HN2800/9

Performance of two ‘good practice’ group homes in Rangiora

Final

A report prepared for Beacon Pathway Limited
October 2012

The work reported here was funded by Beacon Pathway Limited and the Foundation for Research, Science and Technology

About This Report

Title

Performance of two 'good practice' group homes in Rangiora

Authors

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Abstract

This report outlines the outcome of engagement with Stonewood Homes Christchurch and the results of monitoring two houses in Rangiora. These houses represent good practice among group builders and are compared to two high performance affordable homes. This report includes the monitoring report from BRANZ.

Reference

Easton, L. and Blackmore, A. (eds). October 2012. Performance of two 'good practice' group homes in Rangiora. Report HN2800/9 for Beacon Pathway Incorporated.

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1 Executive summary

Beacon Pathway Ltd's new home programme engaged with and the Christchurch office of Stonewood Homes, one of New Zealand's largest group home builders, to build two houses to Beacon's HomeSmart Home specifications. This report outlines the outcome of engagement with Stonewood Homes Christchurch and the results of monitoring two houses in Rangiora.

Stonewood Homes chose two houses from Stonewood's Merivale range, being built in a seven home affordable development in Rangiora by the Waimakariri District Council. Although the houses were loosely based on Stonewood's Eco Sure brand, not all options were selected. Additionally, Stonewood were most interested in the thermal comfort/indoor environment quality and energy efficiency aspects of the specification, and focused their efforts on those aspects of the specification. Consequently, the houses were of limited sustainable design, and very similar to each other, the main point of difference being a Firth EnerG wall in one home.

Monitoring assessed the performance of the houses against the HSS® benchmarks for energy and indoor environment quality. The data also allowed some exploration into the temperatures and energy use to see the performance of the EnerG Wall.

1.1.1 Performance of the homes

The average temperatures measured in both houses were above the HSS® benchmark. The relative humidity measurements for both houses were within the HSS® benchmarks. However, both houses exceeded the benchmark level for reticulated energy use.

While both homes are warm and dry in winter, this is achieved at the cost of very high electricity use in the homes, despite the presence of high efficiency heat pumps. In both Rangiora homes essentially a 24 hour heating regime was used with the heat pumps. Additionally, in the case of the Eco Sure home, the heat pump was used for summer cooling as well, which also contributes to the higher electricity use.

This is indicative of the impact of operation on performance – energy efficient heating does not mean energy conservation. The differences between the homes were relatively minor, and the consequent performance difference is likely due to the impact of occupancy.

1.1.2 Inclusion of the EnerG Wall

It was difficult to assess performance of the EnerG Wall given the set-up of the houses and the way the occupants operated them. From the monitoring results of the two houses, it is not possible to conclude that the inclusion of the EnerG Wall in one of the houses has reduced the overall energy use or improved the comfort of the home. However this is not to say that there could be a benefit, but it was not specifically measurable.

1.1.3 Comparative performance

Although the Rangiora homes both had higher living room average temperatures than either the high performance HomeSmart Home or Waitakere NOW Home, these were achieved through 24 hour heating regimes. Consequently, the HomeSmart Home and the Waitakere NOW Home outperform either of the Rangiora homes in terms of energy use. The HomeSmart Home was the star performer in terms of reticulated energy use – even though it reflects energy generated by photovoltaic panels, it is still the lowest electricity user of the four houses when this is discounted.

Summertime temperatures were lower in the Stonewood Rangiora homes than in the NZHF HomeSmart Home and Waitakere NOW Home; however, both households in Rangiora identified discomfort from overheating as an issue.

1.1.4 Good practice homes

The final home designs represent what can be best described as 'good practice' for a group built home (in particular, as relates to solar design and indoor comfort components). Although Stonewood Homes offers Eco Sure options, the extent to which any of these options are included in the final home is entirely at the discretion of the home buyer. These homes are at better end of group builder homes but still perform poorly in comparison with what can be built, particularly noting that both the Waitakere NOW Home and HomeSmart Home were also at the lower end of the market.

Neither home met Beacon's HomeSmart Home specifications which would have improved their performance. Notably, discussions with Stonewood homes revealed a failure to value water efficiency interventions. This may change if Canterbury gets serious about water conservation and/or needs to be self-sufficient in light of earthquakes.

1.1.5 Design improvements

Improved thermal envelope will offset the need for heating. A heat transfer system, taking heat through to the bedrooms will improve their night time temperatures.

As with both the Waitakere NOW Home and HomeSmart Home, consideration needs to be given to summer overheating. The orientation of bedrooms to the west needs better design for shading and cooling so that mechanical cooling is not needed.

Neither Rangiora home used efficient water heating options which. Solar hot water or heat pump hot water systems rather than standard electric hot water cylinders may have reduced energy use.

The design of the EnerG Wall could potentially be improved to optimise the performance of the thermal mass by exposing it to solar radiation and keeping it within the thermal envelope.

2 Introduction

Beacon Pathway is an incorporated society that seeks to transform New Zealand homes and neighbourhoods to be high performing, adaptable, resilient and affordable through demonstration projects, robust research and a collaborative approach to creating change. Beacon's vision is to 'create homes and neighbourhoods that work well into the future without costing the earth'. Beacon Pathway Inc. builds on the work of its original research consortium, Beacon Pathway Ltd.

To assess the sustainability of homes, Beacon Pathway collaboratively developed a set of benchmarks for a high performing home called the HSS High Standard of Sustainability® (See section 4.1)[1], which were tested through the NOW Home programme. In this programme Beacon partnered with other organisations to design and build two demonstration sustainable homes. These homes were 'live' research projects in that their performance was remotely monitored while tenanted by families. They aimed to show that sustainable, affordable and desirable homes can be built now using available design concepts, materials and products. As pilot projects, the two NOW Homes[2], one in Waitakere City and one in Rotorua, led the way for the HomeSmart Homes project.

Based on learnings from the NOW Homes, Beacon developed procedures and guidelines to design a HomeSmart Home. These included specifications to achieve a home which met the HSS® benchmarks. The NOW100 programme[3] commenced to engage with developers and group home builders around New Zealand to use the HomeSmart Home specifications in their new home offerings. The effort to secure partnerships with leading housing companies was only partially successful as the NOW100 programme unfortunately coincided with the downturn in the building and construction industry with the global recession. The impact on the market was significant with the volume of residential building work in New Zealand falling by 40% between September 2007 and September 2009[4] - the period NOW100 was operating.

The NOW100 programme was successful in engaging with two organisations: the New Zealand Housing Foundation, an affordable housing trust, which built a home in Glen Eden using the HomeSmart Home specifications[5]; and the Christchurch office of Stonewood Homes, one of New Zealand's largest group home builders. This report outlines the outcome of engagement with Stonewood Homes Christchurch and the results of monitoring two houses in Rangiora.

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[1] *See for example Easton and Howell (2008)*

[2] *See www.beaconpathway.co.nz/ for further information on NOW Homes.*

[3] *Cowan, Easton & Popping (2010)*

[4] *Statistics New Zealand. Retrieved from www.stats.govt.nz/browse_for_stats/industry_sectors/construction/valueofbuildingwork_mrsep09qtr.aspx*

[5] *Easton (2011)*

3 The Rangiora homes

Stonewood Homes generally operates as a group home contract builder – where homeowners engage Stonewood to build a home for them on a site of the homeowner's choice. However, they have also diversified beyond this model and been involved in at least one land development with some house + land packages being offered for sale. As a result of the downturn of the housing market, they have further diversified their business model, taking on major renovations and building social housing for councils.

