REAL EXPERIENCE OF RETROFITTING FOR SUSTAINABILITY

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ABSTRACT

While the construction of a new residential dwelling allows the incorporation of sustainable design, there are 1.6 million existing homes in New Zealand which have a limited ability to incorporate sustainable design. In particular, nearly 1 million homes in New Zealand were built before the first New Zealand house insulation standard in 1978. This paper presents some of the challenges and successes of performing sustainability interventions on a set of 10 'ordinary' occupied, New Zealand houses built in Papakowhai (Porirua) in the mid-70s, as a Beacon Pathway project performed by BRANZ Ltd. Interventions made in the renovation of these houses, including the installation of double glazing, bulk insulation in walls, ceilings (to R5.2) and under floors, appliance water flow modifications and space heating improvements, together with solid waste handling and modifications to the indoor environment. While the project includes the long-term monitoring of the internal environment, the aim of this paper is to feature the success of the installation of these sustainability interventions while the houses were occupied.

KEYWORDS

Renovation, sustainability, retrofit, Beacon Pathway Ltd, BRANZ Ltd.

INTRODUCTION

The New Zealand Building Code is focussed on the construction of new housing in New Zealand, and significant new requirements are being introduced to improve the sustainability of new domestic buildings[1]. However there is little regulatory incentive to upgrade the 1.6 million existing dwellings (Amitrano et al 2006) to higher standards of sustainability. The current drivers for sustainability upgrades are primarily the internal ones of maintenance and running cost reductions. In particular, there is much housing constructed prior to 1978 that remains only partially insulated (Clark et al 2005), and is therefore unable to adequately control internal temperatures without substantial investment in space conditioning.

The key goal of Beacon Pathway Ltd[2] is to upgrade 90% of New Zealand's existing housing stock to a high standard of sustainability by 2012 (Easton 2007), and Beacon has initiated the project which this paper discusses as a step to investigate the methodology necessary to achieve this.

[1] For example the revision to the New Zealand Building Code clause H1, dealing largely with insulation requirements, to be implemented in October 2007.

[2] Beacon Pathway Ltd is a residential building industry research consortium aiming to drive sustainability outcomes consistent with New Zealand sustainable development requirements. Beacon is funded by industry, with matched revenue from government research funds from the Foundation for Research, Science and Technology. There are currently five shareholding partners: BR (Building Research Association of New Zealand), Scion, New Zealand Steel, Waitakere City Council and Fletcher Building.

BRIEF

BRANZ[3] was commissioned by Beacon Pathway to undertake a pilot renovation project on 10 'ordinary' owner-occupied New Zealand houses to bring them up to a high standard of sustainability.

To do this, the performances of the homes in the areas of energy, indoor environmental quality (IEQ), water, and solid waste were addressed, and monitoring was undertaken with the consent of the homeowners to measure the effects of the changes to the homes.

The three Beacon Pathway Ltd sustainability levels (Easton and Collins 2007) with corresponding package interventions are described below:

1. The **"Basic Standard"** renovation – uses existing standard packages prescribed in some existing New Zealand retrofit programs[4] plus non-energy interventions to attain an improved level of sustainability. Here basic water-saving (e.g. low-flow showerheads), solid waste minimisation (e.g. recycling and worm farms), energy saving (e.g. cylinder wraps and compact fluorescent lights) and humidity reduction measures (e.g. extraction fans) were combined with non-invasive insulation top-ups or retrofits to augment the energy-oriented retrofits funded and subsidised by local and central government agencies.[4]
2. The **"Beacon Standard"** – uses a heightened level of interventions to bring houses a reasonable way toward the 'Beacon High Standard of Sustainability'™, as outlined below. Water saving, solid waste minimisation and energy saving measures were combined with higher levels of insulation than the Basic Standard package, plus additional simple and moderately priced interventions.
3. The "**Beacon High Standard"** – uses more extensive interventions to allow houses to achieve the 'Beacon High Standard of Sustainability'™. This has all of the Beacon Standard solid waste reduction measures, water and energy saving modifications, but with higher levels of insulation and incorporating more extensive, costly and difficult interventions, including (but not limited to) solar water heaters and sustainable, high efficiency space heating.

