 out of 15 points.	If this is not achieved, a maximum rating of 2-Homestar is available.
5-Homestar or above	The mandatory minimum for 3-Homestar must be achieved.	If this is not achieved, a maximum rating of 4-Homestar is available.
	In the moisture control credit, the home must achieve at least 3 out of 4.5 points.	
	In the whole-dwelling thermal credit, the home must achieve at least 10 out of 15 points.	
6-Homestar or above	The mandatory minimum for 3 and 5-Homestar must be achieved.	If this is not achieved, a maximum rating of 5-Homestar is available
	In the internal potable water use questions, the home must have dual-flush toilets with a maximum 6/3 litre flush), and showers must have a flow of less than 9 L/min.	
7-Homestar or above	The mandatory minimum for 3, 5 and 6-Homestar must be achieved.	If this is not achieved, a maximum rating of 6-Homestar is available.
	In the whole-Dwelling thermal credit, the home must achieve at least 11.5 out of 15 points.	

For a dwelling targeting a 6–10-Homestar rating, the mandatory minimums are essential to achieve, and a standard dwelling design (designed to the Building Code) often fails the EHC-7 mandatory minimum. As Table 83 shows, in order to achieve 3 points in the EHC-7 credit, it is fundamental for at least 0.5 points to be achieved in the minimising condensation component of this credit. This requires that all construction elements as part of the dwelling thermal envelope (walls, floors, roofs) achieve a final construction R-value >R1.5. If this is not achieved, a maximum of 2.9 points can only be achieved in EHC-7, and therefore the dwelling will not comply with the mandatory minimum requirement, in effect limiting the dwelling to a maximum of a 4-Homestar rating.

Table 83. EHC-7 requirements.

EHC-7 compliance items	Points available
Minimising potential moisture sources	
All bathtubs and basins (including kitchen, bathroom and laundry) must have overflow prevention built in, or a floor ground waste must be provided in all wet areas	0.3
Eliminate ground moisture by providing ground cover, i.e. polythene sheeting (automatically compliant for concrete slabs)	0.4
Ensure there are no unflued gas heating systems in the dwelling	0.3
Ensure showers are fully enclosed (shower dome or floor to ceiling shower walls)	0.1
Minimising condensation (points must be achieved from this credit component in order to achieve >3 points in EHC-7)	
All walls, ceiling, floors achieve final R-values >R1.5	0.5
All walls, ceiling, floors achieve final R-values >R1.8 and all glazing achieves >R0.30	1.0
All walls, ceiling, floors achieve final R-values >R2.0 and all glazing achieves >R0.30	1.6
Ventilation	
Ensure a kitchen extract is provided and ducted directly to the exterior	0.3
Ensure all bathrooms have extracts provided and are ducted directly to the exterior	0.3
Bathroom extracts must be automated (hardwired to a light switch with delay start/finish timer, humidistat or passive infrared)	0.3
Bathroom extracts must be placed so as to adequately deal with the moisture produced in these areas	0.1
Extract grilles must be protected from the external elements with a cover/box	0.1
Extract grilles must have rain deflector blades (or be located in the soffit)	0.1
Ensure either no dryer is provided or ensure dryer is vented directly to the exterior or a condensing dryer model is provided	0.2
Moisture removal	
The net openable window area (OWA) must be >5% of the dwelling floor area	0.1
All openable windows must include restrictor stays to protect against intruder entry (and for safety reasons) while allowing for passive ventilation of at least 10 mm along one edge	0.3
EHC-7 total points available	**4.5**

The Building Code only requires a minimum R-value of R1.3 for the floor of a dwelling, and therefore many dwellings designed to the Building Code minimums fail to meet this requirement. The majority of foundations for new dwellings are formed from waffle pod slabs, and to achieve an R-value of R1.5 or greater in an uninsulated waffle pod slab, the area:perimeter ratio of that slab must be greater than or equal to 2.5. The majority of dwellings that the researcher has reviewed, particularly those with attached garages, do not achieve this area:perimeter ratio and therefore need to install slab edge insulation to the waffle pod foundation to achieve the minimum R-value of R1.5 that is required to achieve the Homestar mandatory minimum.

B.3.2 Resource adjustment factor (RAF)

A resource adjustment factor (RAF) is embedded within Homestar to encourage modest dwelling sizes, recognising the implications that large dwellings consume more resources than smaller ones over their life cycle. The RAF seeks to compensate for these impacts by penalising larger dwellings. The allocation of the RAF is dependent on the relationship between unit size and number of bedrooms. The RAF is multiplied by the total number of points achieved for the home/apartment and affects final score.

B.3.3 Points allocation

The Homestar rating tool is broken into seven categories with different credits in each. A project can achieve a rating by meeting the mandatory minimum requirements for that rating level and then achieving the requisite number of points as per Table 84.

