BEACON NOW HOMES® AND NOW HOME® RENOVATIONS: TRANSFORMING NEW ZEALAND'S HOUSING STOCK

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Summary

New Zealand's housing stock is well known for being cold, damp and resource inefficient. Beacon Pathway Limited aims to drive change in the New Zealand housing sector to see a significant improvement in the sustainability of our housing stock. In particular Beacon's focus is on "ordinary" homes and occupants – rather than the top 5% niche normally the subject of eco home and high sustainability aspiration.

In order to achieve this Beacon has developed two NOW Homes® and nine NOW Home® Renovations – houses built and renovated for an average budget for ordinary families which perform significantly better than the vast majority of New Zealand houses. These homes have been monitored in terms of their resource use, quality of the indoor environment and overall sustainability against key performance indicators and benchmarks set by Beacon. The homes have now demonstrated that development and retrofitting of these homes with current technology and for prices within the reach of ordinary households, significantly higher quality and healthier and more resource efficient housing is able to be developed. These results have been achieved without any specific training or behaviour modification of the occupants.

1. Introduction

The sustainability of the residential built environment is an important issue for New Zealand, as a significant proportion of the energy and water consumed (Statistics New Zealand, 2006) and waste produced (Kazor and Koppel, 2007) in the country occurs in people's homes. Similarly the health of the indoor environment within homes has a significant impact on the overall health of the community, particularly as relates to respiratory conditions.

Beacon Pathway is the vehicle chosen by a number of like-minded organisations that seek to radically change the design, construction and renovation of New Zealand's homes and neighbourhoods. Our goal is to significantly improve housing sustainability through scientific research, communication, information sharing, and advocacy, opinion forming and networking.

The Foundation for Research, Science and Technology matches funding from Beacon's shareholding partners, a unique mix of industry, local government and research organisations: Building Research, Scion, New Zealand Steel, Waitakere City Council and Fletcher Building.

Established in 2004, with a focus on new technology for new homes, it became quickly apparent the principal opportunity for Beacon to impact lies not with the 25,000 new homes we build each year, but in transforming our existing 1.6 million homes. A large proportion of these homes are poorly insulated, damp, and consume relatively high quantities of energy and water (Storey, Page, van Wyk, Collins and Kreil 2004).

As part of its applied research approach Beacon has built two resource efficient NOW Homes® in Waitakere and Rotorua and retrofitted nine "average" existing homes in Porirua in the Wellington Region These homes have been monitored against benchmarks that Beacon has set around what defines a High Standard of Sustainability™ for homes. The homes are all occupied by ordinary families with no special training in sustainability behaviour.

1.1 Beacon's High Standard of Sustainability™

In order to provide a framework for Beacon to measure the influence it is having on the sustainability of houses at a national level, and to provide a useful benchmark against which individual households can evaluate their home's performance, Beacon has developed benchmarks for a High Standard of Sustainability™ (HSS) in homes (Easton, 2006). These benchmarks have focused on five key aspects of dwelling sustainability:

- Energy Use
- Water Use
- Indoor Environment Quality
- Waste
- Materials

Underpinning these five technical aspects of dwelling sustainability are the issues of affordability and future flexibility. When considering the individual household benchmarks at which the HSS performance indicators should be set, affordability was a significant consideration (Easton, 2006). The benchmarks have therefore been set at levels where many of the features used to bring about their achievement are:

- low cost (eg simple measures such as fitting of draught stoppers and use of low-flow shower heads)
- have a payback period of less than the expected life of the product
- In the case of new development, can be undertaken at no or minimal extra cost (eg passive solar design).

The benchmarks developed represent a preliminary "line in the sand" for Beacon and are expected to be updated and refined over time, and as the research into the state of New Zealand's home performance continues. While detailed comparative work is still being undertaken, new homes built to achieve the Beacon HSS appear to be roughly comparable with a "good" rating (56-69 points) under the BRANZ Green Homes Scheme (New Zealand's only current sustainable home rating scheme), or a Level 4 compliance with the UK Code for Sustainable Homes. This compares with, for example, the average new New Zealand home, which would score around 10-15 points under the BRANZ Green Homes Scheme and not achieve a rating on the UK Code for Sustainable Homes. In other words while the Beacon HSS benchmarks are significantly higher than the minimum requirements of the NZ Building Code, but are set to be within what is a considered to be able to be a reasonable target for all new homes to achieve by 2012.

