HN2800/7

New Zealand Housing Foundation HomeSmart Home: Evaluation of Performance and Occupancy

Final

A report prepared for Beacon Pathway Limited
September 2011

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

About This Report

Title

New Zealand Housing Foundation HomeSmart Home: Evaluation of Performance and Occupancy

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Abstract

The New Zealand Foundation HomeSmart Home was designed in partnership with Beacon to meet the HSS High Standard of Sustainability®. This report brings together the findings from performance monitoring and occupant experience interview. It compares the performance and family experience of this home to the Rotorua and Waitakere NOW Homes® and to two homes monitored over a similar period built by Stonewood Homes in Rangiora.

Reference

Easton, L. September 2011. New Zealand Housing Foundation HomeSmart Home: Evaluation of Performance and Occupancy. Report HN2800/7 prepared for New Zealand Housing Foundation.

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1 Executive Summary

The New Zealand Housing Foundation's HomeSmart Home was developed in partnership with Beacon Pathway Ltd, a research consortium with the goal of bringing 90% of New Zealand's homes to a high standard of sustainability by 2012. It built on Beacon's two demonstration sustainable homes, one each in Rotorua and Waitakere, which were lived in by families and monitored, as 'live' research projects aiming to show that sustainable homes can be achieved now with existing designs, materials and products.

Beacon used the performance data of these homes to develop and test the HSS High Standard of Sustainability® (HSS®), a set of benchmarks for a high performing, sustainable home.

The HomeSmart Home, located in Glen Eden, Waitakere, was completed in 2009 and a family of five moved in to the house in September 2009. The home's energy, water and indoor environment performance was monitored for the first year of occupation.

This report, prepared by Beacon Pathway Incorporated (the successor organisation to Beacon Pathway Ltd), brings together the findings from performance monitoring and occupant experience interview. It compares the performance and family experience of this home to the Rotorua and Waitakere NOW Homes® and to two homes monitored over a similar period built by Stonewood Homes in Rangiora.

Generally the performance of the house can be regarded as excellent, with the house meeting all of Beacon's HSS High Standard of Sustainability® benchmarks, and exceeding the performance of all the comparator homes in relation to reticulated energy use.

Criteria	Benchmark	HomeSmart Home
Energy use (Climate Zone 1) – New home	5800 kWh/year	3890 kWh/year
Reticulated water use	125 litres / person / day	117 litres / person / day
Average living room temperature	>18°C - 5-11pm in winter*	19.0°C
Average bedroom temperatures	>16°C - 11pm-7am in winter*	18.0°C
Average living room relative humidity	40-70% - 5-11pm in winter*	62%
Average bedroom relative humidity	40-70% - 11pm-7am in winter*	62%

* Winter has been taken as May to September

The occupants' experience of the home was also good, in particular as relates to the "more sustainable" components of the home. The occupants particularly appreciated the significant cost savings, and noted the clear health benefits for the whole family of having a warm, dry, well ventilated house.

1.1.2 Sustainable features

In terms of the "more sustainable" features added into the home, the report draws the following conclusions:

- In this low electricity-using house, the photovoltaic system had a significant benefit providing a third of the total electricity needs of the home. With the installation of a smart meter and an agreement with the power company, the homeowners have been able to receive credits on their electricity bill for power exported back into the grid. Approximately half of the electricity produced by the PV system was actually used by the household, with the rest returned to the grid. The financial cost benefit on the photovoltaic system is not strong enough yet to warrant regular inclusion in NZHF homes, but this should be reviewed frequently as the price of power goes up, and the cost of photovoltaic panels comes down.
- The heat pump hot water system performed well and saved significant electricity. With prices having come down further on these since the house was built, should be considered as a standard feature for inclusion in future NZHF homes.
- The greywater system resulted in significant water savings, although it was also a user of electricity. The household had no problems with the maintenance of the system. While there was some financial benefit from the greywater system, compared to the price this was low, with a payback period of over 30 years and they are not recommended as a standard feature for NZHF homes.
- The improved thermal envelope (heavy insulation, double glazing) had a substantial benefit – both in reducing the heating requirements to near nil, and meaning that the house was warm, dry and healthy throughout winter. Increased insulation specification is recommended for inclusion in all future NZHF homes. Double glazing with low emissivity glass is also recommended for future NZHF homes. Where cost constraints limit the potential for this, it is recommended that at least bedrooms and if possible the main living area has double glazing with low emissivity glass.
- In Auckland rainwater systems are considered to be a good option, however the one in the HomeSmart Home wasn't optimal for the situation. It is recommended that they be considered for future NZHF homes – but plumbed to at least the washing machine and toilet, as well as for garden watering, with a larger tank size in order to optimise the financial benefit to home occupiers.

1.1.3 Improvements which could be made

While generally the performance of the house can be described as excellent, there are a number of areas where improvements can still be made.

Layout and design was the area most commented on by the occupants. Future layouts could consider increasing the amount of usable space in the ground floor design and layout by a more open plan layout which loses less room to circulation, rather than separating kitchen, dining room and living room. As the double garage was largely used for storage and a rumpus area, its relatively large floor area could be reduced to a single car size, reallocating the floor area to living space/storage. This would provide a better insulated, more appropriate space for family activities.

Summer overheating could be addressed by providing deeper eaves for shading on both upstairs and downstairs windows. The solar vent did not appear to provide enough ventilation to get rid of the heat in the upper storey. Future designs could consider high windows which can be left wide open without security stays or alternate window designs with a smaller, separate upper opening which was secure to leave open for natural ventilation.

Finally, ensuring the kitchen range is externally vented will reduce moisture levels in living areas from cooking activities.

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 called the HSS High Standard of Sustainability® (HSS®)[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], in Waitakere and Rotorua, led the way for the Home*Smart* Homes project.

Based on learnings from the NOW Homes, Beacon developed procedures and guidelines to design a HomeSmart Home. As part of the HomeSmart Home project Beacon partnered the New Zealand Housing Foundation (NZHF) in testing these procedures and guidelines on the design of a new home. The NZHF HomeSmart Home was built as part of a NZHF subdivision in Glen Eden, Waitakere City (West Auckland).

This report presents and integrates the results of the following pieces of work:

- An interview with the adult male occupant, on his own and his family's experience of living in the home and the neighbourhood, and compares this feedback with that from NOW Home occupants undertaken in June 2010[3].
- Physical monitoring and research looking at the performance of the NZHF Home*Smart* Home with regard to Beacon's HSS High Standard of Sustainability® benchmarks and specifically at the use of the photovoltaic and greywater systems between Jan-Dec 2010[4].
- A preliminary review of the home and the experience of the occupants of it undertaken by NZHF in August 2010.

As well as presenting and interpreting the results of the research undertaken into the home, this report aims to identify key learnings for NZHF and its funders in relation to the success of different sustainability features applied within the home, and in their potential applicability for use in future NZHF developments.

[1] ***Easton and Howell (2008). Also see www.beaconpathway.co.nz/being-homesmart/article/beacons_hss_high_standard_of_sustainability***

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

[3] ***Trotman (2010)***

[4] ***Roberti et al. (2011)***

3 The NZ Housing Foundation's HomeSmart Home

The New Zealand Housing Foundation (NZHF) is a not-for-profit charitable trust that assists low income households to buy their own home through shared ownership[5] and home equity[6] programmes. With philanthropic funding, the NZHF builds housing for low income families, with one such development located off West Coast Road in Glen Eden, Waitakere, as pictured below.