Tony Anderson's (Stonewood Christchurch Sales Director at the time) attendance at a Beacon research seminar in Christchurch catalysed his interest in working with Beacon as he was looking for a way to drive greater uptake of their Eco Sure option.

3.1 Stonewood Eco Sure option

Stonewood Homes have developed an Eco Sure option for their range of homes. This is a set of higher spec options that home buyers can choose to apply to any of the ranges of homes offered by Stonewood. These incorporate some aspects found in the Home*Smart* Home specifications and in particular offered energy saving options including higher levels of insulation, double glazing and solar hot water heaters. The extent to which any of these options are included in the final home is entirely at the discretion of the home buyer.

Table 1: Stonewood Eco Sure options[6]

** Optional with extra cost to home buyer*

Eco Sure	HomeSmart Home specifications
Appliances	
■ Moisture sensor clothes dryer * ■ Energy rated dishwasher ■ Energy rated oven ■ Front loading washer (water saving) *	■ All supplied whiteware appliances with 4 or more stars in energy rating. ■ AAAA-rated washing machine ■ Energy rated fridge freezer * ■ Other energy rated appliances
Windows	
■ Double glazing ■ Argon gas filled double glazing * ■ Low e glass / tint / laminated glass * ■ Thermal breaks to windows *	■ Double glazed, [IGU Clear] low emissivity windows in climate zone 3. ■ Vented window sashes * ■ Sealed weather strips to all exterior doors ■ Insulated front door

■

[6] www.stonewood.co.nz/ecosure accessed 7 October 2011

Insulation	
■ Upgraded insulation to ceiling ■ Upgraded insulation to exterior walls ■ Foundation perimeter insulation ■ Under floor insulation * ■ Breathable house wrap ■ Building envelope openings taped & sealed ■ Hot water cylinder wrap * ■ Sealed plug sockets and frame to plate joins *	■ R 4.6 insulation in ceiling. ■ R 2.6 insulation in walls. ■ R1.7 expanded polystyrene insulation under the floor slab, footing and up the exterior of the slab or floor R value of 2.5. ■ Insulated slab on ground floor, which in solar exposed areas is tiled or polished i.e. NOT covered in carpet or lino. ■ Full garage insulation including garage doors *
Heat	
■ Passive and active solar design ■ Heated towel rails * ■ Full height doors for passive heat transfer ■ Under floor in-slab heating * ■ Under tile heating pads * ■ Night store space heating * ■ Gas fireplace * ■ Preferential sun north alignment ■ Fully installed heat pump with programmable thermostat ■ Heat transfer system *	Options ■ heat-pump: with an Energy Star rating of at least 5 for both heating and cooling cycles ■ solid fuel heating: Ministry for the Environment approved wood or pellet burners ■ under-floor heating utilising solar hot water system ■ ground-sourced heat pump system.
Water	
■ Adjustable flow restrictors to tap-ware ■ Dual flush toilet cisterns (ceramic) ■ Solar water heating with electronic management ■ Dishwasher is water rated for efficiency ■ Water heater within 12m of the kitchen ■ Front loading washer (water saving) * ■ Automated garden irrigation * ■ Rain water storage for garden reuse * ■ Under sink hot water storage *	■ Rainwater collection and reticulation system to supply toilets, washing machine and garden use (minimum 4500L tank) OR ■ Combination greywater and rainwater system (greywater supplying garden, rainwater indoor uses). ■ AAA-rated [or equivalent WELS] shower, taps and toilet. ■ Water meter for each dwelling. ■ AAA dishwasher if supplied.
Energy	
■ Night rate water heating * ■ Solar energy enhancement and water heating ■ Dual electric HWC elements ■ Heat pump hot water heater * ■ Low Energy account guarantee * ■ Water heater within 12m of the bathrooms it services	■ Solar-gas hot water, solar-electric hot water, or heat pump hot water system OR ■ A low emissions wetback or ground source hot water heat pump system.

Air Quality	
■ Air exchange management system * ■ Low VOC (volatile organic compound) paints not to exceed 150 grams per litre ■ Low VOC hard flooring ■ E zero finishing timbers ■ Granite benches* ■ Low VOC construction adhesives ■ Non CFC or HCFC heating system ■ Solvent base not to exceed 380 grams per litre ■ Dryer is vented to the exterior * ■ Range hood vented to exterior ■ Ventilation fans to bathrooms ■ Formaldehyde free materials used or specifically sealed ■ Carbon monoxide detector * ■ Smoke detectors	■ Low toxicity products and materials are used, especially considering VOC content (such as in flooring material, wood based furniture, paints, glues and sealants, carpets). ■ Environmental Choice certified products and materials are used if these are available for the product/ materials class. ■ No air conditioning/comfort cooling systems are installed. ■ Extraction fans in bathrooms and ensuites (externally vented). ■ Range hood in kitchen (externally vented). ■ Passive vents in bedrooms and living spaces. ■ Natural ventilation over 5% of floor area
Lights	
■ Recessed lights are sealed type ■ Halogen lighting * ■ Energy efficient lighting system and products ■ LED lighting *	■ No artificial lighting needed from 9am-4pm year-round. ■ 85% of lights must be CFLs or LED. ■ No recessed lighting

3.2 Engagement with Stonewood Homes

After initially considering the HomeSmart Home specification for the larger more costly homes, Stonewood decided it was more logical to focus on their Merivale range, a smaller affordable range of houses, some of which were being built in a new subdivision in Rangiora. Stonewood were most interested in the thermal comfort/indoor environment quality and energy efficiency aspects of the specification, and focused their efforts on those aspects of the specification. Beacon's project manager felt that the value of continuing the engagement with Stonewood was worth pursuing a project which would have only a limited element of sustainable design, and agreed to work with Stonewood on the thermal aspects of the design.

Beacon's project manager also brought Firth to the table with Stonewood, as they were interested in trialling a new type of thermal wall they had developed (the Firth EnerG Wall) which they believed would give significant thermal mass benefits to houses which incorporated it.

In order to assist with options analysis for the thermal design, initial HERS (Home Energy Rating Scheme) thermal modelling, commissioned by Beacon, was conducted in August 2008. The standard house rated 4.5 stars and modelling suggested that the interventions required to bring the house to a HERS 6 star thermal performance rating were very straightforward and that the Firth EnerG Wall would provide a technology which could assist with this.

A seven home affordable development in Rangiora by the Waimakariri District Council was identified by Stonewood as providing a good opportunity to test some different thermal options with almost identical design and orientation. The houses were built for, and are now owned by the District Council and are rented as part of their low income rental housing scheme.

However, as the discussions on the project progressed, the number of additional Eco Sure spec features in the homes was reduced. The final home designs represent what can be best described as 'good practice' for a group built home (in particular, as relates to solar design and indoor comfort components), with one home featuring the Firth EnerG Wall as a demonstration of potential thermal mass benefits.

Two houses were ultimately used for this research, one with Eco Sure design features (referred to as the Eco Sure home) and the other with the additional experimental thermal mass wall being trialled by Firth (referred to as the EnerG Wall home). A third house was originally proposed as a control but by the time the houses were constructed, it was clear that the differences between the houses were relatively minor (and related only to thermal aspects) compared with the likely impact of occupancy. Consequently, monitoring of this third house was not undertaken.