2. Beacon's NOW Homes®

Beacon has developed two NOW Homes® – in Waitakere and Rotorua. The Waitakere NOW Home® was completed in August 2005 and the Rotorua NOW Home® in September 2006. Both homes were designed and built to budgets and constraints typical of "ordinary" New Zealand housing rather than aimed at the top 5% of the market more typical of other "ecohomes". The Rotorua NOW Home® was developed in conjunction with Housing New Zealand Corporation and was designed and built for a budget at the affordable end of the market.

Passive solar design, resource efficiency, minimisation of hazardous materials and future flexibility were all key considerations in designing and building the homes. As a result less than 2.5 tonnes of construction waste was produced in each home's construction. This compares with a Tauranga study of construction waste produced in the development of new 3 bedroom homes that found that each home produced 6 tonnes of construction waste (Kazor and Keppel, 2007).

2.1 Waitakere NOW Home®

The Waitakere NOW Home® uses timber weatherboards, fixed to a timber frame on a heavily-insulated concrete slab. The roof is concrete tile, and the ceilings and walls are heavily insulated. The entire building is double glazed.

The building is sited to maximise the benefits of passive solar heating, using the highly insulated envelope to trap and retain the sun's warmth – mainly via the polished (no carpets) concrete slab. Passive ventilation is incorporated in the design to facilitate air changes without creating draughts – important for a healthy indoor environment.

A solar water heater is installed on the roof, and a water tank collects rainwater from the roof. The tank water is used for many non-potable water needs within the house. Where possible light fittings are high-efficiency compact fluorescent types.

The majority of the appliances belong to the tenants, however the range, fridge, dishwasher and washing machine are new efficient items supplied as chattels.

The Waitakere NOW Home® was been occupied over the period September 2005 – March 2008 by a family of four (two adults, two children). At the start of the tenancy the two children were of pre school age.