The house was built by Goldsmith Developments Ltd. It has two storeys with four bedrooms, an overall area of 160m^2, and was valued at around $410,000 at the time of construction in 2009. It has a weatherboard and brick exterior with Colorsteel roofing, and aims to achieve high levels of energy, water and waste efficiencies while providing a comfortable and healthy house.

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[5] ***Shared ownership involves first home seekers purchasing around 75% of the value of the property with NZHF purchasing the remainder. The new home owner can choose when and if they wish to purchase more, or the house can be sold and the profit used to purchase their own home outright.***

[6] ***In home equity programmes a household occupies a NZHF home and pays a market rent, and the NZHF helps the household through advice and support to clear its debts. Over time, the household gets 75% of the property's increase in value to use to buy their own home.***

This home was designed and built in accordance with the HomeSmart Home Procedures. The home's sustainability features are laid out in Table 1.

Table 1: Key systems and appliances featured in the NZHF HomeSmart Home[7]

Performance area	Features
Passive thermal design	Good solar orientation (NNW) R4.6 ceiling insulation R2.6 external wall insulation R0.35 U-PVC framed double glazing Thermal backed curtains
Energy generation	Photovoltaic solar power system
Energy efficiency	310L heat pump hot water (HPHW) system 4 star washing machine Induction cook top 3.5 star dishwasher 4 star fridge/freezer LED and compact fluorescent lighting Stand by easy reach switches and remote control
Water efficiency	6 star water efficient taps Low flow shower head 4 star dual flush toilets 4000L rainwater tank for external use Greywater recycling system to supply toilets 4.5 star water efficient washing machine 4.5 star water efficient dishwasher Rain garden to reduce stormwater run-off
Indoor environment quality	Low environmental impact paints Extraction fans vented to outside in bathroom and laundry Opening windows for good ventilation Low profile, roof-mounted, solar powered ventilation vent
Waste	Good construction waste management practices Multiple waste bins in the kitchen

When assessed under the HERS (Home Energy Rating System) scheme, the HomeSmart Home received a thermal rating of 8.0 stars.

[7] ***http://www.beaconpathway.co.nz/new-homes/article/nz_housing_foundations_homesmart_home***

A comparison was undertaken of the NZHF HomeSmart Home with Beacon's HomeSmart Home specification[8].

Compliance with the HomeSmart Home specification	Variations from the HomeSmart Home specification
■ Thermal envelope (insulation) ■ Hot water system, lighting ■ Outdoor clothesline ■ Maximum dwelling size ■ Passive ventilation ■ 4 star energy efficient fridge freezer ■ Low flow shower, taps and toilet ■ Water meter ■ 4.5 star water efficient washing machine ■ 4.5 star water efficient dishwasher ■ Outside rainwater tank for the garden ■ Kitchen composting ■ Space for recycling bins and composting.	■ Unlagged pipes for the heat water pump ■ No windows or mechanical ventilation in the laundry located in the garage ■ Kitchen rangehood not externally vented ■ No uniform use of low toxicity products and materials and of environmental choice certified materials. ■ The rainwater system supplies the garden only, with the greywater system supplying the toilet but not the washing machine. ■ This house also has a double garage which is not part of the Home*Smart* Home specification.

The house was occupied by a family in September 2009. Physical monitoring of the home was undertaken by BRANZ[9] to December 2010, of energy and water consumption, indoor temperatures and moisture levels. A detailed evaluation of the unique NZHF HomeSmart Home features – the grid connected photovoltaic panels and the greywater system was also undertaken. Alongside the physical monitoring of the home, as with other Beacon research, the experience and behaviour of the occupants in the home are key to understanding its performance. An occupancy interview and evaluation was therefore also undertaken in June 2010[10].

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[8] ***Cowan et al. 2010***
[9] ***Roberti et al. 2011***
[10] ***Trotman, 2010***

3.1.2 Indoor temperatures

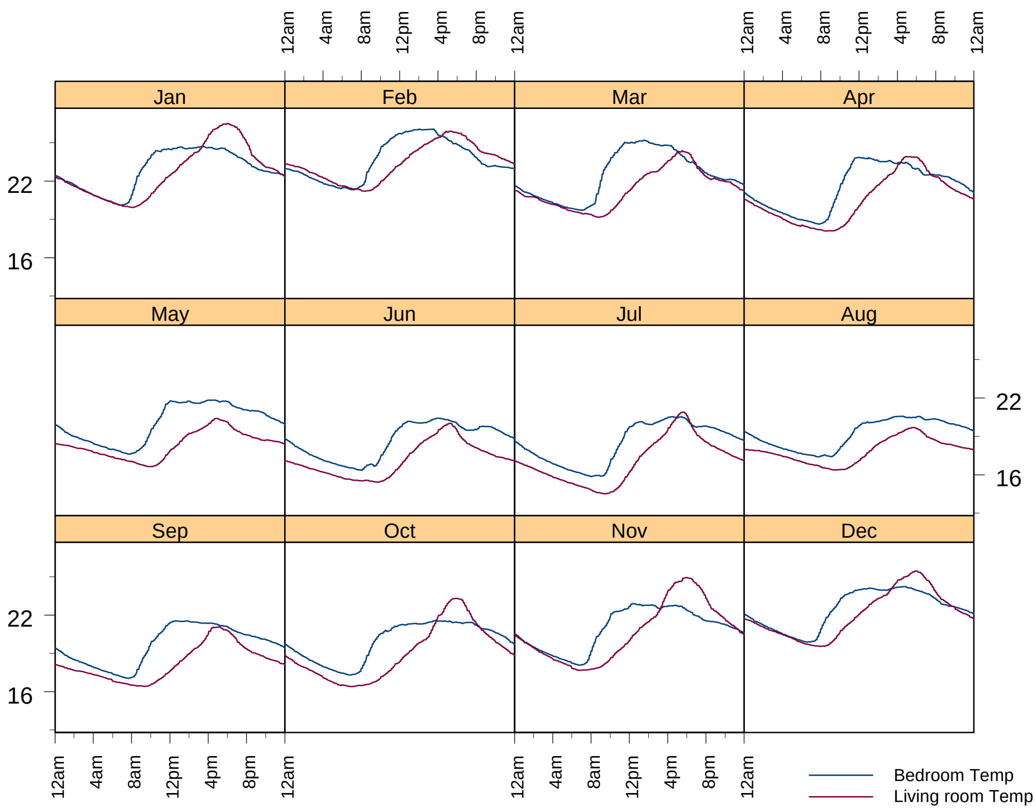

Figure 1: Average daily temperature profile (°C) by month

As can be seen from Figure 1, the average daily temperature in winter was higher in the bedroom than the living room. During the evening, the bedrooms were 20.2°C while the living room was 18.95°C, while overnight the bedrooms were 17.95°C compared to the living rooms at 17.0°C. This is unusual in New Zealand homes, as generally living areas are more likely to be heated and is likely to be because the upstairs bedrooms both receive more winter sun, and because the stack effect means that heat rises.