PROJECT AIM

The project was designed to develop understanding through a research project on how to retrofit a high standard of sustainability to the existing New Zealand housing stock. By installing groups of interventions at differing levels of sustainability, the project was to determine the most cost-effective changes in each of the areas of energy, IEQ, water and solid waste to enable the achievement of the Beacon High Standard of Sustainability™.

In the planning of the project, initial sustainability interventions were identified, and in order to allow manufacturers and the building industry to support and engage in this project, donated materials were sought (the full list of project support is included in the Acknowledgements section of this paper). This gave the project the potential to expand the interventions available,

[3] BRANZ is a commercial organisation wholly owned by Building Research Ltd, and funded in part by the Building Research Levy. BRANZ undertakes research, consultancy, testing and publishing of issues pertinent to the built environment.

[4] The EECA and the Environment Canterbury upgrade programs are among such initiatives where ceiling, insulation, energy-efficient lighting and hot water cylinder wraps are among the interventions mooted.

and as the materials and funding available was confirmed, the applied interventions were continually modified to match, ensuring that the research aims were not compromised.

It was intended for this project to help set a new achievable level of renovation, using technology widely available now in the implementation of sustainable intervention packages on pre-1978 houses. While not the subject of this paper, the project will conclude with a cost-benefit analysis of the renovation options drawn from monitoring the houses from spring 2006 to the end of spring 2008.

SELECTING THE HOUSES

In order to minimise the cost of monitoring, 10 houses were selected in Papakowhai. This is a typically middle-class area first developed in the mid-1960s on the eastern side of Porirua Harbour around 20 km north of Wellington, and close to BRANZ's campus at Judgeford.

All of the homes were owned by the occupiers, and included single, split level and two-storey houses with a range of sizes, materials and designs, demographically stratified.

A letter was sent out to house occupants within the designated area explaining the project and its objectives, and requesting offers of participation. The incentive to become part of the project was having an improved indoor environment from which they would continually reap the benefits, and retaining any resulting profit upon sale of the house. Interested occupants/homeowners were asked to complete a form establishing the characteristics of the house and occupancy, methods of heating, and fuels used in the home to assist with the selection of the houses.

The response rate to the project was high, with an overall reply rate of over 51%, and a positive reply rate of over 41% of all letters sent out, as seen in Figure 1. The high response rate was likely to be a reaction to the potential value of the return offered to the homeowners.

	Number	Percentage
Letters sent	355	100%
Overall Reply Rate	182	51.3%
Positive Replies	148	41.7%
Negative Replies	34	9.6%
No Reply	173	48.7%

Figure 1: Response rate to the letter appealing for participants for the Beacon Renovation Project.

The information provided by the 148 positive responses was compiled, and the houses were sorted by occupancy types. Occupancy groups included families/high occupancy, small families/lower occupancy (1+ spare bedrooms likely), couples/non-families/low occupancy (2+ spare bedrooms likely). From the responses, 10 houses were randomly selected to go into the project with a certain number from each occupancy type.

Homeowners were notified of their involvement, and upon agreeing to participate were surveyed in part to establish what might be the most effective retrofits to install into their home. When the intervention packages for each house were decided upon, homeowners were given proposals of the packages likely to be installed (which were subject to change), and provided confirmation that they agreed to and understood which retrofit options were expected to be completed to improve their house. Before work commenced, a Memorandum of Understanding was signed by both the homeowner and BRANZ representatives.

Before the sustainability interventions took place, one house was sold, reducing the sample to nine. Unfortunately this is always a risk when carrying out long term monitoring in houses for research purposes and it is not easily avoided by stipulating legal requirements etc. Ideally protection against this eventuality should be built into the sample size.

INTERVENTION SELECTION AND IMPLEMENTATION

New Zealand houses use a wide range of products to increase the liveability and sustainability of the built environment. Many retrofit products are regarded as almost exclusively suitable for new-build applications, such as wall and mid-floor insulation. Others are highly expensive, with paybacks that remain higher than the typically acceptable 5 – 7 years which in turn relates to the average ownership period in the New Zealand situation. This project was designed to establish those interventions that would advance the sustainability of the subject houses, while the economic costs and benefits were being measured. The interventions had to take place while the houses were occupied, with only short periods of occupant vacancy acceptable. Consequently the selection of the sustainability interventions was carefully considered from many different perspectives.