Stonewood received a final unconditional approval to progress with this development on 12 March 2009. Construction commenced in mid April 2009. The houses were completed in September 2009 and tenanted from October 2009.

3.3 Engagement with Firth

Firth agreed to participate in the project by trialling a passive high mass internal wall that, when modelled, contributed a HERS 1 star improvement in the house's thermal performance.

The EnerG Wall is a 90mm concrete block wall lined on both sides with the purpose of acting as a thermal mass, i.e. absorbing heat when the air temperature is higher than the concrete temperature and then release the heat when the air temperature lowers. The EnerG Wall differs from a more standard thermal wall design in that it is lined (in this case with plasterboard) and does not need to be located in an area receiving direct heat from either solar gain via windows or from an adjacent radiant heat source such as a wood burner.

3.4 Engagement with Waimakariri District Council

Stonewood Homes undertook the direct liaison with Waimakariri District Council over the project, seeking their approval for the key design elements and additional features. Records of the discussions unfortunately were not kept, and during the construction period the Council liaison person left, with a new staff member, who was unfamiliar with the project, taking over the liaison role.

3.5 Resulting design of Rangiora homes

3.5.1 Design and layout

Both houses are from Stonewood's Merivale range and include some Eco Sure design specifications. Both are three bedroom homes with a $142m^2$ footprint. The key difference between the homes is that one includes the EnerG Wall (shown as the red lines on the EnerG Wall house plan)

The houses were built on opposite sides of the same road in Rangiora (EnerG Wall and Eco Sure home respectively). To compensate for the north-south street orientation, the floor plans were mirrored so the living rooms of both houses faced north. The EnerG Wall house received a 6 star HERS rating and the Eco Sure house received a 4.5 star HERS rating when modelled on AccuRate.

Figure 1: Rangiora house plans (left EnerG Wall, right Eco Sure)

Figure 2: EnerG Wall home

Figure 3: Eco Sure home

The main bedroom of the EnerG Wall home was located on the western side, with west-facing glazing receiving the evening sun. The main bedroom in the Eco Sure home was east-facing with east-facing glazing receiving morning sun. Heat pumps were installed in both houses in the living rooms on the northern side.

Table 2 provides a summary of the variance between the designs of the Rangiora homes and the HomeSmart Home specifications.

Table 2: Comparison between Rangiora homes and HomeSmart Home Specification

HomeSmart Home Specification	Rangiora Eco Sure home	Rangiora EnerG Wall home
Thermal Envelope – 6 Star HERS	Ribraft floor Maximum insulation specified but actual R value not known by Beacon project team. Double glazing. HERS 4.5 Star	Ribraft floor R 2.4 wall insulation R 3.2 ceiling insulation Double glazing Firth EnerGWall HERS 6 Star
Hot water system – 6 star HERS OR Solar hot water OR Hot water heat pump	Rheem 250 litre high pressure electric hot water cylinder	Rheem 250 litre high pressure electric hot water cylinder
Lighting – natural, energy efficient, no thermal compromise	CA rated downlights used throughout	CA rated downlights used throughout
Fixed heating – 6 star HERS. Designed for home to meet HSS temperature benchmarks	Heat pump – no HERS Assessment of heating system	Heat pump – no HERS Assessment of heating system
Appliances 4 star energy Efficiency	Not known	Not known
Outdoor clothesline, any dryer vented outside	Space for dryer in garage next to washing machine. No venting provided. Not known if clothesline provided.	Space for dryer in garage next to washing machine. No venting provided. Not known if clothesline provided.
Maximum dwelling size ■ 165m^2 for 2 bedroom	142.01 m^2 for 3 bedroom house	142.01 m^2 for 3 bedroom house

HomeSmart Home Specification	Rangiora Eco Sure home	Rangiora EnerG Wall home
■ 180m² for 3 bedroom ■ 200m² for 4 bedroom ■ 222m² for 5 bedroom home.		
No presence of mould rating is achieved using the ALF 3.2 ventilation section for all areas (i.e. kitchen, bathroom, ensuite, bedroom, living space).	ALF 3.2 not tested Bathroom extract ventilation, kitchen rangehood present.	ALF 3.2 not tested Bathroom extract ventilation, kitchen rangehood present.
All wet area rooms with openable windows	Openable window in bathroom and living areas. Laundry in garage with external door, no window.	Openable window in bathroom and living areas. Laundry in garage with external door, no window.
Low toxicity products & materials – VOC low	Environmental Choice certified finishes and paints used.	Environmental Choice certified finishes and paints used.
Environmental Choice certified materials	Unknown	Unknown
No comfort cooling system	Heat pump located in living area – able to be used for summer cooling.	Heat pump located in living area – able to be used for summer cooling.
3 star WELS rated shower, taps & toilet	Unknown.	Unknown
Water meter	None	None
4 star WELS rated washing machine	Unknown	Unknown
3 star WELS rated dishwasher	Unknown	Unknown
Alternative water source washing machine, toilets and garden	Not present	Not present
A maximum of 2.6 tonnes per house or 16kg/m² of construction waste	Unknown	Unknown
Waste Management Plan in accordance with REBRI	Not undertaken	Not undertaken
Space in kitchen for organic waste – 5 litres	Unknown	Unknown
Space for recycling bins -20 litres	Sufficient space but no bins provided	Sufficient space but no bins provided
Space for compost	Sufficient space but no bins provided	Sufficient space but no bins provided
House Manual provided	Standard Stonewood Homes Manual	Standard Stonewood Homes Manual

4 House performance monitoring

BRANZ was engaged to monitor the thermal performance of both Rangiora homes[7]. Each home had a similar design but differed in the level of thermal mass. The thermal performance was assessed against the benchmarks set in Beacon's HSS High Standard of Sustainability® (HSS®). The hypothesis for this research was that the house with a higher level of mass would provide greater thermal comfort without using more energy. The houses were also considered to represent an example of 'good practice' from the group home sector. The research also sought to see how this good practice was manifested in house performance.

4.1 The HSS® Benchmarks

The HSS High Standard of Sustainability® (HSS®) is a set of benchmarks which a high performing home should reach. It sets benchmarks in five key performance areas:

1) Energy
2) Water
3) Indoor environment quality
4) Waste
5) Materials

Beacon has designed the benchmarks to be a realistic set of targets by which homeowners are able to measure their home's performance.

The HSS® benchmarks[8] relevant to this research are:

Criteria	Benchmark
Energy use (Climate Zone 3)	7300 kWh/yr
Average temperature Living room, 5-11pm in winter	18°C
Average temperature Bedroom, 11pm – 7am in winter	16°C
Average relative humidity Living room, 5-11pm in winter	40-70%
Average relative humidity Bedroom, 11pm – 7am in winter	40-70%

4.2 Method

Indoor temperatures and relative humidity were monitored in both houses using I-button[9] sensors in each living room and main bedroom (Bedroom 1). Monitoring was undertaken at 30 minute intervals from March 2010 to March 2011.