Summer temperatures within the home were on the high side, however, with temperatures above 25°C common. As is discussed in 4.2 below, the household did find that the temperatures could be too high for comfort in summer – and that they were hindered by the presence of security stays on the upper windows from fully opening the upstairs windows (and thus ventilating the home using the stack effect). While a solar powered stack vent was included in the home, it is not clear how effective this was as overheating still occurred.

3.1.3 Humidity performance of the home

The humidity levels in the home averaged 62% in the living room and bedroom, meeting Beacon's HSS High Standard of Sustainability® benchmarks. This is very pleasing as humidity levels are difficult to control in the very humid Auckland conditions. The humidity data are shown in Figure 2 below:

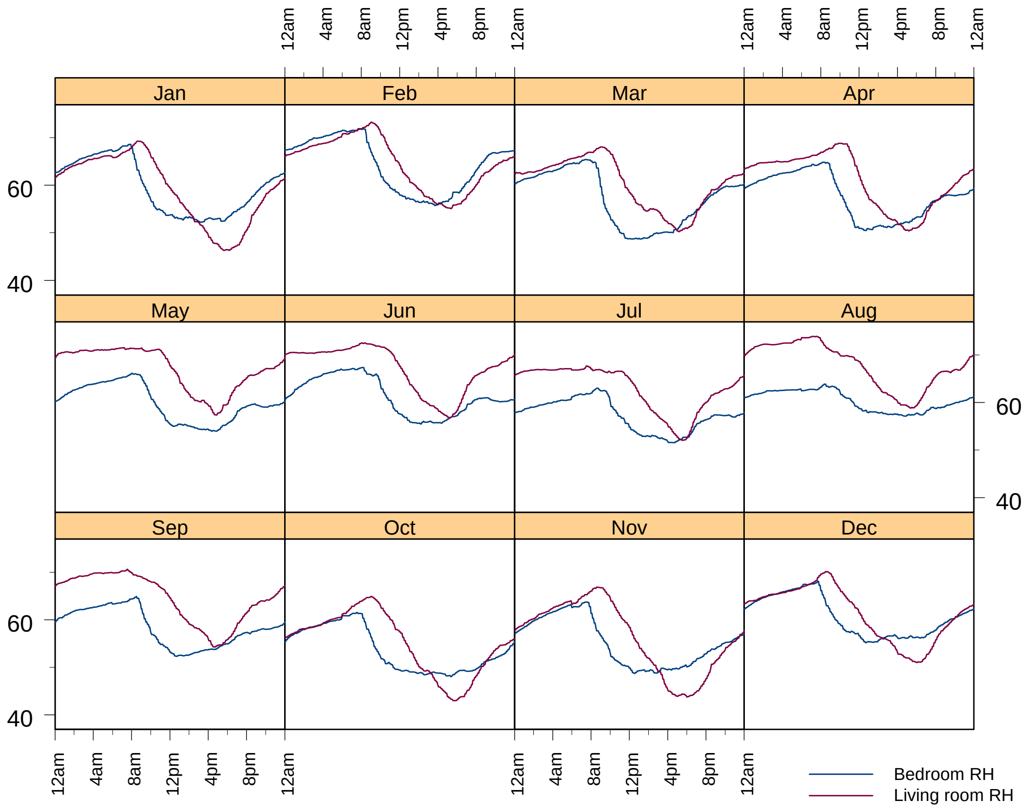

Figure 2: Average daily profile for relative humidity (%) by month

As can be seen by the data, the living room relative humidity levels are consistently higher than the bedroom. This can be partly explained by the higher temperatures found in the bedroom during winter (warmer air can hold more moisture and thus has lower relative humidity); however, the relative humidity is also higher in the living room in summer.

While the HSS High Standard of Sustainability® benchmarks were met, the living room at times has relative humidity levels which are on the high side of what is ideal. It is likely that the unvented kitchen range is a significant source of moisture into the living room, and that if the rangehood had been externally vented, relative humidity levels in the living room would have been lower.

3.1.4 Electricity use in the home

Electricity use in the home was very modest and the house also met the HSS High Standard of Sustainability® benchmark for reticulated energy use. The net (after photovoltaic generation) annual power use for the home was 3890 kWh/year – well below the benchmark of 5800 kWh/year – and less than half of the annual electricity use in the Waitakere and Rotorua NOW Homes®. As is discussed further in 4.2.5 below, the photovoltaic array produced 2000 kWh of electricity (1000kWh of which was used by the household). Even with the energy generation excluded, the house used a total of 5890kWh and was a very efficient electricity user. The combination of energy efficient appliances, lighting and hot water combined with good passive heating and thermal design has had a very significant benefit in relation to electricity use.

3.1.5 Water use in the home

Water use in the home was also modest and the house met the HSS High Standard of Sustainability® benchmark for reticulated water use. The average water use per person per day over the 12 month monitoring period was 117 litres/person/day. This is somewhat higher than either the Waitakere or Rotorua NOW Homes®, due to the rainwater tank size/design/location not being ideal to supply all outdoor water uses. The average use in summer was much higher-particularly in the first year when the lawn was being established. In addition, no alternative water supply was provided for the laundry or shower – normally these account for about 50% of total water use in the home.

3.1.6 Performance of the photovoltaic system

In total, the house used 5890 kWh of electricity – sourced from both the grid and the photovoltaic system. In total the photovoltaic system produced 2000 kWh over the year. Of this 1000 kWh was able to be used by the household, with the remaining 1000 kWh exported to the grid. Once the family installed a smart meter, they were able to receive a credit on their electricity bills for the 1000 kWh exported to the grid – on a tariff of 26.6 cents/kW this is estimated at $265 worth of electricity. Figure 3 shows the monthly electricity generation and use within the home. As was expected, generation was greatest in summer, where the photovoltaic system was providing more than half the electricity used in the house. Over winter generation dropped back, and with the increased lighting, heating and hot water requirements, the contribution from the photovoltaic system to total electricity sourced was a lot less.

The photovoltaic system is capable of producing in excess of 2100 kWh per annum.The amount of electricity generated by the system was about what was expected based on Auckland's predicted solar radiation. This indicates that the system was optimally installed.