Table 84. Homestar v2 rating tool.

Credit	Points
Energy, health and comfort	
EHC-1 Space Heating	6
EHC-2 Hot Water	4.5
EHC-3 Lighting	2
EHC-4 Whiteware & Appliances	2
EHC-5 Renewable Energy	8
EHC-6 Whole Dwelling Thermal Performance	15
EHC-7 Moisture Control	4.5
EHC-8 Washing Line(s)	1
EHC-9 Sound Insulation	2
EHC-10 Inclusive Design	3
Subtotal	**48**
Water	
WAT-1 Rainwater Harvesting	6
WAT-2 Internal Potable Water	6
WAT-3 Grey Water Re-Use	3
Subtotal	**15**
Waste	
WST-1 Construction Waste Management	3
WST-2 Construction Waste Reduction	3
WST-3 Recycling Facilities	1
WST-4 Composting Facilities	2
Subtotal	**9**

Credit	Points
Management	
MAN-1 Miscellaneous – Unwanted Features	2
MAN-2 Safety & Security	2
MAN-3 Home User Guide	2
MAN-4 Responsible Contracting	2
Subtotal	**8**
Materials	
MAT-1 Materials Selection	9
MAT-2 VOCs & Toxic Materials	3
Subtotal	**12**
Site	
STE-1 Stormwater Management	3
STE-2 Native Ecology	1.5
STE-3 On-Site Food Production	1.5
STE-4 Site Selection	2
Subtotal	**8**
Total	**100**
Innovation	
INN – Innovation 1	Up to 5 points
INN – Innovation 2	
INN – Innovation 3	
INN – Innovation 4	
INN – Innovation 5	
Subtotal	**5**
Total	**105**

B.4 Homestar v3

Homestar v3 is very similar to Homestar v2, with only a few credits being modified in a manner that would affect a stand-alone dwelling. These changes are detailed below.

- A new credit in relation to natural lighting (EHC-11) was added to the tool.
- A new water calculator was developed for rainwater harvesting (WAT-1) that evaluated the percentage ability of the rainwater tank to supply the dwelling's water demand for the year. Points are then awarded on the percentage of supply that the rainwater harvesting can satisfy. This differs from Homestar v2 where a blanket number of points were awarded for different levels of connection to the dwelling.
- Composting (WST-4) was reduced to 1 point from 2 points in Homestar v2. This does not affect costing in any way but does mean that the impact of the money expended is less.
- The miscellaneous credit (MAN-1) was reduced to 0 points, with points being deducted should any of those features appear in the dwelling.
- Stormwater management (STE-1) was decreased to 2 points while transport (STE-4) was increased to 3 points with the credit criteria changed. A new credit on common area amenities (STE-5) was added to the tool. However, only multi-unit developments are eligible to target points in this credit.
- In Homestar v2, the allocation of the RAF was dependent only on the relationship between a dwelling's size and number of bedrooms, but in Homestar v3 the RAF is

made of two components – a dwelling resource adjustment factor (DRAF) and a density factor (DF). The DRAF is the same as the RAF in Homestar v2 and remains the relationship between the conditioned area of the dwelling and the number of bedrooms. The DF is the ratio of the building footprint to the building GFA.

Table 85. Homestar v3 rating tool.

Credit	Points
Energy, health and comfort	
EHC-1 Space Heating	6
EHC-2 Hot Water	4.5
EHC-3 Lighting	2
EHC-4 Whiteware & Appliances	2
EHC-5 Renewable Energy	8
EHC-6 Whole Dwelling Thermal Performance	15
EHC-7 Moisture Control	4.5
EHC-8 Washing Line(s)	1
EHC-9 Sound Insulation	2
EHC-10 Inclusive Design	3
EHC-11 Natural Lighting	2
Sub-total	**50**
Water	
WAT-1 Rainwater Harvesting	6
WAT-2 Internal Potable Water	6
WAT-3 Grey Water Re-Use	3
Sub-total	**15**
Waste	
WST-1 Construction Waste Management	3
WST-2 Construction Waste Reduction	3
WST-3 Recycling Facilities	1
WST-4 Composting Facilities	1
Sub-total	**8**
Management	
MAN-1 Miscellaneous – Unwanted Features	0
MAN-2 Safety & Security	2
MAN-3 Home User Guide	2
MAN-4 Responsible Contracting	2
Sub-total	**6**
Materials	
MAT-1 Materials Selection	9
MAT-2 VOCs & Toxic Materials	3
Sub-total	**12**
Site	
STE-1 Stormwater Management	2
STE-2 Native Ecology	1.5
STE-3 On-Site Food Production	1.5
STE-4 Site Selection	3
STE-5 Common Area Facilities	1
Sub-total	**9**

Credit	Points
Total	**100**
Innovation	
INN – Innovation 1	Up to 5 points
INN – Innovation 2	
INN – Innovation 3	
INN – Innovation 4	
INN – Innovation 5	
Sub-total	**5**
Total	**105**

B.5 Homestar v4

In 2017, the NZGBC went through 6 months of extensive industry consultation to completely rewrite the Homestar tool. One of the fundamental changes to Homestar v4 was the elimination of levels 1–5 of rating. Under Homestar v4, it is therefore no longer possible to achieve anything lower than a 6-Homestar rating.