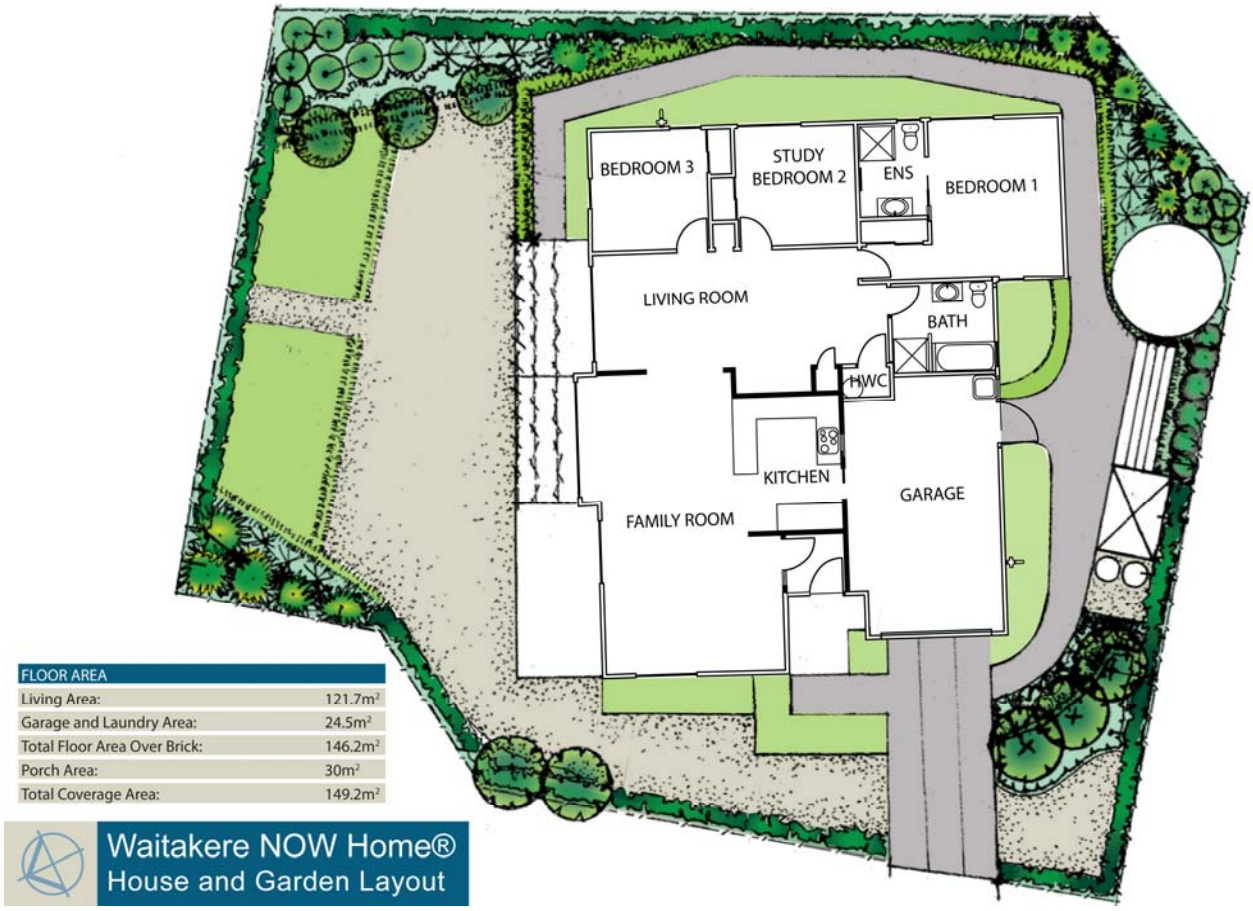

Figure 1 The Waitakere NOW Home®

2.2 Performance of the Waitakere NOW Home®

Monitoring of the Waitakere NOW Home® includes the collection of end use information for both the electricity and water use. Temperature and humidity are measured in each room as well as CO_2 in the living room. The water temperatures, solar radiation and water flows for the solar water heater were also measured (French et al, 2006).

Post occupancy evaluation surveys were also undertaken to capture the occupants' experiences compared with the previous house they lived in, to gain an understanding of the occupants' behavior and influence on the house performance as well as the influence of the house on the occupants.

2.2.1 Energy use within the Waitakere NOW Home®

In its first year of occupancy the Waitakere NOW Home® used 7400 kwh/year of electricity, with supplementary heating required on only two days. When compared to the occupants' previous dwelling, this was 45% less electricity than they used in their previous home (French et al, 2006). Figure 2 compares the electricity use between the occupants' previous dwelling and the first year of occupancy of the Waitakere NOW Home®. While there is a substantial difference, it can be seen that the gap was gradually closing over time. This trend continued into the second year of occupancy – with the occupants using 8500 kwh/year. A matched pair analysis of the electricity use was undertaken against the HEEP dataset[1], this showed that in the second year of monitoring the home used 25% less energy than comparable households, a reduction from the 33% less energy than comparable households used in the matched pair analysis undertaken in the first year (Pollard, French, Heinrich, Jaques, and Zhao, 2008).

Analysis of the both the monitoring data and post occupancy survey information reveals that the main cause of this significant rebound effect has been in the form of additional hot water use (longer and more frequent showers) and additional appliances being introduced into the home.

[1] HEEP – Household Energy End Use Project – a BRANZ Limited project where the energy end uses of 400 households across New Zealand were monitored and analysed in detail.

In addition the electricity use was supplemented by the electricity load (850 kwh/year) of the principal income earner in the family setting up a home office in the house, a core component of which was a computer server.

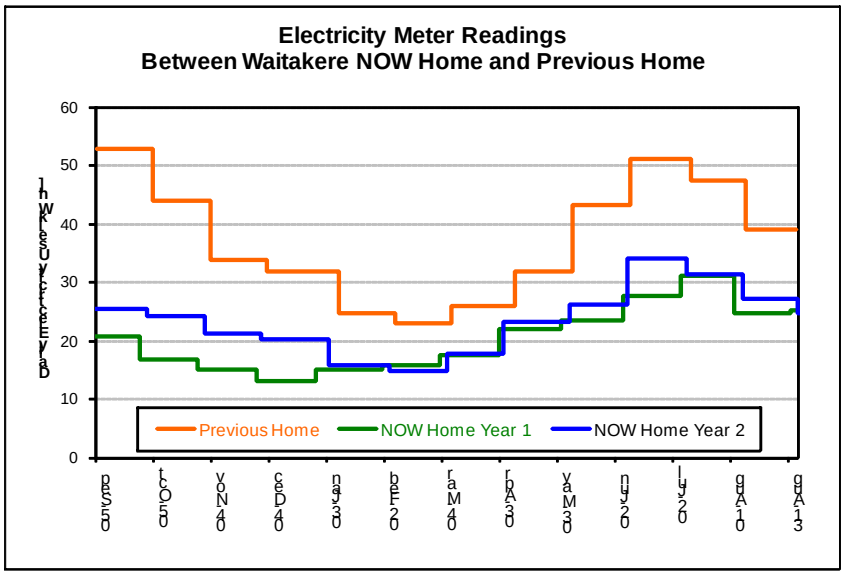

Figure 2 Comparison of electricity use by the occupants of the Waitakere NOW Home® compared to their previous home (after Pollard et al, 2008)