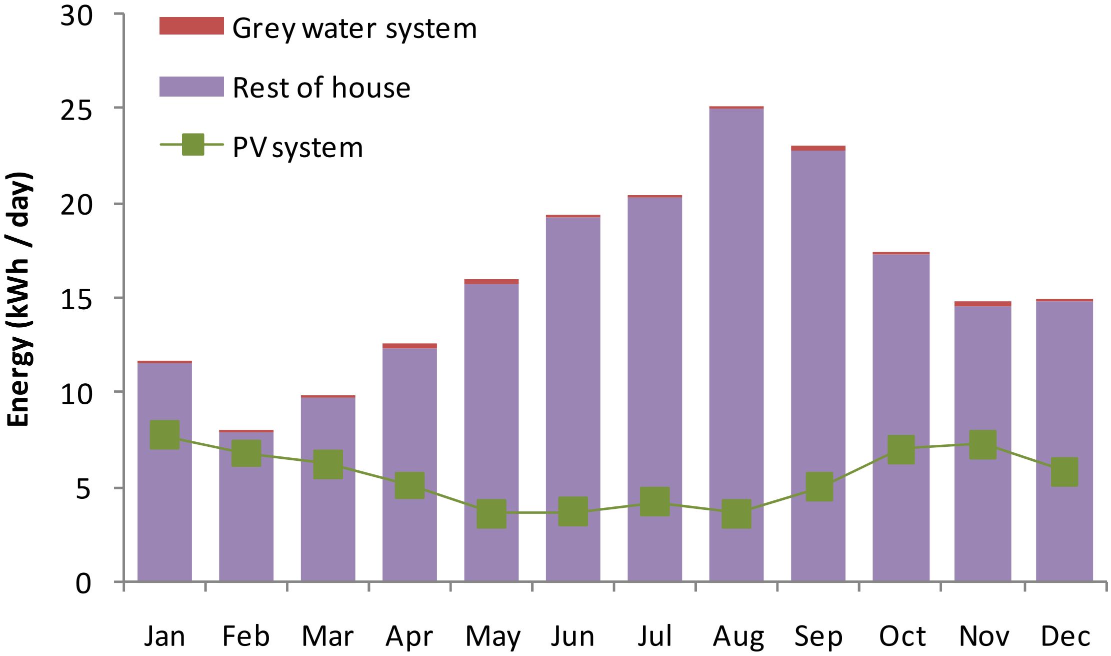

Figure 3: Average monthly electricity used and photovoltaic system output

3.1.7 Performance of the greywater system

The greywater system was used by the family for 243 of the 257 monitored days with the family switching the system off when they left the house for several days. Early on in its use, the system malfunctioned, but was repaired under warranty and no further problems were identified. On average, the system saved 23 litres of water per person per day and 42 m^3 of water annually. As a result, household usage of reticulated water was reduced by 20%, from 255 m^3 to 213 m^3 per annum. The greywater system also reduced the wastewater stream from the household by the same volume, removing 115 litres of wastewater per day from the waste stream.

The greywater system used 68 kW of electricity over a one year period – at 25 cents/kWh, approximately $17. It is estimated that the greywater system reused about 30% of the total greywater produced by the household on an annual basis.

4 Occupant experience of the home

4.1 Method

This research began with a preliminary analysis of the occupancy research findings from the Waitakere and Rotorua NOW Homes® and the background reports for the development of the NZHF HomeSmart Home. This was used to inform the development of an interview question schedule for the home occupants, which incorporated issues covered in the NOW Homes® research

The face to face interview took place at the occupants' home at 5pm on Monday 31 May 2010 (Queen's Birthday weekend public holiday). The interview was held solely with the adult male occupant of the household, as the adult female householder was still at work for most of the interview and then busy with childcare and preparing food upon arriving home. Children and extended family members came and went during the interview.

The focus of the interview was on the family's experience of the home and its features; their experience of the local neighbourhood; any changes in attitudes and behaviour since living in the home; and suggestions for future homes.

4.2 Key findings

4.2.1 Temperature

The family found the house overall to be very warm. Due to the very young age of the baby, they had at first used both a portable electric heater and the lounge inset heater to keep the baby warm, but after this initial period the heaters were not used at all. The family's last house was described as a 'fridge box' so the warmer winter performance was a highly valued feature of the home.

The family did find that the house overheated in summer, particularly upstairs, where it was difficult to sleep at night at the hottest times. The family ran the solar powered stack vent continuously, and left the upstairs windows open permanently during summer; however, these were limited in their ventilation ability as security stays prevented the windows from opening very effectively. Ventilation through the living room doors (which don't open fully) and a lack of shading into the living area was also considered problems, and the family intended to install additional shading ahead of the next summer.

4.2.2 Hot water

The family were generally very happy with the performance of the heat pump hot water system – noting that two teenage boys can use a lot of hot water, but they had no problems with hot water running out. The hot water system in particular was identified as a big contributor to the lower power bills experienced by the family. The family did note that the Rheem system installed had been identified as a poorer performer than other heat pump hot water systems, and that a split system (with the hot water cylinder located in the garage) would be a better option – less heat loss from the outdoor location of the hot water cylinder, and also better aesthetics.

4.2.3 Greywater system

The family had no problems with the greywater system after the initial leak was fixed. They quickly got into a regular routine of putting the chlorine tablet in once a week when they put the rubbish out.

4.2.4 Rainwater tank

When the family moved in, no grass had been sown, and the first sowing failed, so for the first summer they were heavy garden water users while establishing the lawn. This, combined with the drought over the 2009/2010 summer in Auckland, meant the rainwater tank was quickly exhausted, and not replenished. The family also found the low location of the tap for the rainwater tank difficult, and suggested it needed to be put up on a base to get better flow from the gravity feed, as well as more easily access the tap to use the water.

4.2.5 Other features

While the family valued having the LED lighting, they felt it could have been better located for greater effectiveness to light up the bench area as task lighting, rather than its more general use. Hall lighting, particularly of the stairwell, was considered to be less than ideal, with the lights required to be on during the day. A solar tube was suggested to address this problem.
There was also a specific concern about the absence of extract ventilation in the kitchen. The internal location of the stove meant that there was no rangehood in the kitchen to extract steam from cooking.

The family have been composting their food waste and plan to build a vegetable garden.

4.2.6 Design and layout

The family had the most comments on the design and layout of the home. While not specifically sustainability features as such, they impact a lot on how people feel about a home, and its effective function. A number of issues were identified which are useful for New Zealand Housing Foundation to consider in future housing designs.

While the house was considered to be a good size, some of the segmentation of rooms meant that areas were wasted in circulation space. As a general comment it was felt that the downstairs area needed to be more open plan. The separate dining area was small and it was felt that it would have been better to have combined the living, dining and kitchen areas into a more open plan and functional space. The location of the downstairs toilet (next to the lounge) was seen as being undesirable – it reduced the size of the lounge further, as well as creating privacy issues with its use.

The bedrooms were seen as being a good size, and the built in storage appreciated. The double garage was highly valued – but not for its use by cars, instead it was used as a rumpus room for the kids and for storage.

4.2.7 Low maintenance features

A splash back for the stove and use of non carpet flooring in dining areas were two key features identified to help reduce maintenance (and wear and tear) within the home.

4.2.8 Most positive aspects of the house

Domain affected	Aspects rated most positive
Children	Level of insulation (don't need to heat the rooms) Kids don't get sick any more ("they were always getting sick in the last place which was damp and cold)
General comfort	Insulation
Awareness raising (of their environmental impact and features that made them think most about their behaviour)	The energy efficiency features
Cost savings/household expenditure	Insulation Hot water pump Energy efficiency features, including solar power
Health	Insulation
Interfamily relationships	Having extended family close by ("the kids love having family close, they can play close by")

Table 2: Most positive aspects of the NZHF HomeSmart Home as rated by occupant

4.2.9 Past and future houses

When considering past houses, and what he would look for in future homes a number of very positive comments were made.

On the same scale of one to ten he was asked how much better or worse is it living in this house? James gave the same score of 8-9 in terms of being better than previous houses they had lived in. In terms of what specifically is better about this house, James noted warmth, dryness, more room, more bedrooms, more living space and the garage.

He also noted that in previous houses, the boys had often been sick and snuffly, and that his wife had often used an inhaler. Now she didn't use the inhaler at all and no-one had been sick since arriving in the house. James commented that "now we know the baby is teething when he is out of sorts" (instead of being cold or otherwise sick).

In terms of what the family would look for in future houses, James noted warmth (insulation), good ventilation, open plan layout and spaciousness, plus a hot water heat pump if possible.