Intervention choice

While initially the project was to implement standardised retrofit packages, the focus shifted in accordance with research that concluded that standardised packages may not be the best approach to achieve maximum sustainability benefits (McChesney and Amitrano 2006). Therefore, the sustainability interventions were chosen on the basis of a study that was performed as the first stage of this work (Page 2007), together with other recent New Zealand research (Amitrano et al 2006) and recommendations from other retrofit programmes (McChesney and Amitrano 2006). Over-riding this was the economic imperative, where the impact of the sustainability interventions must compare well to the cost of their purchase and installation, as well as fitting within the budget that was available for the research project. Consequently, a shortlist of interventions was decided upon.

For the more substantial interventions, they were approved if they achieved some or all of the following:

- Reduced energy use and associated emissions
- Likelihood of the interventions paying for themselves
- Desirable and readily available on the open market
- Tried and tested – nothing highly experimental
- Good results with minimal maintenance requirements and costs.

The focus then shifted to the availability of some standard interventions, including assessing what had previously been done and promoted in New Zealand through charitable organisations, local government projects and central government, with options for extension and improvement considered (McChesney and Amitrano 2006).

In order to incorporate sustainability enhancements in all the areas of energy, IEQ, water and solid waste interventions (Buckett et al 2007), the following items were proposed for the major interventions:

- solar water heaters
- efficient wood-burner with wetback to replace an old model
- pellet burner

- heat pump
- ceiling, underfloor and wall insulation
- heat pump hot water system
- rainwater tanks
- grey water waste treatment system
- water-saving devices (e.g. water-saving showerheads)
- double glazing
- secondary glazing
- incandescent light bulb replacement with CFLs
- instant gas water heaters
- heat transfer kits
- extraction fans and/or rangehoods.

Since it was not possible to use the "Cookie cutter" approach with a standard intervention package, this meant that each house ended up with a sustainability intervention that was uniquely tailored to each house, giving nine different packages. This involved project management involvement to a far greater level than was originally anticipated at the start of the project.

The following are examples from the nine different packages that were offered to meet each of the three sustainability levels:

Beacon High	Skillion ceiling lowered and R 3.9 fibreglass batts installed Roof replaced and R 1.8 blanket insulation installed into original skillion roof cavity R2.0 underfloor insulation Underfloor polythene R2.4 fibreglass batt wall insulation installed Rangehood installed Pelmets rebuilt Plumbing check Solar hot water panels and cylinder Wormfarm Double glazing panes and frames Dual flush toilets

Table 1: Example of Beacon High sustainability intervention in P03.

Beacon High Sustainability - Other interventions done as part of the "Beacon high" package included a high efficiency woodburner with a wetback to replace an old, non-wetback model to complement the solar water heating system installed. A pellet burner was installed into another property, along with a ducted heat transfer system in the lowered and insulated skillion ceiling. It was decided not to install a heat pump into the sample as one house had two heat pump units in operation, and one other installed a heat pump near the beginning of the project. Up to five compact fluorescent light bulbs (CFLs) were put into high-use areas where possible. Draughtstopping of doors and windows was installed where necessary.

Beacon Standard	Ceiling insulation top up R2.0 underfloor insulation Insulation between garage and main bedroom

	Underfloor polythene
	Wall insulation in one specific area
	Hot water cylinder wrap and hot pipe lagging
	Showerdome
	Plumbing check
	Wormfarm

Table 2: Example of Beacon Standard sustainability intervention in P09.

Beacon Standard Other interventions done as part of the "Beacon Standard" package included the replacement of an original, 1970s electric hot water cylinder. Up to five compact fluorescent light bulbs (CFLs) were put into high-use areas where possible. Draughtstopping of doors and windows was installed where necessary.

	Ceiling insulation top up
	R2.0 underfloor insulation
	Underfloor polythene
Basic	Hot water cylinder wrap and hot pipe lagging
	Extraction fan installed
	Wormfarm
	Plumbing check

Table 3: Example of Beacon Basic sustainability intervention in P02.

Beacon Basic Other interventions included putting up to five compact fluorescent light bulbs (CFLs) into high-use areas where possible. Draughtstopping was installed where necessary.