[7] *Burrough et al. (2011)*
8 *http://www.beaconpathway.co.nz/being-homesmart/article/the_benchmarks*
9 *I-buttons are made by Maxim (www.maxim-ic.com/products/ibutton)*

As both houses were all electric, billing records were used for collecting energy use data. The occupants were interviewed for anecdotal evidence as to their heating and cooling schedules.

4.2.1 Occupants and lifestyle

The occupants of the houses could be categorised in the same group, both being families of two parents with young children: three children in the case of the EnerG Wall home and two children in the Eco Sure home.

Through an interview with the occupants of each of the houses, the heating and cooling schedules were reported.

Heat pumps were used in both houses and both were set on a 24 hour schedule. The EnerG Wall home's heating schedule was set overnight and during the middle of the day at 18°C, then increased to 22°C from 7am to 9am, then again from 3pm until approximately midnight. The Eco Sure home's heating schedule was set overnight at 18°C, then increased to 25°C from 6am until about 10pm.

The EnerG Wall occupants stated that although the house felt overheated in summer, they did not use the heat pump for cooling. The Eco Sure home occupants used the heat pump for cooling as well as heating.

4.3 Results

4.3.1 Daily temperature profiles

The following chart (Figure 4) gives the average daily profiles for the living room in both the houses by month.

The profile information shows, via the gradient of the curve, how quickly (or slowly) the houses are heating up in the morning and cooling down in the evening. The difference between the peak and trough shows the average temperature variation occurring over the 24 hour period. This information can assist in understanding whether the extra thermal mass has changed the performance of the EnerG Wall home, compared to the Eco Sure home.

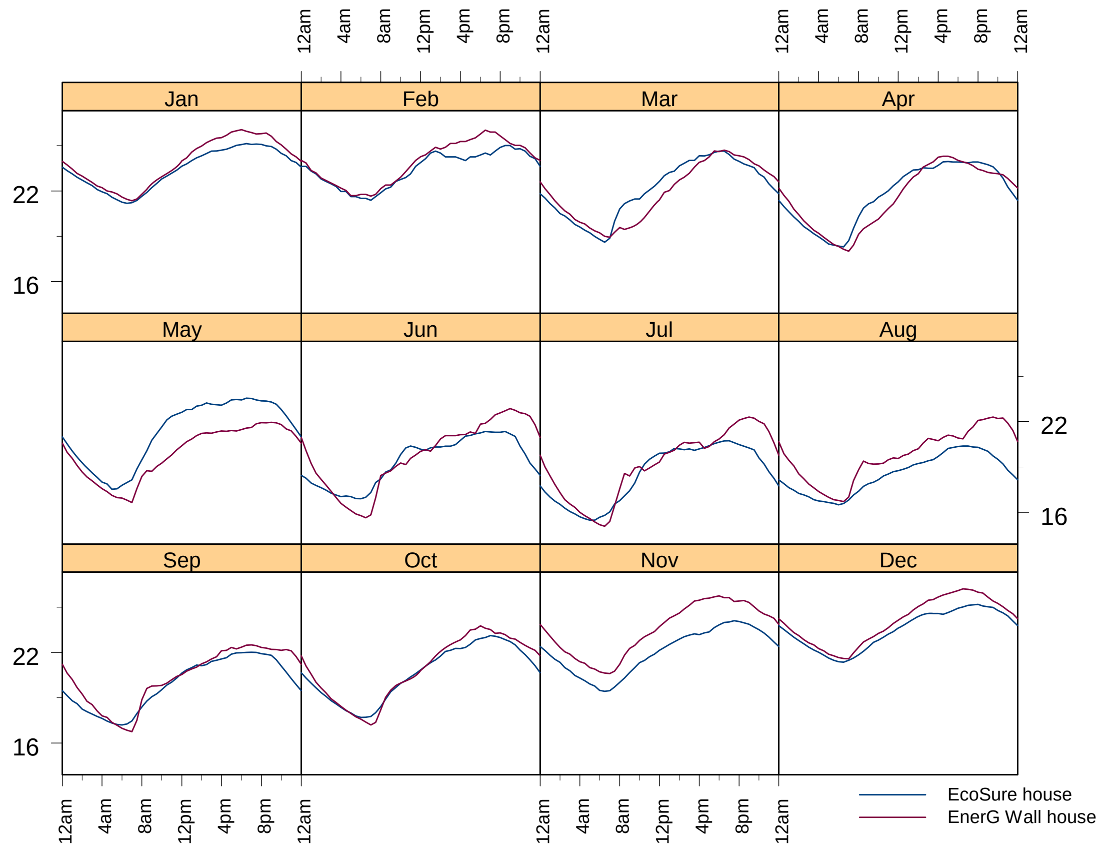

Figure 4: Average daily profiles for living room temperature by month

Both houses have similar average profiles. In summer the EnerG Wall home appears to hold heat for longer and temperatures do not drop as low as the Eco Sure home, which may be due to the extra thermal mass. However, during September and October, the temperature in the EnerG Wall home drops slightly lower than the Eco Sure house. This may be due to operation of the house as the Eco Sure home occupants actively heated more during these months. The effect of thermal mass during the winter heating months is hidden due to the 24 hour heating schedule of the occupants. For both houses, the maximum temperatures are reached late in the afternoon and early evening at a similar time to what was found in the HEEP houses[10].

The following chart (Figure 4) gives the average daily profiles for the main bedroom in the two houses by month. The bedrooms both face different compass directions – the Eco Sure home's main bedroom faces east with the EnerG Wall bedrooms facing west. The time and amount of solar gains will therefore differ between the houses. Neither house uses heaters in their bedroom, nor is there any heat transfer system.