4.2.10 Implications for future NZHF housing

The HomeSmart Home occupants had been in the house for nine months and had not experienced a full winter at the time of the interview. Regardless, this household via reported a reasonably high level of satisfaction with the house overall, particularly in terms of its level of insulation and thermal performance, dryness, spaciousness, the hot water heat pump and other energy efficiency measures, cost savings and the double garage.

The cost savings were significant and appreciated by this household, and clear health benefits were noted for the whole family of having a warm, dry, well ventilated house. The family's wellbeing was also enhanced by having extended family living nearby and strong relationships with neighbours. The adult occupant interviewed noted that living in a "green house" forced a lowering of the household's carbon footprint and made it easy to act more sustainably.

In terms of future NZHF housing, key implications from this HomeSmart Home occupants experience include the following.

- A high level of insulation, proper ventilation and lighting result in reported health benefits and are greatly appreciated by occupants.
- The ventilation system in this house worked well in winter but there was overheating in summer – due in part to safety catches on upstairs windows and being unable to open the lounge doors.
- Proper ventilation of the kitchen to the outside is needed, including placement of stoves on outer walls.
- Cost savings from energy efficiency features will be valued by low income households.
- Open plan living is likely to facilitate family connection.
- High quality finishing is important, as well as attention to detail (for example placing of lighting over work areas).
- Spending money on small features such as stovetop splashbacks can save money in the longer term.
- Do not put carpet in areas where eating commonly occurs, such as dining rooms (note also that the Waitakere NOW Home® family rated their concrete floor very highly).
- Consider how to ensure proper ventilation in upstairs rooms that have safety catches on windows.[11]
- Ensure stairways are well lit, with natural light if possible (for example via solar tubes).
- Do not put toilets next to shared social spaces such as lounges, kitchens or dining rooms.

[11] ***Note that in the Rotorua NOW Home, cedar louvres were installed and were considered to work well.***

5 Comparison with other monitored homes

This section looks at a comparison of the house performance with monitoring data from the two Beacon NOW Homes - the Waitakere NOW Home® and the Rotorua NOW Home® as well as two new homes built by Stonewood Homes in Rangiora. Like the NZHF HomeSmart Home, the two NOW Homes were built as high performance homes. The Rangiora Stonewood 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

5.1.1 Comparison with Beacon NOW Homes

Overall of the three high performance houses, the NZHF HomeSmart Home was the best performer in relation to the key performance areas looked at by Beacon. Table 3 below compares the performance across the three homes.

	HSS® benchmark	NZHF HomeSmart Home	Waitakere NOW Home*	Rotorua NOW Home*
Number of Occupants		6	4	5
Annual reticulated energy use	5800 kWh/year	3890kWh/year	7400 kWh/year	6900 kWh/year
Average reticulated water use	125 litres/person/day	117 litres/person/day	100 litres/person/day	57 litres/person/day
Average living room temperature	>18°C 5-11pm in winter**	19°C	20.3°C	17.5°C
Average bedroom temperature	>16°C 11pm-7am in winter**	18°C	19.1°C	12.9°C
Average living room relative humidity	40-70% 5-11pm in winter**	62%	57%	58%
Average bedroom relative humidity	40-70% 11pm-7am in winter**	62%	60%	69%

*Year 1 data for both NOW Homes is shown from Pollard et al, (2008) and Pollard and Jaques, (2009).
**Winter has been taken as May to September

Table 3: Physical monitoring data from NZHF Home*Smart *Home, Waitakere NOW Home and Rotorua NOW Home

As can be seen from the data, the temperature and humidity levels in the two Auckland homes were very similar, with good performances achieved in both, particularly in winter. Data from the Waitakere NOW Home® also shows, like the NZHF HomeSmart Home, the house being uncomfortably hot at times over summer[12]. 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.

The major areas of difference relate to the reticulated energy and reticulated water use of the houses. The Rotorua NOW Home® was the lowest water user, with an automated Rain bank system allocating tank and mains water (rainwater supplied toilet, laundry and outdoors) and a 4500 litre tank. Despite its much larger 13,500 litre tank feeding toilet, laundry, hot water and outdoors, the Waitakere NOW Home® was only marginally more efficient than the NZHF HomeSmart Home – the manual system switching from tank to reticulated water was sub-optimally operated by the occupants.

The NZHF HomeSmart Home was the star performer in terms of reticulated energy use – and even if the energy generated by the photovoltaic panels is discounted, it is still the lowest electricity user of the three houses.

5.1.2 Comparison with Stonewood Rangiora Homes

Table 3 shows the monitoring data from the NZHF HomeSmart Home and two Stonewood Homes built in Rangiora and monitored by BRANZ over the same time period. These homes were expected to perform more poorly than the NZHF HomeSmart Home, and received HERS ratings of 4.5 ("EcoSure" home) and 6 ("EnerGWall" home respectively). They also had standard electric hot water cylinders for water heating, and included efficient heat pumps for space heating.

When a comparison is made with the Stonewood Rangiora Homes monitoring data[13] for energy use and indoor environment quality it can be seen that the NZHF HomeSmart Home substantially outperforms either of the homes in terms of energy use. 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 Stonewood Rangiora homes will be a direct reflection of the higher average temperatures – as well as the drier winter climate in Rangiora.

[12] ***Pollard et al. 2008***

[13] ***Burrough, et al, 2011***

	HSS® benchmark	HomeSmart Home	Stonewood Rangiora home "EcoSure"	Stonewood Rangiora home "EnerGWall"*
Number of Occupants		6	4	5
Annual reticulated energy use	5800 kWh/year (Climate zone 1) 7,300 kWh/ year (Climate zone 3) *	3890kWh/year	14,400 kWh/yr	10,800 kWh/yr
Average living room temperature	>18°C 5-11pm in winter**	19°C	21°C	22°C
Average bedroom temperature	>16°C 11pm-7am in winter**	18°C	16.3°C	17.7°C
Average living room relative humidity	40-70% 5-11pm in winter**	62%	51%	48%
Average bedroom relative humidity	40-70% 11pm-7am in winter**	62%	66%	60%

*Due to the greater heating demand in the South Island, the HSS benchmark for reticulated energy use in Rangiora is 7300 kWh/year
**Winter has been taken as May to September

Table 4: Physical monitoring data from NZHF HomeSmart Home, and the two Stonewood Rangiora homes

Summertime temperatures were lower in the Stonewood Rangiora homes than in the NZHF HomeSmart 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.

5.2 Occupancy experiences

Occupancy evaluations were undertaken with the households in the Beacon NOW Homes® and the NZHF HomeSmart Home. Key characteristics of the households are compared below.

Characteristic	HomeSmart Home*	Waitakere NOW Home	Rotorua NOW Home
House built by	New Zealand Housing Foundation, 2009	Beacon, Waitakere City Council provided the land, 2005	Housing New Zealand Corporation[14], 2006
Housing type	Two storey, four bedrooms	Single storey, three bedrooms	Single storey, three bedrooms
Household composition	Two adults, three teenagers, one infant	Two adults, two young boys	Two adults, two children, plus one adult lodger
Ethnicity	Fijian	Māori and Pakeha	Māori
Income	Medium	Higher than average	Low
Time spent in the house	Nine months	Two and a half years	Arrived September 2006

Table 5: Household characteristics of the NOW Homes and NZHF HomeSmart Home

The above shows that the housing providers in each case are different; each household involved a unique family, though all included children, each with different ethnicity, income and time spent in the house. Each house also included different sustainability specifications.