Installation of Interventions

There was found to be considerable difficulty in retrofitting items and materials into '70's dwellings, which in some cases involved the site becoming unliveable while work was in progress. As this had been anticipated, the willingness and ability of the homeowners to accommodate the changes was taken into account when forming the renovation packages, with some negotiation needed to ensure mutually acceptable outcomes.

Soon after the bulk of the donations of goods and services had been negotiated, project management was passed on to EnergySmart.[5] Contractors were used to carry out the jobs, with EnergySmart in direct contact with the majority of these contractors and tradespeople. Due to the complexity of the renovations, the number of homes each with a different set of renovations, and the cross-over of different contractors and tradespeople for some of the interventions, project management was far from straightforward. Despite a very good level of project management, sue to labour shortages, lack of industry knowledge for these types of retrofits and miscommunication, there were substantial delays and the cancellation of some of the interventions after the renovation timeframe had closed. Cancellations included secondary glazing and rainwater tanks.

The delays experienced by the project led to the initial renovation period being extended from 2 months to around 8 months. Homeowners, while accepting the delays due to realising the end

[5] EnergySmart is wholly owned by the Hutt Mana Charitable Trust. They supply and install energy-efficiency products and services, and undertake consultancy and project management contracts.

benefits from the work, were inconvenienced for far longer than anticipated, particularly for those where substantial changes were made to homes.

OVERCOMING CHALLENGES TO THE PROJECT

LOSS OF SAMPLE

Challenges to the project were experienced early on, with one of the households having to pull out due to a house sale forced by illness.

A second house having aspects of the indoor environment monitored was to receive no interventions, and the homeowner indicated that they would pull out of the project because of this. In order to retain the house in the sample and continue monitoring, the decision was made to put in a basic retrofit. This proved to be a good incentive to stay on, so the work was performed and the house remained in the sample.

In this case, having a constant team member downloading data at the home on a monthly basis allowed for problems to be picked up quickly and feedback to come through and homeowners concerns and expectations managed.

CONSENT ISSUES

Due to the scale of the project, the council required drawings to be submitted of all changes to the external envelope of the house, which led to the submission of more documentation to the council than would ordinarily be required of a homeowner.

Solar water heating systems were installed into three houses during the project. In one house, the cylinder was shifted away from supporting walls to cope with its increased height. Strongbacks were needed to spread the additional load and further drawings and consents required.

Confusion surrounding the consent process is a barrier to achieving substantial renovations, and significant ongoing communication was essential.

DOUBLE GLAZING

As part of the interventions on two of the houses, double glazing was to be installed. Drawings of the proposed work were approved by the council, and constructed, but prior to inspection, advice was received that the windows would have to comply with New Zealand Building Code's E2 AS1 – the acceptable solution for new-build installation of aluminium windows. Given that this was not possible, an alternative solution to E2 was approved, but could not be installed appropriately. Once flashings had been modified and the windows installed for the third time, a solution was finally achieved.

MATERIALS AND SERVICES

In order for the larger interventions to proceed, donations of materials and services were sought. However, this reduced the choices available and subverted the normal supply channels, substantially increasing project management costs.

Few tradespeople were prepared to take on the multiplicity of 'small' work with potentially high risks that were inherent in this project. In the end a construction company with their own project management team did most of the construction work, allowing much of it to be streamlined.

During the renovation process, several issues arose with construction. One example of this was the installation of off-cuts of plasterboard onto a lowered skillion ceiling, creating a sort of patchwork effect. Gaps and damage to the plasterboard meant the plasterer could not achieve an acceptable finish. After a delay, the situation was resolved with the ceiling relined with new sheets of plasterboard, and the plastering was completed.

HOMEOWNERS' PERSPECTIVE

The homeowners typically entered the project due to the potentially large rewards for doing so, because they were enthusiastic about sustainability, or because they were already planning renovation work. For each household, not knowing where to begin and the cost - perceived or real – of the renovations desired, had prevented or delayed them carrying out retrofit or renovation work themselves.

The homeowners were generally receptive to the suggested interventions proposed to them, and one household replaced a leaky skillion roof to allow the installation of insulation in the roofspace.

During the installation process homeowners contended with periods when the house was unliveable, moved furniture, damage to décor, and sometimes extensive delays when setbacks were experienced during the installation period. For items that had been consented by local authorities there was some confusion with the consent process and about when an appliance (e.g. wood-burner) was deemed safe to use due to the many parties involved.