[10] *Isaacs et al (2010)*

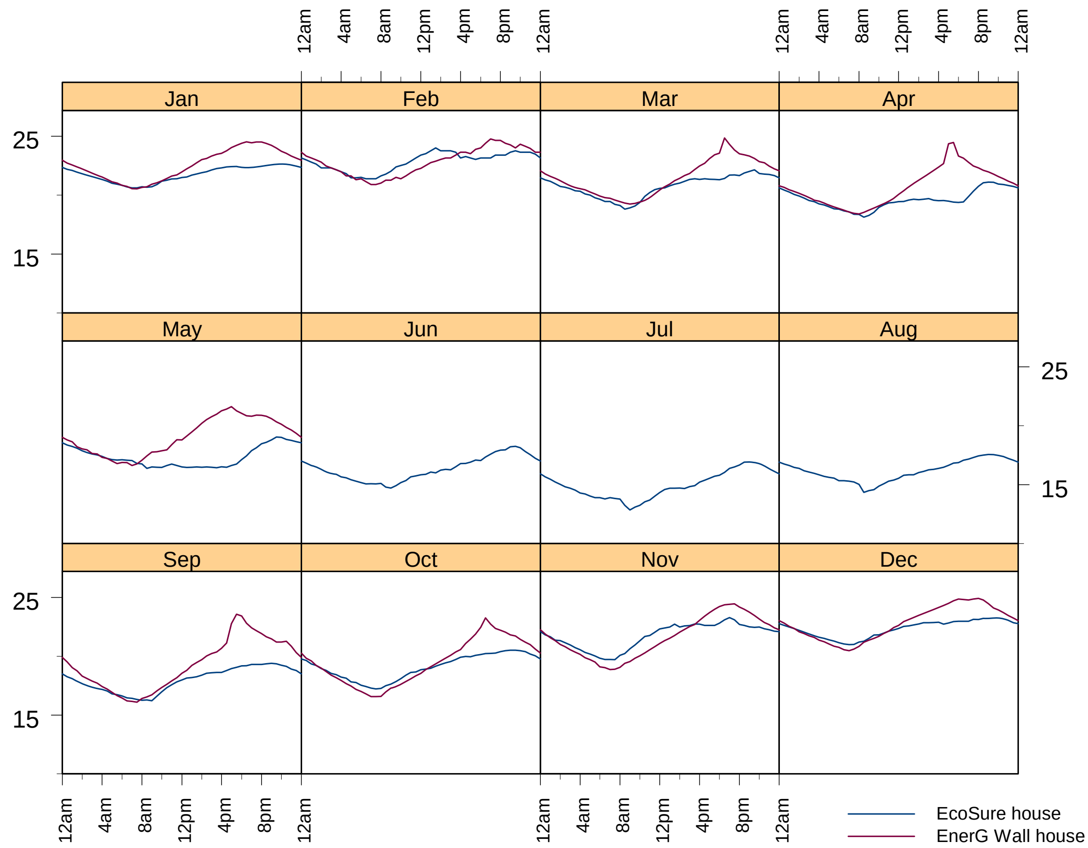

Figure 5: Average daily profiles for bedroom temperature by month

The Eco Sure home's east-facing bedroom will have solar gains in the morning that will not be as strong as the solar gains in the afternoon/evening that the EnerG Wall home's west-facing bedroom will receive. As anticipated, the average temperature in the EnerG Wall bedroom is higher than the Eco Sure house due to the afternoon/evening solar gains. The EnerG Wall home's bedroom profile has a strong peak in the afternoon from the solar gain, whilst the Eco Sure home's bedroom daily temperature profile has less variation over the 24 hours. For most months through the year the Eco Sure home's bedroom does not reduce in temperature as quickly as the EnerG Wall home, primarily because of its orientation.

4.3.2 Average temperatures

The following table (Table 3) gives the average temperatures by month for both the living room and main bedroom in each of the two houses.

For both houses, the average temperatures in the living room through the year can be considered both healthy (above 18°C) and comfortable (between 20°C and 25°C)[11]. They also meet the benchmarks of the HSS High Standard of Sustainability® which sets an average living room temperature of 18°C between 5-11pm in winter.

Ideally the bedroom temperatures should be above 16°C between 11pm-7am in winter to meet the benchmarks of the HSS High Standard of Sustainability®[12] and for good health. The Eco Sure home only goes below this for the coldest month of the year. Data gaps for the coldest months of the year for bedroom in the EnerG Wall home meant it is not possible to confirm average temperatures in the bedrooms. However, for the rest of the year, the average temperatures are very similar to the Eco Sure home. Given the EnerG Wall home's bedroom receives afternoon/evening solar gains, it is likely the temperatures will be the same or higher than the Eco Sure home during the coldest months.

Table 3: Living room and bedroom average temperature by month

	Living room (°C)		Bedroom (°C)	
	Eco Sure home	**EnerG Wall home**	**Eco Sure home**	**EnerG Wall home**
Jan	23.4	23.9	21.8	22.6
Feb	23.4	23.9	22.9	22.8
Mar	22.1	21.9	20.8	21.5
Apr	21.8	21.6	19.7	20.7
May	21.3	19.9	17.4	19.1
Jun	19.4	19.8	16.4	
Jul	18.5	19.2	15.0	
Aug	18.5	19.8	16.2	
Sep	19.9	20.4	18.0	19.3
Oct	20.6	20.9	19.1	19.5
Nov	22.0	23.5	21.7	21.6
Dec	23.5	24.1	22.3	22.8

[11] *WHO (1987); French et al (2007)*
[12] *WHO (1987)*

Further tables showing the maximum and minimum temperatures and average, maximum and minimum relative humidity are in Appendix A – Temperature and relative humidity tables. There are also tables giving the time of day the maximum and minimum temperatures are reached.

4.3.3 Energy use

Energy use data was received from the electricity companies for each house. Meter readings were taken every second month and daily energy use calculated by averaging units used across the two-monthly period (Figure 6). The houses use only electricity.

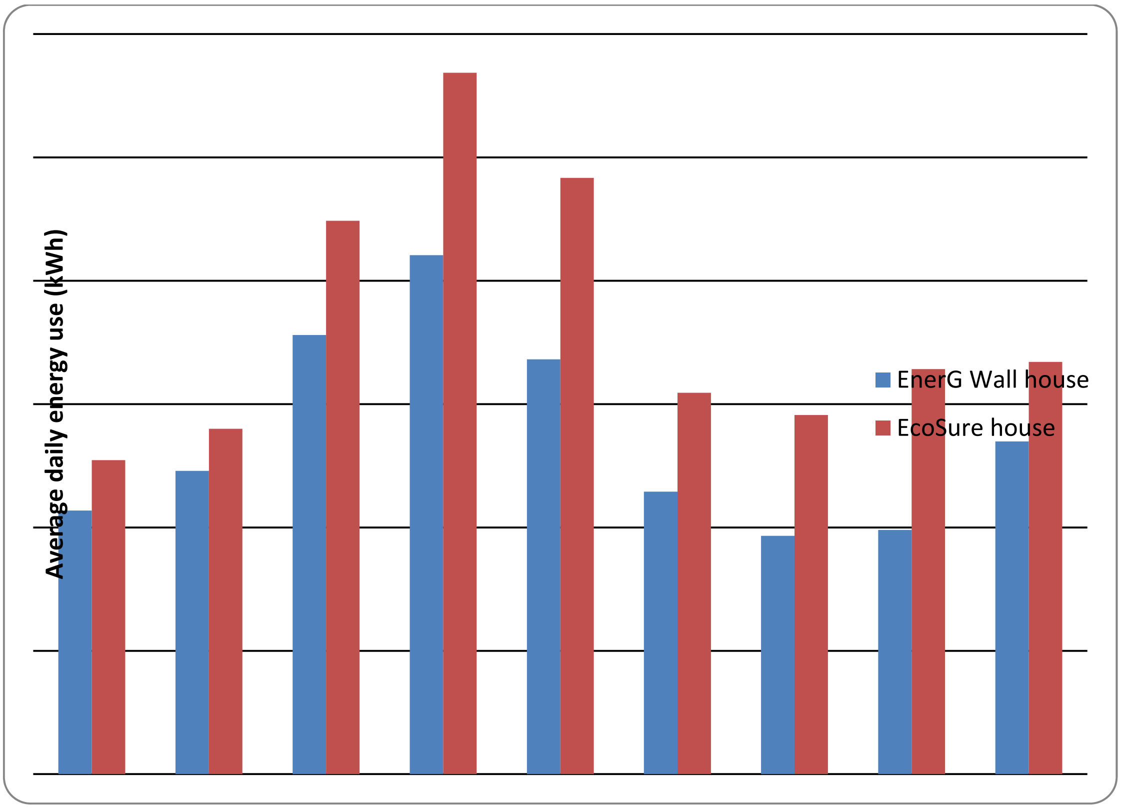

Figure 6: Average daily energy use

For both houses, the average energy use per day follows a typical seasonal pattern, with lower use in summer, and higher use in winter. Heating needs and extended periods of lighting would account for the increased use in winter.