The table below summarises <u>key</u> likes and dislikes among the three households (in no order).

	HomeSmart Home	Waitakere NOW Home	Rotorua NOW Home
Likes	Warmth Hot water heat pump Energy efficiency features Cost savings	Natural light Warmth Open plan and layout Concrete floor Cost savings	Natural light Ventilation No step shower tray
Dislikes	More open plan Move the stove to the outside kitchen wall	Privacy Security Range of minor issues all addressed	Finishing Privacy Security

Table 6: Likes and dislikes of the occupants of the NOW Homes and the HomeSmart Home

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[14] *As part of its Community Renewal programme in the Rotorua suburb of Fordlands*

The Waitakere occupants appeared to be most satisfied with their home, based on the research findings. Security was an issue for all three houses (noting the break-in at the HomeSmart Home), and to some degree privacy was also noted as an issue by all three. Two of the houses noted warmth, cost savings and natural light as being important.

Little can be drawn from a comparison among the three houses, other than that common features liked were:

- Warmth (insulation and thermal performance)
- Natural light
- Ventilation
- Cost savings
- Energy efficiency features

A need for quality control of the building work and finishing were also important across the households, as were security, safety and privacy.

The experiences of the three households point to the unique nature of each household, but also to the universal requirements for warmth, natural light, ventilation and dryness that every household will have. Outside of these requirements for comfort and health, cost savings are important for most households.

5.2.2 Living space/storage issues

The occupants identified that they valued having the garage and used it extensively for storage, and as a rumpus room for the children. This, combined with the comments about the living space being less than optimum in terms of layout, raises a significant issue about the purpose of the garage.

In a small footprint, 2 storey house, where the living space is downstairs, a double garage takes up a substantial component of the total floor area. Yet in this home, as in the Rotorua NOW Home, it wasn't used for storing cars. As can be seen from the ground floor plan in Figure 4, the garage was a similar size to the dining room and living room combined. Without windows, or insulation, this is not a suitable space to be used as a regular living space.

A better option would be to make the ground floor more open plan so that less space is lost to circulation, and to consider providing only a single garage and increasing the living area footprint.

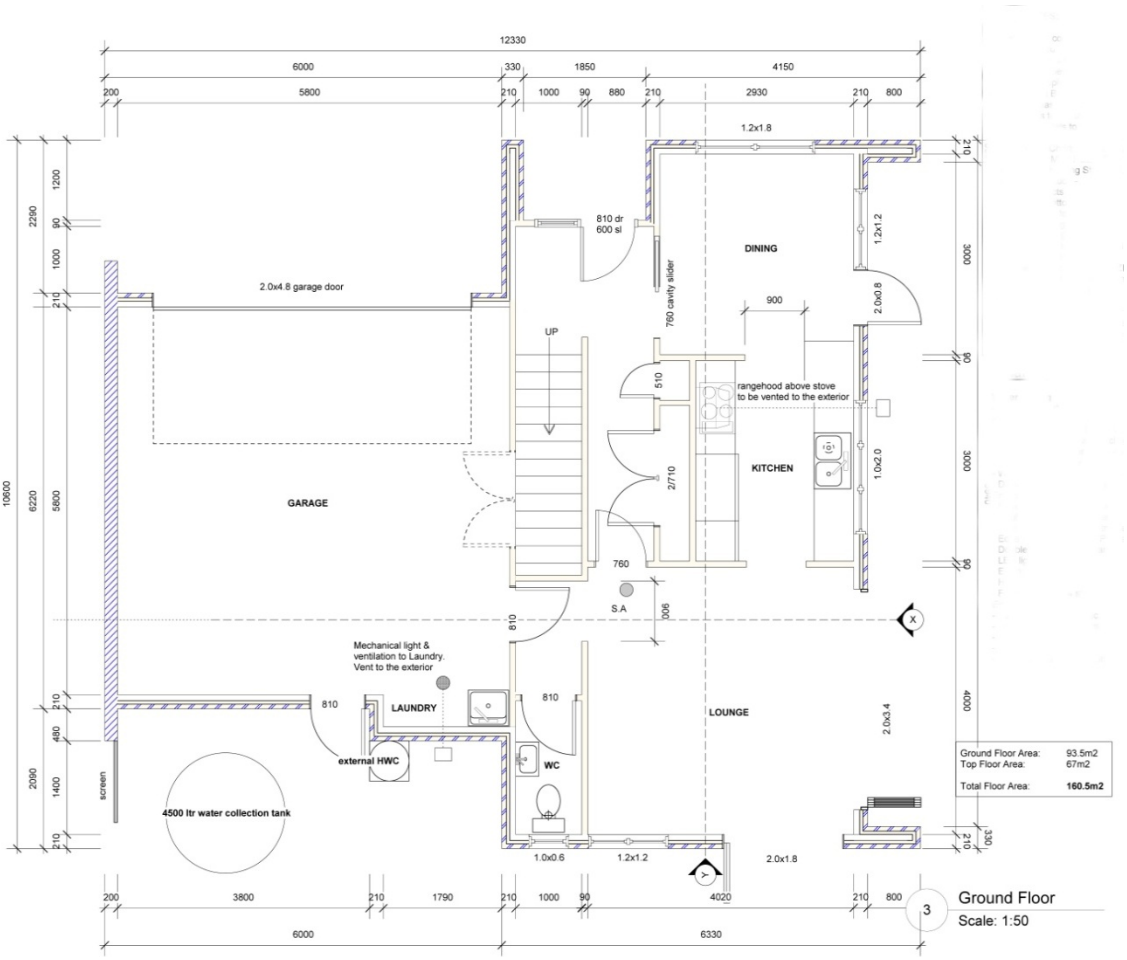

Figure 4: Ground Floor Plan NZHF Home**Smart** ***Home***

6 Cost Benefit Analysis

6.1 Energy efficiency measures

6.1.1 Photovoltaic system

In terms of simple cost benefit, the photovoltaic system cost $19,000 installed, and generated $530 of electricity per annum – giving a simple payback period of just under 36 years. However, the price of photovoltaic systems has decreased by 40% since the time that this array was installed to $11,650**,** and electricity prices are expected to continue to rise. Even on current electricity prices, the 2011 pricing of a similar photovoltaic system to that used in the HomeSmart Home at $11,650 gives a payback period of 22 years, which while more appealing, is probably not sufficient to yet justify their installation on a more regular basis. However given the 40% price drop in just over 2 years, this is clearly a technology worth watching. Electricity prices have risen by 72%[15] over the last 10 years and there are no indications that the increasing price trend will not continue.

For grid installed systems – where electricity is sold back to the retailer on a dollar for dollar basis – it is considered that once the payback period falls below 15 years, then photovoltaic systems should be installed on a more regular basis. On current electricity prices in Auckland this would occur when the system cost is $7950, however this might be reached sooner in other parts of the country where electricity prices are higher, and solar radiation levels are similar to or better than Auckland's. For example, electricity costs around 34 cents/unit (low user tariff) in Gisborne, which also receives 200 more sunshine hours annually than Auckland, meaning a grid connected photovoltaic system priced at $11,650 currently has a payback period of 16 years (based on 2011 power prices).