Homestar v4 has two possible approaches for achieving 6-Homestar. The first is a checklist method where a dwelling can follow a checklist of predetermined items that are deemed to be equivalent to a 6-Homestar-rated dwelling. The second is via the traditional credit and point selection method used in Homestar v2 and v3.

Homestar v4 has two possible approaches for achieving the mandatory minimum requirement of the previously named EHC-6 (whole-dwelling passive thermal performance) points, now renamed EHC-1 (thermal comfort) in Homestar v4.

B.5.1 Mandatory minimums

Homestar v4 has also changed the mandatory minimums required to achieve the different rating levels. Table 86 illustrates these mandatory minimum requirements.

Table 86. Homestar v4 mandatory minimum requirements.

Homestar credit	6-Homestar	7-Homestar	8-Homestar
EHC-1 (thermal comfort)	A score of at least 12 points must be achieved	A score of at least 14 points must be achieved	A score of at least 16 points must be achieved
EHC-2 (efficient space heating)	A fixed heating source serving the main living area except when the annual heating energy demand is less than 15 kWh/m^2		
EHC-3 (ventilation)	A score of at least 0.5 points must be achieved	A score of at least 1.5 points must be achieved	
EHC-4 (surface and interstitial moisture)	A score of at least 0.5 points must be achieved	A score of at least 1.5 points must be achieved	
WAT-1 (water use in the home)	Flow rates of all showers <9 L/min and WCs <6 L/3 L		

Where required, the various mandatory minimum requirements are explained in more detail in the subsections below. EHC-2 and WAT-1 are not expanded on due to the simplistic nature of their requirements.

B.5.2 EHC-1 (thermal comfort)

Up to 20 points are available in Homestar v4, which is an increase of 5 points from what was available in Homestar v2 and v3. The EHC-1 credit forms part of the mandatory minimum requirement for any Homestar rating.

Homestar v4 has divided New Zealand into four major climate zones, which impact the thermal performance requirements of a dwelling (see Table 87.

Table 87. Homestar v4 climate zones.

Climate Zones for Use in Homestar		
Zone	Territorial Regions	Representative Climate
1	Northland, Auckland Franklin District and the Coromandel Peninsula	Auckland
2	The rest of the North Island except the Central Plateau	Wellington
3A	The Central Plateau of the North Island and all of the South Island except 3B	Christchurch
3B	Queenstown-Lakes, Mackenzie, Western Waitaki, Central Otago regions	Queenstown

In Homestar v4, there are four pathways available for a dwelling to demonstrate compliance:

1. Schedule method – 6 or 7-Homestar ratings only.
2. Heating load calculations using the online BRANZ ALF calculator – 6 or 7-Homestar ratings only.
3. Energy modelling – using NZGBC-approved software and protocol.
4. Passive dwelling – for dwellings that have achieved passive dwelling certification, the full 20 points are awarded.

Out of this list, only items 2 and 3 are familiar from Homestar v2 and v3, with items 1 and 4 being completely new compliance methods. The schedule method is discussed and elaborated on below.

Schedule method

Homestar v4 has introduced a schedule method to try and reduce the time and cost associated with determining the thermal performance of a dwelling.

To be eligible for assessment under the schedule method, a dwelling must meet the following criteria:

- The total glazing area is no more than 30% of the total wall area.
- The combined area of glazing on the east, south and west-facing walls is no more than 30% of the combined area of these walls.
- The area of skylights is less than 1.5% of the conditioned roof area.

If a dwelling is eligible to use the schedule method, each building element must be greater than or equal to the construction R-values in relation to its climate zone location as shown in Table 88.

Table 88. Homestar v4 schedule method requirements.

Building element	Building element minimum R-value requirement (including thermal bridging)							
	Climate zone 1		Climate zone 2		Climate zone 3A		Climate zone 3B	
	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar	6-Homestar	7-Homestar
Roof	3.6	3.6	3.8	3.8	4.1	4.3	4.9	5.1
Wall	2.1	2.1	2.1	2.2	2.2	2.9	2.9	3.2
Floor*	1.3	1.5	1.8	1.8	2.3	2.3	3.0	3.0
Glazing	0.26 2-star WEERS	0.32 3-star WEERS	0.32 3-star WEERS	0.43 4.5-star WEERS	0.43 4.5-star WEERS	0.43 4.5-star WEERS	0.43 4.5-star WEERS	0.44 5-star WEERS
Skylights (max. 1.5%)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

* Note: If underfloor heating is present, slab insulation is recommend in all cases, and a minimum R1.9 is required as per the Building Code.