2.2.2 Water use within the Waitakere NOW Home®

Water use in the Waitakere NOW Home® was similar over the two years of occupancy, with a reduction in both total and reticulated water use in the second year (Pollard et al, 2008). Little good data exists on average water use in New Zealand (one of the reasons why NOW Home® data is significant), however comparisons with the surrounding households can be made due to the existence of metering. In their first year of occupancy the household used an average of 100 litres per person per day of reticulated water, with 189 litres per person per day of total water - the difference being supplied by the rainwater tank (French et al, 2006). In the second year of occupancy the household water use dropped to 85 litres per person per day of reticulated water and 172 litres per person per day of total water (Pollard et al, 2008).

2.2.3 Indoor Environment Quality within the Waitakere NOW Home®

Temperature and humidity data collected across the first year of occupancy identified that the temperatures within the home were maintained within healthy and comfortable parameters for the vast majority of the time occupied (Pollard et al, 2008**)**. In terms of user behavior, a portable heater was only required to be used by the tenants twice during what was a colder than average winter. Humidity levels however in the home were sometimes higher than considered desirable, particularly in winter and in the main bedroom next to the ensuite (French et al, 2006). Installation of a mechanical venting system in both bathrooms occurred prior to the second winter of monitoring, as it was suspected that this was a contributing cause to the humidity problems.

2.2.4 Experience of the occupants of the Waitakere NOW Home®

Interviews with the tenants and post occupancy evaluation identified that they considered the Waitakere NOW Home® to be "their best home ever". When compared with previous dwellings the family had occupied, in particular they valued the following features of the home:

- comfort (thermal, fresh air, lighting, sound insulation),
- physical attributes (concrete floor),
- utility (spaciousness, interior layout and flow), and
- service provision (electricity bills and hot water heating, recycling, security[2], clothes line)

[2] This rating is somewhat artificial, as their views were based on a private security firm checking the area at regular periods – which would not happen in more standard situations.

In terms of the features that were repeatedly discussed as being exemplary, the three that stood out were:

- the layout of the rooms and good use of space
- the thermal performance of the house, in terms of temperature stability and (almost) negating the necessity for winter-time space heating
- the concrete floor – in terms of its ability to keep clean.

The tenants thought that the overwhelmingly positive features of the house and its surroundings made a significant positive contribution to their inter-family relationships (Pollard et al, 2008).

2.3 Rotorua NOW Home®

The Rotorua NOW Home® has been built on the same principles of design and material selection as the Waitakere house, with the benefit of subsequently available knowledge, as well as meeting Housing New Zealand Corporation requirements for social housing. The house is owned by Housing New Zealand Corporation (HNZC), the main social housing provided in New Zealand, and forms part of their rental housing portfolio.

The Rotorua NOW Home® uses preprimed timber plywood and prepainted steel for cladding, fixed to a timber frame on a heavily-insulated concrete slab. The roof is prepainted steel, and the ceilings and walls are heavily insulated. The entire building is double glazed.

A solar water heater is installed on the roof, and a 5000 litre underground water tank collects rainwater from the roof. The tank water is used for toilet flushing and to supply the washing machine within the house. All light fittings are high-efficiency compact fluorescent types. Unlike the Waitakere Home, appliances were not supplied with the home, with the exception of the stove as HNZC policy is to not include whiteware.

Due to Rotorua's colder climate, the space heating requirement was four times that of the Waitakere NOW Home® and a low emission pellet burner was installed to provide supplementary heating.

The house was designed to provide for wheelchair access, and a second bathroom included was specifically designed for accessibility.

The home has been tenanted since September 2006 by ordinary HNZC tenants.

2.3.1 Preliminary Monitoring Results from the Rotorua NOW Home®

Monitoring results for the first year of occupancy have been analysed. Due to gaps in the data set because of issues with continuous data collection, the findings are considered to preliminary only. Analysis of the results (Jaques, Mathews and Pollard, 2007) indicates that reticulated energy use is lower than for the Waitakere NOW Home®, with 6800 kwh used in the first year of occupancy. In particular the proportion of energy used for appliances is significantly lower than that in the Waitakere NOW Home®.