The higher energy use in the 2010/2011 summer may have resulted from the need for cooling as recorded temperatures were higher than in the 2009/2010 summer[13].

The highest average energy use per day was in June/July with 42 kWh for the EnerG Wall home and 57kWh for the Eco Sure home.

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[13] *National Climate Centre (2010 and 2011)*

Through the whole year, the Eco Sure home consumes more energy than the EnerG Wall home. It is not possible to determine if this is due to the EnerG wall as the occupants of the houses use energy differently. Varying comfort preferences resulted in differences in use of the heat pump for cooling and heating through the year, use of windows and coverings, hot water consumption and different entertainment appliances.

4.3.4 Annual energy use

The EnerG Wall house used approximately 10,800 kWh of energy for the year. This is higher than the HSS® benchmark of 7,300kWh for new houses in Zone 3, but slightly lower than the HEEP[14] average household energy use of Christchurch households of 11,010kWh[15].

By comparison the Eco Sure house used approximately 14,400 kWh of energy. This is nearly double the HSS® benchmark of 7,300kWh and well above the HEEP Christchurch average energy use of 11,010kWh.

4.3.5 Assessment against HSS® benchmarks

When the Rangiora homes were assessed against the HSS® benchmarks for indoor environment quality and energy use, the houses were successful for most indoor environment quality criteria but not all.

The average temperatures measured in both houses were above the HSS® benchmark. The relative humidity measurements for both houses were within the HSS® benchmarks. However, both houses exceeded the benchmark level for reticulated energy use.

Table 4: Rangiora houses assessed against relevant HSS® benchmarks

Criteria	Benchmark	EnerG Wall home	Eco Sure home
Energy use (Climate Zone 3) 16	7,300 kWhr/yr	10,800 kWh/yr	14,400 kWh/yr
Temperature (Living room)	Average 18°C 5-11pm in winter	22.0°C	21.0°C
Temperature (Bedroom)	Average 16°C 11pm-7am in winter	17.7°C	16.3°C
Relative humidity (Living room)	Average 40-70% 5-11pm in winter	48%	51%

14 The Household Energy End-Use Project (HEEP) measured the way energy is used in New Zealand households.
15 Isaacs et al (2010)
16 http://www.beaconpathway.co.nz/being-homesmart/article/the_benchmarks

Criteria	Benchmark	EnerG Wall home	Eco Sure home
Relative humidity (Bedroom)	Average 40-70% 11pm-7am in winter	60%	66%
IEQ checklist	Mechanical extract ventilation of kitchen, bathroom and laundry	Yes	Yes
IEQ checklist	Means to passively vent dwelling	Yes	Yes
IEQ checklist	No unflued gas heaters	Yes	Yes
IEQ checklist	Damp proof membrane under house	Yes	Yes
IEQ checklist	No indoor clothes drying	No covered washing line provided	No covered washing line provided
Winter has been taken as May to September RH data for both houses is based on May for winter months While some data was absent for both houses, the data we have (temperatures and relative humidity at the other times of year, as well as the energy use through winter and confirmation from occupants) lead to confidence that the houses will still reach average relative humidity and temperature benchmarks throughout winter.			

4.4 Discussion

4.4.1 Energy and IEQ performance

Energy use in the houses was average to above average for a typical Christchurch house with neither house meeting the HSS High Standard of Sustainability® benchmarks for reticulated energy. User behaviour is clearly a major factor in relation to this, as the heat pump settings in both homes were greater than required for good health or a generally accepted level of comfort. In the HEEP research[17] one third of energy use was for hot water use, therefore, in terms of additional technology to reduce reticulated energy use, the biggest impact would be to change to a solar or heat pump hot water system. A well installed and specified system could potentially save 3,000 kWh per year.

The houses are both well heated and meet the IEQ benchmarks; however, the reliance on electrical heating through heat pumps – where user discretion is very large and are also able to be used for cooling - can make it less likely that the energy benchmarks will be achieved. Use of a low emission wood burner or pellet burner as the primary heating source, combined with a

17 Isaacs et al (2010)

heat transfer system, would be an obvious way to reduce the reticulated energy use within the home.

Heating energy use could also be reduced by including higher insulation R values in ceiling and walls, full underfloor insulation (with rib raft flooring, the floors in these homes would have been very poor performers), and higher thermally performing glass and window frames. It is important to ensure all appliances are energy efficient, especially Energy Star rated where applicable, including the heat pump.

External shading would benefit both houses to reduce maximum temperatures and therefore the need for mechanical cooling.

4.4.2 Thermal mass

The EnerG Wall is designed to act as thermal mass. Thermal mass acts as a buffer to reduce temperature variations, absorbing heat and releasing it when the ambient temperature is lower than that of the thermal mass. One key benefit of thermal mass is a lower daily temperature range. This means the difference between the lowest and highest daily temperatures is reduced or smoothed out[18]. Unusually for thermal mass, the wall is not located in an area where it will receive radiant heat (such as from solar gain or a wood burner) and the wall is lined with plasterboard. The wall was also combined with a rib raft type concrete floor (which has less thermal mass than a conventional slab concrete floor) which was also not exposed to direct sun.

When examining the results of the two houses, it seems the EnerG Wall home has a similar or higher daily temperature range in both the main bedroom and living room throughout the year (Figure 4 and Figure 5). This is counter-intuitive to expectations.

The impact of thermal mass as an energy saving feature is very difficult to measure and determine in practice. The impact of the EnerG Wall is overshadowed by the 24 hour heating schedules – the occupants' choice of heating schedules dominates the measured performance and therefore it is not possible to determine any specific benefit of the EnerG Wall. One way of better determining the impact of the EnerG Wall would be to test the heat loss from both houses when empty – a test commonly used by Professor Bob Lloyd's energy research team at Otago whereby the houses are sealed, heated up to a standard temperature and then the heat loss monitored over a 24 hour period.

The effectiveness of thermal mass depends on whether it is exposed or covered (exposed mass will absorb and release heat quicker), the placement within a home and the amount (volume). In general, there is potential to add thermal mass to a typical New Zealand house, as typically the only thermal mass is in the floor and is often covered with carpet so is ineffective.

[18] ***Donn & Thomas (2010)***

The design of the EnerG Wall could potentially be improved to optimise the performance of the thermal mass. Some design improvements are:

- Maximise the exposure to solar radiation by way locating the wall closer to the external environment (in this case the walls were situated deep within the building)
- Leave the surface exposed (in this case the wall was lined with plasterboard)
- Locate the wall within the insulated envelope of the house (in this case one wall backed onto an unconditioned space, the garage).

4.4.3 HERS ACCURATE Rating

The EnerG Wall home received a 1.5 star increase in HERS rating over the Eco Sure home, due to the presence of thermal mass. It's not clear from this research that this increase is warranted in terms of increased thermal performance– rather than just an artefact of the model which does not take into account either solar gain, or the effect of exposure vs covering of the thermal mass.

5 Comparison with other monitored homes

This section compares the Rangiora homes' performance with monitoring data from the Waitakere NOW Home and the NZ Housing Foundation's HomeSmart Home, both built as high performance affordable homes. The Rangiora homes represent what is delivered by the group home market – albeit at the better end of the scale with these homes having good solar design and efficient heating.

5.1 Physical monitoring comparison

Overall of the four houses, the HomeSmart Home was the best performer in relation to the key performance areas looked at by Beacon. Table 5 below compares the performance across the four homes.