For a dwelling to achieve a 6-Homestar rating when using the schedule method, it only needs to achieve compliance with the R-value requirements noted above. However, if aiming for a 7-Homestar rating, at least 1 point from the cooling energy component of the schedule method must be achieved in order to achieve mandatory minimum compliance. Two out of the three of these items must be achieved to award 1 point:

- The solar aperture of each façade of the dwelling is less than 20%.
- For each habitable space, the net openable window area is greater than 5% of the conditioned floor area of that space. Furthermore, at least 30% of the total required openable window area (refer to EHC-2) of the dwelling is located on an opposite/adjacent façade (or dwelling level).
- At least one window in each habitable space is fitted with lockable stays or secure restrictors to allow passive ventilation of at least 10 mm along one edge.

B.5.3 EHC-3 (ventilation)

Homestar v4 has changed the requirements for mandatory minimums when it comes to ventilation from what was previously required in Homestar v2 and v3. Table 89 shows the new requirements for Homestar v4.

Table 89. Homestar v4 EHC-3 ventilation requirements.

EHC-3 compliance items	Points available
Intermittent extract ventilation	
There is a dedicated rangehood for the cooking hob vented to the outside.	0.5
There is a dedicated extraction system for each bathroom vented to the outside and automated to turn off such that the fans run sufficiently long to ensure effective moisture removal (delay timer).	0.5
There is a net openable area of windows to the outside of no less than 5% of the floor area. Windows/openings required for passive ventilation (at least one per room) are constructed in a way that allows them to be. Accessible (ground floor) windows: secured against intruder entry while minimally open (to at least 10 mm along one edge) for background ventilation. All other windows: fixed open to around 10 mm along one edge for background ventilation or Background (trickle) ventilators have been installed in each habitable room in accordance with the areas set out in Building Code clause G4.	0.5

EHC-3 compliance items	Points available
Continuous extract ventilation	
There is a dedicated rangehood for the cooking hob vented to the outside	0.5
A whole-dwelling continuous extract system is installed consisting of extract fans in each bathroom/toilet in accordance with Building Code clause G4. These fans should be set to produce a total of at least 0.35 ach through the entire home. Doors to habitable rooms will require undercut or transfer grille set-up (20 mm high gap under 760 mm wide door if no final finish or 10 mm high if carpeted). Attached garage door to the inside of the dwelling must be sealed on all four edges to minimise the ingress of pollutants.	1.5
Continuous extract ventilation	
A whole-dwelling balanced ventilation system is installed consisting of ducted supply and extract fans. The balance of flow rates for air volume supply and extract must be shown in the design documentation. The ventilation scheme does not require heat recovery and may have a temperature boost to temper the external supply air temperature. Door to habitable rooms will require undercut or transfer grille set-up (20 mm high gap under 760 mm wide door if no final finish or 10 mm high if carpeted). Attached garage door to the inside of the dwelling must be sealed on all four edges to minimise the ingress of pollutants.	2.5
Balanced mechanical ventilation with heat recovery	
A whole-dwelling balanced ventilation system is installed consisting of ducted supply and extract fans. The balance of flow rates for air volume supply and extract must be shown in the design documentation. Door to habitable rooms will require undercut or transfer grille set-up (20 mm high gap under 760 mm wide door if no final finish or 10 mm high if carpeted). Attached garage door to the inside of the dwelling must be sealed on all four edges to minimise the ingress of pollutants.	3
Commissioning of ventilation systems	
Installed ventilation systems are inspected and checked and required volume flow rates for mechanical systems are measured. A report of letter is provided demonstrating that the inspections, checks and testing required by Table 9 of the Homestar Technical Manual has been carried out as a minimum.	1

B.5.4 EHC-4 (surface and interstitial moisture)

Up to 5 points are available in this credit where it is demonstrated that indoor moisture levels have been managed. A dwelling achieving passive dwelling certification is deemed to comply and will achieve the full 5 points. Otherwise, points can be achieved as shown in Table 90.

Table 90. Homestar v4 EHC-4 requirements.

EHC-4 compliance items	Points available
Minimising thermal bridges	3
Minimising condensation within the building envelope	2
Ground cover is provided to all suspended timber floors (points are awarded by default for concrete floors, which are assumed to be impervious)	0.5
Air and vapour control layers are identified on wall and ceiling construction drawings.	1