6.1.2 Heat pump hot water system

Previous Beacon research[16] identified that at an installed cost of $5157 and an electricity cost of 18.3c/kW the simple payback on a heat pump hot water system would be 12.9 years. The NZHF HomeSmart Home system cost $6000 installed. Based on the current per unit electricity rate of 26.6c/kW, then the payback period would be similar at 12.5 years.

However since the NZHF HomeSmart Home was built, heat pump hot water systems have come down in price – and cheaper, better performing systems are available. The Econergy system could now be installed for $4800. In addition, the Energy Efficiency and Conservation Authority is now offering a subsidy scheme for heat pump hot water systems, with a contribution of $575 towards the cost. This would bring the installed price of an Econergy system down further and result in a very reasonable simple payback of 8.5 years based on current electricity prices in Auckland.

[15] ***Ministry of Economic Development, 2011***
[16] ***Philips, 2007***

6.1.3 Solar hot water vs heat pump hot water

The combination of heat pump hot water system alongside the photovoltaic panels in the NZHF HomeSmart Home was not the ideal situation. Where photovoltaic panels are used in homes, solar hot water systems would be a better choice – as the heat pump hot water system would have been a major component of the electricity use in the home. It could be expected that if a solar hot water system was installed in the home, that electricity use would have been even lower, and greater direct benefit to the family would have been gained from the electricity generated from the photovoltaic system.

However, as photovoltaics are unlikely to become a standard inclusion in NZHF in the near future, it's the author's view that generally heat pump hot water systems are the right choice for this type of housing, despite the fact that they are less efficient than a good solar hot water system. Supply and installation costs are generally cheaper by around $2000, and also there is a lower installation risk, as solar hot water systems have been plagued by poor installation problems. Heat pump hot water systems can also be used in situation where no good location for solar panels exists.

The three main issues of concern for installation of heat pump hot water systems are:

1) Noise – the unit is noisy and shouldn't be located outside bedrooms – or neighbours' bedrooms
2) Hot water pipe lagging/heat loss. Because the hot water cylinder is located outside (or in a garage) it's important that hot water pipes are lagged, and ideally a cylinder wrap is also used, as heat loss from standing
3) Best for larger households. Hot water heat pumps don't perform as well if they don't have frequent draw downs of water. They're not an ideal technology for small, low hot water using households.

6.1.4 Efficient lighting and appliances

Lighting and appliances represent an increasing proportion of household energy use – particularly where heating and hot water loads have been decreased, as occurred in the NZHF HomeSmart Home. For comparison in the Waitakere NOW Home Year 1, lighting and major appliances (fridge, dishwasher, stove, washing machine) used 6% and 17% of electricity use in the home respectively[17]. Cost benefit work done on compact fluorescent lighting[18] indicates that the payback period for this type of lighting is less than 3 months, using only $5 worth of electricity per annum compared to $25 per annum for an incandescent bulb.. Similarly, up-specifying refrigeration appliances to higher efficiency models at time of purchase has a short payback due to their 24 hour operation.

[17] *Pollard et al. 2008*
[18] *http://www.rightlight.govt.nz/campaign*

Less work has been done on simple paybacks for LED lighting, and this is a technology which is still rapidly reducing in price – and increasing in efficiency. At current prices an LED light is around $45, with an expected life of 50,000 hours (45 years at 3 hours per day). The long life expectancy means that the bulb will pay for itself in its lifetime, but it is expected that in five years time the purchase price will be substantially reduced.

6.1.5 Future cost benefits (rising electricity prices – technology mass production)

In the case of both the photovoltaic system, the heat pump hot water system, and the LED lighting these are technologies which are relatively recent in their development, and where economies of scale as they become more widely installed mean that substantial cost decreases are occurring over time. In the time since they were installed in the NZHF HomeSmart Home these technologies have all come down in price by at least 20%, and further price reductions can be expected as their uptake increases. This, combined with expected continuing electricity price increases means that the simple payback can be expected to improve over time – as for the examples shown in Table 6.

Table 7: Effect of electricity price increases on payback periods of energy efficient/generating systems

	Simple payback at 2011 electricity prices	Payback if 10% electricity price increase[19]	Payback if 30% electricity price increase[20]	Payback if 30% electricity price increase and 20% unit cost decrease[21]
Photovoltaic Panels	22 years	20 years	16.9 years	13.5 years
Heat Pump Hot Water System[22]	8.5 years	8 years	6.8 years	6 years – or 5.2 years if EECA subsidy still applies

[19] ***Based on the trends for the last 10 years, a 10% increase could be expected within 2 years***

[20] ***Based on the trends for the last 10 years, a 30% increase could be expected within 5 years***

[21] ***Based on the unit pricing trends since the NZHF HomeSmart Home was developed, this could be expected within 5 years***

[22] ***Assuming the EECA subsidy of $575 continues***

6.2 Water efficiency measures

6.2.1 Greywater system

Based on the current general water supply fees and waste water charges in Auckland[23], an effective price of $4.34 per m³ has been calculated for water use savings. Use of the greywater system saved the NZHF HomeSmart Home 42m³ of water, which corresponds to an annual saving of approximately $182 for the household.

Running the greywater system requires 68 kWh of energy. Based on the unit rate of $0.266 per kWh, the cost to be offset is about $18. Additional expenditure associated with the greywater system includes chemical treatment of the water. Recommended in the owner's manual of the system is the use of two standard calcium hypo chlorite tablets per week with an estimated cost of around $45 per year. On balance, the greywater system produces an overall annual financial benefit to the household of $120.

The greywater system cost approximately $3,745[24] excluding installation. Based on these calculated savings, the simple payback period on this system is at least 32 years.

Like electricity charges water and wastewater charges in the Auckland region have been increasing. It's unclear what longer term effect the amalgamation of the Auckland councils will have on these charges, but the 2007 Auckland City Long Term Plan identified that wastewater charges would increase by 115% over the next 10 years. Similarly high increases were also projected to occur for water charges and wastewater charges across the councils in the region. When the amalgamation occurred Watercare Services increased wastewater charges by 4.5% from 1 July 2011 and it is clear that future price rises can be expected.

6.2.2 Rainwater system

The rainwater system installed supplied water only for outdoor uses. The tank size was small at 4000 litres and, according to the homeowner, it quickly ran out in the first summer due to the high water use associated with establishing lawn cover. The rainwater tank was not specifically monitored, so it is not possible to identify the contribution it made towards offsetting reticulated water use. In the Waitakere NOW Home®, where the tank supplied toilets, laundry, hot water and outdoor uses, over 60% of water used was sourced from the rainwater tank. In order for a combined greywater and rainwater system to be effective, it is suggested that rainwater be plumbed into the laundry, hot water system and outdoor uses, with greywater supplying the toilets.

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[23] ***Water Care Services Ltd., valid 1 July,2011 until 30 June 2012 (Water supply rate of $1.30/m³; waste water price structure of $43.28 fixed charge and 75% of volumetric charge of $4.06 per m³)***

[24] ***www.wastewater-recycling.co.nz (supplier of the grey water system)***

Previous Beacon research[25] has identified that a 7500 litre rainwater tank, plumbed to toilet, shower and laundry, with a unit cost of $2821 installed and a water price of $1.48/m^3 will have a payback period of 17.4 years in Auckland.