Despite the presence of a pellet burner as a heating source, temperatures in the home occasionally fall below the benchmarks set in the Beacon High Standard of Sustainability – and World Health Organisation recommended minimums. Investigations into the cause of this are still underway, but indications are that this is as a result of a combination of factors:

- The tenant has covered the concrete floor thermal mass with carpet, preventing it from functioning as intended
- Tenant operation of the pellet burner does not appear to optimize its performance
- Difficulty in heat circulation to the bedrooms

Total water use is 199 litres per day, however at this stage the reticulated water use is not known, as analysis is still being undertaken.

3. Beacon's NOW Home® Renovations

In order to research how to improve the sustainability of existing homes, over February to June 2007 nine homes in Papakowhai, Wellington have been retrofitted with different packages of interventions. The houses were selected to provide case studies of "ordinary homes" in a middle income suburb. Middle income households were chosen because an evaluation of existing retrofit programmes (McChesney and Amitrano, 2006) found that low income households were the major beneficiaries of current government and community sponsored retrofit programmes, and often where the householders suffer from respiratory health problems. While laudable programmes, the performance data collected from the retrofitted homes is not considered to be representative of the wider performance of New Zealand's housing stock as the homes are generally chronically under heated. In addition, research has found (McChesney and Amitrano, 2006) that because of the very low level of energy retrofits undertaken as part of the programmes, temperatures in the homes

remain well below World Health Organisation suggested standards (and the Beacon HSS benchmarks) and, unsurprisingly, significant rebound effect occurs in any energy savings.

Accordingly, the project is testing a range of retrofit options aimed at determining what are the best (lowest cost, easiest to implement and most effective) packages of retrofit options which will substantially improve the resource use of a home and improve the indoor environment to meet Beacon HSS benchmarks. These retrofit packages address a number of core components which Beacon considers need to be included in a retrofit which will substantially improve the sustainability of a home. Different combinations of the following key features have been included in the packages:

- Significant increases in insulation (ceiling, underfloor and walls)
- Double glazing
- Solar hot water systems
- Fixed heat sources (heat pump, pellet burner and low emission wood burner)
- Water efficiency measures such as low flow fittings
- Mechanical ventilation of kitchen (rangehoods) and venting of driers
- Showerdomes (a device fitted over the top of the shower to prevent steam creation or release of moisture to air)
- Compost or worm bin
- Basic energy efficiency measures (draught stopping, compact fluorescent lightbulbs etc)

The pre-retrofit energy and water use, temperature and humidity of the homes was been monitored by BRANZ Ltd, and a pre-retrofit waste audit was also undertaken. While the post retrofit monitoring will continue to the end of winter 2008, some preliminary analysis of the pre-retrofit monitoring data has been undertaken. This analysis indicates that winter time temperatures in all but one of the homes were below desired benchmark levels of 16°C in bedrooms and 18°C in living spaces. Average winter air temperatures in the living room ranged from 16.1°C to 22.2°C during the evening and 11.6°C to 16.7°C during the night in the main bedroom (Buckett, French, Zhao, Burgess and Hancock, 2007).

Detailed analysis of the pre-retrofit energy and water use has not yet been undertaken, but preliminary analysis indicates a wide range of energy use patterns influenced by a range of factors. The highest energy use occurred in a home with all electric heating, cooking and hot water (Buckett et al, 2007).

4.0 Discussion

The findings NOW Home® and NOW Home® Renovation projects to date raise a number of interesting discussion points about the interaction between homes and their occupants, and the effect on occupant behavior of living in a more resource efficient home than their previous experiences. Further research is being undertaken to better understand this interaction, but there are some key points which arise from the data to date.

4.1 Rebound Effects in the Waitakere NOW Home®

The Waitakere NOW Home® was occupied by an “average” income household, who, by comparison with the HEEP matched pairs for energy use and surrounding households for water use (French et al, 2006) were relatively high resource users. In the first year of occupancy, the energy and water use of the household appeared to be substantially mitigated by the features of the Waitakere NOW Home®. This was experienced by the occupants in the form of reduced energy and water bills, with substantial financial savings. Towards the end of the first year, and into the second year, substantial rebound effects occurred (Pollard et al, 2008). This was largely in the form of increased hot water and appliance use, with new appliances introduced into the dwelling. In addition occupancy of the dwelling, in the form of its use as a home office appeared to increase over time – perhaps in response to the level of comfort provided by the dwelling. While not all of the resource efficiency gains have been taken back by the occupants (which still remains, compared to their previous home, 25% more energy efficient), there has been a substantial increase in energy use in particular. The increase in water use through showering has been more than mitigated by a decrease in outdoor garden water use – perhaps reflecting the initial garden establishment process being complete.