BRANZ PERSPECTIVE

Since there were five different groups involved in the Beacon Renovation Project: BRANZ, Beacon Pathway, EnergySmart, homeowners and tradespeople, communication became perhaps the greatest challenge to undertaking this part of the project.

As this was a research project monitoring the houses to assess the viability of the sustainability interventions, it was important that all decisions made during the renovation preserved the integrity of the research being undertaken. The results need to provide sound research conclusions and result in robust recommendations for the improved environmental sustainability of the New Zealand built environment. (The monitoring results will be available in 2008).

SUCCESS

Throughout the renovations the project has educated homeowners about the technologies available, what can be achieved, and how one goes about using the interventions installed. By the

end of the project it is anticipated that the homeowners will be well-educated as to how their active interventions work.

While not all of the planned interventions were able to be included in the project, the vast majority have been, including three solar hot water systems (including one supplemented by a wetback connection), two whole-house insulation packages, and two double glazing packages. This is a significant 'step up' from a typical New Zealand retrofit.

When one household was considering pulling out of the monitoring project, the installation of a basic sustainability package won back their continued participation, showing the perceived value of improving the sustainability of the home.

Less than four months after the installation of interventions there has been positive feedback from homeowners indicating that the renovation interventions have noticeably changed the living environments in their homes. The extent to which this has occurred will be confirmed when the monitoring data is completed and analysed.

The Beacon Renovation Project is an opportunity for the term 'renovation' to acquire a new meaning to New Zealanders. From concentration on the superficial 'do-up', it is hoped that this project and others like it, will encourage renovations of homes to be based on more than just aesthetics and focus on improving the sustainability, health and comfort of the living environment. This project represents the opportunity for government agencies and charitable trusts to assess the additional benefits of the next level of the renovation process involved in more extensive interventions.

KEY LEARNINGS

It is likely the shortage of tradespeople willing to do 'small' jobs will continue to have an impact on people improving the sustainability of their homes.

While individual sustainability packages are likely to obtain better results, use of standardised packages would have been a much less expensive way of retrofitting the homes in this project.

Use of differing interventions meant that, tradespeople were unable to perfect the installation of the desired interventions, leading to higher labour costs. Also, because there were few multiple purchases of particular interventions, bulk discounts were not readily available.

Communication paths must be open between homeowners, tradespeople, designers and/or project managers in order for this work to be successful.

Homeowners must remain well-informed throughout the process. It is wise to bear in mind that ultimately it is the homeowners who will (or will not) use the interventions and therefore it is imperative that they are involved in the final decision process. Where occupants are hesitant or reluctant, incentives may improve participation.

There is a need for an acceptable solution to cover the installation of heavier double glazed windows as replacement for older aluminium or timber window systems.

CONCLUSION

BRANZ have successfully renovated these homes with a very positive response by the homeowners. This has led to identifying key areas that are barriers to New Zealanders carrying out substantive retrofits and renovations on their homes, and opportunities for further work in providing tools and information to reduce or remove these barriers. These include:

- Standardized and consistent building consent requirements and information
- Communication requirements between parties involved in the process
- Education of industry as to an acceptable level for 'higher' levels of retrofitting, covering the definition of 'higher' levels of retrofit, as well as how to carry it out
- Double glazing retrofits require second acceptable solution (AS2)

Although it cannot be confirmed until the full project is completed, initial indications show the interventions have improved the sustainability and liveability of these homes.

ACKNOWLEDGEMENTS

The support of the following companies and organisations is gratefully acknowledged. Without this the project would not have been possible.

Azzuro Solar donated three solar water heating systems and installation
EnergySmart provided project management
Fletcher Aluminium provided the aluminium extrusions for window frames
Hutt Mana Charitable Trust provided funding towards the insulation installations
Metro GlassTech kindly supplied glazing systems
Porirua City Council donated building consents and provided support and advice
Rinnai New Zealand donated two instant gas water heaters
Tasman Insulation provided discounts on the insulation products
Winstone Wallboards donated plasterboard.

This project was funded by Beacon Pathway Ltd, and BRANZ Ltd benefited from their project involvement.

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