Where the rainwater system is not metered, an unintended benefit is also a reduction in the wastewater charges. When this is taken into account, the effective water cost saving is $4.34/m^3 giving an effective payback period for a 7500 litre rainwater tank plumbed for internal and external use of 5.9 years.

6.2.3 Water efficient fittings and fixtures

Because of the substantial water shortages in Australia, there is no additional cost for water efficient fittings and fixtures with a 3 star showerhead, 4 star toilet and 4 star taps all able to be purchased for the same price than inefficient models. Because there is no extra cost, and a direct financial benefit in relation to water and wastewater costs, as well as electricity costs in the case of showerheads, water efficient fittings and fixtures are strongly recommended to be incorporated in all future NZHF homes.

6.3 Passive solar and high performance thermal envelope

A substantial benefit was received by the home occupiers from the passive solar design and high quality thermal envelope included in the NZHF HomeSmart Home. However, the bulk of the benefit achieved is not in energy savings, but in the improved warmth and comfort of the dwelling and the health and wellbeing of the occupants. It is not considered useful to provide detailed estimates on simple paybacks for thermal improvements – they are still quite long in Auckland, and are not the driver for making these types of improvements.

From the monitoring data, criteria used for NZHF households and discussions with the principal householder, it's clear that this family are careful users of energy, and are living on a strict budget. These are the types of households who normally use minimal heating and tend to "put on another jumper" if things get cold. But the monitoring data indicate there was no need for jumper wearing in this house, with all indices performing above World Health Organisation minimums, and normally well in the range of what are considered comfortable temperatures - of the type most often enjoyed by the rich.

In terms of the ongoing health and wellbeing of the households in NZHF homes, clearly incorporating good passive solar design should be an essential element in all new houses. Because passive solar design is primarily an issue of window sizing and placement, in theory this comes at no extra cost – the main issue being that designers of the homes must be sufficiently skilled to ensure good outcomes. It is strongly recommended therefore that NZHF ensure that all future designers of their homes are skilled in passive solar design techniques. Particular care is needed to ensure that summer shading/prevention of overheating is

[25] ***Philips, 2007***

incorporated into this. As a rule of thumb, a one metre overhang of eaves should be considered for all north facing windows.

In terms of thermal envelope specification, there is also a clear hierarchy of improvements which give the greatest benefit for the lowest cost. Generally this is as follows:

1. No downlights in thermal envelope (free)
2. Thicker ceiling insulation (low cost)
3. Thicker wall insulation (low cost)
4. Double glazing of windows (moderate cost)
5. Low emissivity glass on double glazed windows (low cost if windows are double glazed, not suitable for single glazed windows)

Other thermal improvements made in the NZHF HomeSmart Home included the use of high performance PVC window frames. While desirable, these are a high cost item for the thermal improvement gained. Use of low emissivity glass will give the same level of thermal improvement as PVC, wood or thermally broken frames at a fraction of the cost. Unfortunately low emissivity glass scratches easily and isn't suitable for single glazed windows.

7 Conclusions

Generally the performance of the house can be regarded as excellent, with the house meeting all of Beacon's HSS High Standard of Sustainability® benchmarks, and exceeding the performance of all the comparator homes in relation to reticulated energy use. Similarly the occupants' experience of the home was also good, in particular as relates to the "more sustainable" components of the home. The occupants particularly appreciated the significant cost savings, and noted the clear health benefits for the whole family of having a warm, dry, well ventilated house.

7.1.1 Sustainable features

In terms of the "more sustainable" features added into the home, there are a number of conclusions which can be drawn:

- In this low electricity-using house, the photovoltaic system had a significant benefit providing nearly a third of the total electricity used in the home. With the installation of a smart meter and an agreement with the power company, the homeowners have been able to receive credits on their electricity bill for power exported back into the grid. Approximately half of the electricity produced by the PV system was actually used by the household, with the rest returned to the grid. Currently the financial benefit of electricity exported back to the grid is not being gained and suggestions are made to enable this. The financial cost benefit on the photovoltaic system is not strong enough yet to warrant regular inclusion in

NZHF homes, but this should be reviewed frequently as the price of power goes up, and the cost of photovoltaic panels comes down.

- The heat pump hot water system performed well and saved significant electricity. With prices having come down further on these since the house was built, should be considered as a standard feature for inclusion in future NZHF homes.
- Compact fluorescent (CFL) lighting is a substantial cost saver and should be included as standard in all future NZHF homes
- LED lighting is coming down in price, but at the moment is not cheap enough to warrant use in reticulated homes. Prices are expected to fall substantially over the next 5 years where they may well become very competitive with CFLs.
- Energy efficient appliances (particularly refrigeration and dishwashers) can save substantial amounts of electricity due to their high use. Where these are supplied within the home, the most efficient appliance in the price range should be provided.
- The greywater system resulted in significant water savings, although it was also a user of electricity. The household had no problems with the maintenance of the system. While there was some financial benefit from the greywater system, compared to the price this was low, with a payback period of over 30 years and they are not recommended as a standard feature for NZHF homes.
- In Auckland rainwater systems are considered to be a good option, however the one in the HomeSmart Home wasn't optimal for the situation. It is recommended that they be considered for future NZHF homes – but plumbed to at least the washing machine and toilet, as well as for garden watering, with a larger tank size in order to optimize the financial benefit to home occupiers.
- Water efficient fittings and fixtures should be considered as standard in all NZHF homes. The aim should be for 3 star showerheads and a minimum 4 star taps and toilets. Efficient fittings are available at no extra cost above inefficient fittings.
- Passive solar design is a cheap/free method of optimising the comfort of the home and reducing heating and cooling requirements. It is strongly recommended that a designer familiar with passive solar design principles (including managing summer overheating) is used for all future NZHF developments.
- The improved thermal envelope (heavy insulation, double glazing) had a substantial benefit – both in reducing the heating requirements to near nil, and meaning that the house was warm, dry and healthy throughout winter. Increased insulation specification is recommended for inclusion in all future NZHF homes. Double glazing with low emissivity glass is also recommended for future NZHF homes. Where cost constraints limit the potential for this, it is recommended that at least bedrooms and if possible the main living area has double glazing with low emissivity glass.

7.1.2 *Improvements which could be made*

While generally the performance of the house can be described as excellent, there are a number of areas where improvements can still be made.

Layout and design was the area most commented on by the occupants. Future layouts could consider increasing the amount of usable space in the ground floor design and layout by a more open plan layout which loses less room to circulation, rather than separating kitchen, dining room and living room. As the double garage was largely used for storage and a rumpus area, its relatively large floor area could be reduced to a single car size, reallocating the floor area to living space/storage. This would provide a better insulated, more appropriate space for family activities.

While large northern windows and extra insulation result in excellent winter performance, they make the need for effective shading and ventilation in summer more important. Summer overheating could be addressed by providing deeper eaves for shading on both upstairs and downstairs north-facing windows. The solar vent did not appear to provide enough ventilation to get rid of the heat in the upper storey. Future designs could consider high windows which can be left wide open without security stays or alternate window designs with a smaller, separate upper opening which was secure to leave open for natural ventilation.

Finally, ensuring the kitchen range is externally vented will reduce moisture levels in living areas from cooking activities.

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