Informal discussions with the occupants of the home indicated that they were surprised when their power bills began to increase, and when combined with rising electricity costs, in the second winter became comparable with those from their previous home. It may be that there is a threshold above which the occupants would not increase their resource usage because of affordability limits and that this, combined

with the amount of physical space in the home to accommodate more appliances, may result in a tailing off of the rebound effect in subsequent years.

While monitoring data for the second year of occupancy of the Rotorua NOW Home® is not yet available, it will be interesting to compare what, if any, rebound effect occurs for this low income household with little discretionary income. Already appliance use (and therefore electricity) costs, is substantially lower than in the Waitakere NOW Home®, and overall electricity use is lower. It may be that, given the fixed income of the household, that takeback in the form of increased use of the pellet burner to gain additional comfort, ahead of appliance use, may occur. In this respect a carbon neutral heating appliance such as a pellet burner (which burns pellets made from wood waste generated in the plantation timber industry) is an ideal heating source for a low income household. Pellets are purchased in bags and the household is able to manage their heating costs on a weekly basis though how many bags they purchase.

4.2 Passive Solar Design and Thermal Mass in the Rotorua NOW Home®

The response of the Rotorua NOW Home® occupant to the concrete thermal mass floor in the home was unexpected, given that the Waitakere NOW Home® occupants valued this feature very highly. In the case of the Rotorua NOW Home®, the occupants quickly covered the floor with several rugs, adversely affecting its function. This is likely to be a contributor to colder than ideal temperatures being experienced in the home, as the thermal mass function was included in the design phase modeling the expected thermal performance of the home.

The reasons why the floor has been covered raise issues which need to be addressed if this approach is used more widely in this type of housing.

The occupants moved into the home immediately on it's completion in September 2006 – which in Rotorua is still cold and a core part of the heating season. The concrete slab had had little time to dry out, a process which could be expected to occur over the next year or so. To the new occupants it felt cold and they complained of this. In addition, one of the occupants was an elderly lady in her 90s, and the occupants expressed concern that a fall onto the floor may result in her suffering significant harm, or even broken bones. Whether or not such an occurrence is likely was immaterial to the occupants, as the perception issues drove their behavior.

Tenancy agreements do not generally include requirements around use of temporary floor coverings. If thermal mass is to be used in social housing, then it may be that other methods of incorporating high thermal mass, where occupant operation would have less influence may be preferable.

5.0 Conclusions

When considering how to move New Zealand homes towards a higher degree of sustainability, engagement of dwelling owners is a primary consideration. While the NOW Home® projects are showing the ability of features within a home to substantially mitigate against high resource using behaviours, these can easily be taken back by occupants in the form of increased services (eg hot water, heating) or through the addition of appliances.

A fundamental difference between more sustainable, and conventional housing however, is the ability of the home to be operated in an efficient and comfortable manner. Much conventional housing has no ability to be operated efficiently, without significant impacts on the comfort and health of the home. Homes such as the Beacon NOW Homes® are able to be operated with relatively low resource use, while still maintaining healthy and comfortable conditions inside.

The vast majority of homes which will be in use over the next 50 years have already been built (Amitrano, Kirk and Page 2006). Yet, the BRANZ House Condition Survey indicates that New Zealanders already under-maintain their homes (Clark et al 2005). When renovation data is considered, it is clear that much of the renovation undertaken is cosmetic in nature (Amitrano et al, 2006) and does not address the sustainability of New Zealanders' homes.

New Zealander's homes are the single largest investment that many people will make in their lifetime. They are also the place where many people spend most of their time. Yet when compared to a motor car, existing New Zealand homes have very few regulatory requirements placed upon them. A car requires a six monthly warrant of fitness and an annual registration, yet once they have achieved Code Compliance our homes do not require any kind of check, even at change of ownership or tenancy, to determine whether they are healthy, efficient or suitable for the household type who is proposing to live in them.

The Beacon NOW Home® and NOW Home® Renovation Projects aim to provide robust evidence around ways to improve the sustainability of New Zealand homes. While primarily research projects, there has been strong interest in the demonstration value of the homes – how ordinary New Zealanders can live ordinary lives but with a lesser impact on the environment, and in greater health and comfort than is currently the norm.

Acknowledgements

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