Table 5: Physical monitoring data from the Eco Sure home, the EnerG Wall home, HomeSmart Home, and the Waitakere NOW Home

	Rangiora Eco Sure* home	Rangiora EnerGWall* home	NZHF HomeSmart Home	Waitakere NOW Home¥
Number of occupants	4	5	6	4
Annual reticulated energy use	14,400 kWh/yr	10,800 kWh/yr	3890kWh/year	7400 kWh/year
Average winter living room evening temperature	21°C	22°C	19°C	20.3°C
Average winter bedroom overnight temperature	16.3°C	17.7°C	18°C	19.1°C
Average living room relative humidity	51%	48%	62%	57%
Average bedroom relative humidity	66%	60%	62%	60%

*Due to the greater heating demand in the South Island, the HSS benchmark for reticulated energy use in Rangiora is 7300 kWh/year

¥Year 1 data for Waitakere NOW Home® is shown[19].

Both Rangiora homes were expected to perform more poorly than the high performance Waitakere NOW Home and HomeSmart Home, and received HERS ratings of 4.5 (Eco Sure home) and 6 (EnerG Wall home respectively). They also had standard electric hot water cylinders for water heating, and included heat pumps for space heating.

[19] *French et al. 2007*

As can be seen from the data, both the Waitakere NOW Home and the HomeSmart Home outperform either of the homes in terms of energy use. The HomeSmart Home was the star performer in terms of reticulated energy use –even though it reflects energy generated by photovoltaic panels it is still the lowest electricity user of the four houses when this is discounted. This reflects a combination of house factors as well as undoubtedly careful energy management by the occupants. Key features which contributed to the HomeSmart Home performance being substantially better than the Rangiora homes are:

- Very high performing thermal envelope (ceiling and wall insulation and windows were considerably superior to those used in the Rangiora homes)
- Careful passive solar design to minimise heating requirements
- Auckland's warmer climate resulting in a shorter heating season
- Heat pump hot water system
- Absence of cooling equipment

While the Rangiora homes are also warm and dry in winter, this is achieved at the cost of very high electricity use in the homes, despite the presence of high efficiency heat pumps. In both Rangiora homes essentially a 24 hour heating regime was used with the heat pumps. Despite this, the winter overnight temperatures in the bedrooms were lower than in the NZHF HomeSmart Home where no heating occurred. The lower relative humidity averages in the living rooms for the Rangiora homes will be a direct reflection of the higher average temperatures – as well as the drier winter climate in Rangiora.

Summertime temperatures were lower in the Rangiora homes than in the HomeSmart Home and Waitakere NOW Home; however, both households in Rangiora identified discomfort from overheating as an issue. In the case of the Eco Sure home, the heat pump was used for summer cooling as well, which is also a contributor to the higher electricity use.

Data from the Waitakere NOW Home also shows that, like the HomeSmart Home, the house was uncomfortably hot at times over summer[20]. Both homes have large northern windows and extra insulation, and while these have resulted in excellent winter performance, they make the need for effective shading and ventilation in summer more important. This is an area where more care in design is clearly needed.

Another issue is that although these homes had overheating problems, they all received good ratings: The HomeSmart Home received an 8 star HERS rating, and the Rangiora homes received 4.5 stars and 6 stars respectively. It seems neither HERS nor ALF (and now Homestar) deal with overheating issues adequately.

[20] ***Pollard et al. (2008)***

6 Conclusions

Monitoring assessed the performance of the houses against the HSS® benchmarks for energy and indoor environment quality. The data also allowed some exploration into the temperatures and energy use to see the performance of the EnerG Wall.

6.1.1 Performance of the homes

The average temperatures measured in both houses were above the HSS® benchmark. The relative humidity measurements for both houses were within the HSS® benchmarks. However, both houses exceeded the benchmark level for reticulated energy use.

Table 6: Rangiora houses assessed against relevant HSS® benchmarks

Criteria	Benchmark	EnerG Wall home	Eco Sure home
Energy use (Climate Zone 3) [21]	7,300 kWhr/yr	10,800 kWh/yr	14,400 kWh/yr
Temperature (Living room)	Average 18°C 5-11pm in winter	22.0°C	21.0°C
Temperature (Bedroom)	Average 16°C 11pm-7am in winter	17.7°C	16.3°C
Relative humidity (Living room)	Average 40-70% 5-11pm in winter	48%	51%
Relative humidity (Bedroom)	Average 40-70% 11pm-7am in winter	60%	66%

While both homes are warm and dry in winter, this is achieved at the cost of very high electricity use in the homes, despite the presence of high efficiency heat pumps. In both Rangiora homes essentially a 24 hour heating regime was used with the heat pumps. Additionally, in the case of the Eco Sure home, the heat pump was used for summer cooling as well, which also contributes to the higher electricity use.

This is indicative of the impact of operation on performance – energy efficient heating does not mean energy conservation. The differences between the homes were relatively minor, and the consequent performance difference is likely due to the impact of occupancy.

21 http://www.beaconpathway.co.nz/being-homesmart/article/the_benchmarks

6.1.2 Inclusion of the EnerG Wall

It was difficult to assess performance of the EnerG Wall given the set-up of the houses and the way the occupants operated them. From the monitoring results of the two houses, it is not possible to conclude that the inclusion of the EnerG Wall in one of the houses has reduced the overall energy use or improved the comfort of the home. However this is not to say that there could be a benefit, but it was not specifically measureable.

6.1.3 Comparative performance

Although the Rangiora homes both had higher living room average temperatures than either the high performance HomeSmart Home or Waitakere NOW Home, these were achieved through 24 hour heating regimes. Consequently, the HomeSmart Home and the Waitakere NOW Home outperforms either of the Rangiora homes in terms of energy use. The HomeSmart Home was the star performer in terms of reticulated energy use – even though it reflects energy generated by photovoltaic panels, it is still the lowest electricity user of the four houses when this is discounted.

Despite the heating regime, the winter overnight temperatures in the bedrooms were lower in the Rangiora homes than in either the Waitakere NOW Home or the HomeSmart Home where no heating occurred.

The lower relative humidity averages in the living rooms for the Stonewood Rangiora homes will be a direct reflection of the higher average temperatures – as well as the drier winter climate in Rangiora.

Summertime temperatures were lower in the Stonewood Rangiora homes than in the NZHF HomeSmart Home and Waitakere NOW Home; however, both households in Rangiora identified discomfort from overheating as an issue.

6.1.4 Good practice homes

The final home designs represent what can be best described as 'good practice' for a group built home (in particular, as relates to solar design and indoor comfort components). Although Stonewood Homes offers Eco Sure options, the extent to which any of these options are included in the final home is entirely at the discretion of the home buyer. These homes are at better end of group builder homes but still perform poorly in comparison with what can be built, particularly noting that both the Waitakere NOW Home and HomeSmart Home were also at the lower end of the market.

Neither home met Beacon's HomeSmart Home specifications which would have improved their performance. Notably, discussions with Stonewood homes revealed a failure to value water efficiency interventions. This may change if Canterbury gets serious about water conservation and/or needs to be self-sufficient in light of earthquakes.

6.1.5 Design improvements

Improved thermal envelope will offset the need for heating. A heat transfer system, taking heat through to the bedrooms will improve their night time temperatures.

As with both the Waitakere NOW Home and HomeSmart Home, consideration needs to be given to summer overheating. The orientation of bedrooms to the west needs better design for shading and cooling so that mechanical cooling is not needed.

Neither Rangiora home used efficient water heating options which. Solar hot water or heat pump hot water systems rather than standard electric hot water cylinders may have reduced energy use.

The design of the EnerG Wall could potentially be improved to optimise the performance of the thermal mass by exposing it to solar radiation and keeping it within the thermal envelope.

7 References

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Appendix A – Temperature and relative humidity tables

This section gives tables with the following information:

Table 7: Time of maximum and minimum daily temperatures (Living rooms)

Table 8: Time of maximum and minimum daily temperatures (Bedrooms)

Table 9: Average maximum daily temperatures (Living room and Bedrooms)

Table 10: Average minimum daily temperatures (Living room and Bedrooms)

Table 11: Range of averaged daily temperature (Living room and Bedrooms)

Table 12: Average daily maximum relative humidity (Living room and Bedrooms)

Table 13: Average daily minimum relative humidity (Living room and Bedrooms)

Table 14: Range of average daily humidity readings (Living room and Bedrooms)

Note: Some data was lost due to the Christchurch earthquake interrupting time critical replacement of the I-buttons.

Time of maximum and minimum temperatures

Table 7: Time of maximum and minimum daily temperatures (Living rooms)

	Time of minimum temperature		Time of maximum temperature	
	EnerG wall home	**Eco Sure home**	**EnerG wall home**	**Eco Sure home**
Jan	07:00	06:30	18:00	18:30
Feb	07:00	07:00	18:30	20:30
Mar	07:00	06:30	18:30	18:00
Apr	07:00	06:30	17:00	17:00
May	07:00	05:00	21:00	18:30
Jun	06:30	06:00	21:00	18:30
Jul	06:30	05:00	21:00	19:00
Aug	06:30	06:00	21:30	18:30
Sep	07:00	06:00	19:00	19:00
Oct	07:00	06:00	18:00	19:00
Nov	07:00	06:30	18:00	19:30
Dec	07:00	06:30	18:30	20:00

Table 8: Time of maximum and minimum daily temperatures (Bedrooms)

	Time of minimum temperature		Time of maximum temperature	
	EnerG wall home	**Eco Sure home**	**EnerG wall home**	**Eco Sure home**
Jan	07:30	07:00	18:30	21:30
Feb	07:00	06:30	19:00	13:30
Mar	09:00	08:30	18:30	21:30
Apr	08:00	08:30	17:30	21:00
May	07:00	08:30	17:00	21:30
Jun		09:00		21:30
Jul		09:00		21:00
Aug		08:30		21:00
Sep	07:30	09:00	17:30	21:00
Oct	07:30	07:30	18:30	21:30
Nov	07:00	07:30	19:30	19:00
Dec	07:00	07:00	20:00	21:30

Daily maximum temperatures

Table 9: Average maximum daily temperatures

	Living room (°C)		Bedroom (°C)	
	EnerG wall home	**Eco Sure home**	**EnerG wall home**	**Eco Sure home**
Jan	26.1	25.1	24.5	22.6
Feb	26.0	25.0	24.8	24.0
Mar	24.7	24.6	24.9	22.2
Apr	24.3	24.0	24.5	21.1
May	22.0	23.6	21.6	19.0
Jun	22.9	21.3		18.3
Jul	22.3	20.7		16.9
Aug	22.3	20.4		17.6
Sep	22.5	22.0	23.6	19.4
Oct	23.8	23.1	23.3	20.5
Nov	25.8	24.1	24.5	23.3

	Living room (°C)		Bedroom (°C)	
	EnerG wall home	Eco Sure home	EnerG wall home	Eco Sure home
Dec	26.2	25.2	24.9	23.3

The EnerG Wall house has a west-facing main bedroom, while the Eco Sure house has an east-facing main bedroom. The differing orientation of these rooms makes meaningful comparisons between the houses difficult.

Daily minimum temperatures

Table 10: Average minimum daily temperatures

	Living room (°C)		Bedroom (°C)	
	EnerG wall home	Eco Sure home	EnerG wall home	Eco Sure home
Jan	21.4	21.2	20.5	20.6
Feb	21.7	21.4	20.9	21.4
Mar	18.9	18.6	19.3	18.8
Apr	18.0	18.3	18.4	18.1
May	16.6	17.5	16.6	16.4
Jun	15.6	16.9		14.7
Jul	15.1	15.5		12.8
Aug	16.7	16.5		14.3
Sep	16.8	17.2	16.1	16.2
Oct	17.2	17.7	16.6	17.2
Nov	20.6	19.4	18.9	19.7
Dec	21.6	21.4	20.5	21.0

Daily temperature range

Table 11: Range of averaged daily temperature

	Living room (°C)		Bedroom (°C)	
	EnerG wall home	Eco Sure home	EnerG wall home	Eco Sure home
Jan	4.7	4.0	4.0	2.0
Feb	4.4	3.6	3.9	2.6
Mar	5.8	6.0	5.6	3.4
Apr	6.3	5.7	6.1	3.0
May	5.3	6.1	5.0	2.7
Jun	7.3	4.5		3.5
Jul	7.2	5.3		4.1
Aug	5.6	3.9		3.2
Sep	5.8	4.8	7.5	3.2
Oct	6.6	5.4	6.7	3.3
Nov	5.1	4.7	5.6	3.6
Dec	4.6	3.8	4.5	2.3

The average daily temperature range for both houses follows a similar profile, however the Eco Sure house has a flatter profile than the EnerG Wall house, displaying fewer fluctuations in temperature.

The higher daily temperature range for the EnerG Wall house is likely due to the higher solar gain from west facing windows.

Daily maximum relative humidity

Table 12: Average daily maximum relative humidity

	Living room (%)		Bedroom (%)	
	EnerG wall home	**Eco Sure home**	**EnerG wall home**	**Eco Sure home**
Jan	57	58	60	61
Feb	53	53	59	55
Mar	56	56	64	62
Apr	53	55	65	66
May	53	56	66	67
Jun				
Jul				
Aug				
Sep			58	
Oct			64	
Nov	58	55	64	56
Dec	56	57	62	59

Daily minimum humidity

Table 13: Average daily minimum relative humidity

	Living room (%)		Bedroom (%)	
	EnerG wall home	**Eco Sure home**	**EnerG wall home**	**Eco Sure home**
Jan	49	50	53	57
Feb	48	47	50	44
Mar	43	46	47	50
Apr	43	46	46	57
May	44	47	50	62
Jun				
Jul				
Aug				
Sep			42	

	Living room (%)		Bedroom (%)	
	EnerG wall home	Eco Sure home	EnerG wall home	Eco Sure home
Oct			51	
Nov	49	50	51	52
Dec	48	49	51	54

Daily humidity range

Table 14: Range of average daily humidity readings

	Living room (%)		Bedroom (%)	
	EnerG wall home	Eco Sure home	EnerG wall home	Eco Sure home
Jan	8	7	8	4
Feb	5	6	8	11
Mar	13	10	17	12
Apr	10	9	19	9
May	9	9	16	5
Jun				
Jul				
Aug				
Sep			16	
Oct			14	
Nov	9	5	13	4
Dec	8	7	11	5