TE106/9

Papakowhai Renovations – Impacts on Householders and Dwelling Performance

February 2008

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

About This Report

Title

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Reference

Saville-Smith., K., January 2008. *Papakowhai Renovations – Impacts on Householders and Dwelling Performance.* Report TE106/9 for Beacon Pathway Ltd

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1 Background

Beacon Pathway is committed to improving New Zealand's sustainability in the residential built environment through the provision of relevant and robust research. Beacon Pathway places considerable emphasis on technology and knowledge transfer. To test the performance opportunities and benefits of retrofitting existing houses, retrofits of varying components and levels of investment have been undertaken in a small set of case study dwellings in Papakowhai. The impacts of those retrofits have been monitored by BRANZ. The results of that monitoring must be contextualised in relation to household characteristics, behavioural patterns, expectations, perceptions and experiences. This has been undertaken through semi-structured, conversation-based interviewing.

2 Scope of the report

This report:

- presents the findings of the in-depth interviews with nine of the ten householders involved in the Papakowhai retrofit, and
- comments on the learnings from Papakowhai in relation to:
  - retrofit processes
  - retrofit packages, and
  - research method.

The report is structured as follows:

- Section 3 presents an overview of the interview and analytic methods.
- Section 4 presents the findings for each of the households/dwellings that participated in the interviews – nine of the ten households in retrofitted dwellings.
- Section 5 comments on some implications for the interpretation of the dwelling performance monitoring findings emerging from the householder interviews.
- Section 6 comments on learnings in relation to retrofit processes and packages.

3 Overview of Method and Data

This section:

- Provides an overview of case study method and its particular application in relation to the Papakowhai Renovation Project.
- Sets out the process and instrumentation used for the householder interviews.
- Comments on the data used in this report and associated analytic limitations.

Case Study Method and Papakowhai

The retrofit of the Papakowhai dwellings presents Beacon Pathway with cases studies of dwelling performance the data from which needs to be interpreted in the context of householder expectations, experiences, behaviours and perceptions. Case studies are useful ways in which micro-level data, both objective and subjective, can be collected and analysed. While the case set has no statistical power and the cases can not be generalised to the populations (either dwellings or households) of which they are an example, case studies can lend themselves to exploring areas of contrast and continuity.

To allow for that sort of analysis, case studies are typically characterised by:

- A case frame that allows certain case characteristics to be varied systematically while other characteristics are held constant and the ability to undertake controlled comparative analysis.
- Collection of qualitative, narrative data from participants.
- Collection and use of a wide range of quantitative and qualitative data with a particular emphasis on triangulation and using different datasets to illuminate and interpret each other.
- An analytic emphasis on comparing cases to establish care similarities and contrasts.

Those conditions have not all been met in the Papakowhai Renovation Project.

The case frame for Papakowhai is characterised by high levels of variation in each of the critical domains – the dwelling, the household and the retrofit. There has not been close control over the dwelling type. Consequently the dwellings have significant dissimilarities despite being built, broadly, around the same period. The household structures of the participant household also vary. That variation is both synchronic and diachronic. Synchronic variation refers to differences between households at any particular moment across the full set of cases. Diachronic variation refers to variations in a single case across time. Both the household composition and household use of the dwellings have changed in some cases over the research period. Finally, the renovation packages installed in each dwelling also differ from dwelling to dwelling. The analytic implications of this high level of variation are discussed in section 3.3. It suffices simply to note at this point that the variation presents particular challenges to undertaking comparative case analysis.

Three sets of data have been collected in relation to the cases. They are:

- Pre- and post- retrofit monitored or administrative data in relation to:
  - energy use
  - indoor temperatures
  - indoor humidity
  - water use.
- Information about the retrofit interventions delivered to each dwelling and their approximate market value.
- Data related to the household and householder experiences. The bulk of the latter has been collected through initial self-reports and the interviews reported in this report.

Interview Process and Instrumentation

Householders were interviewed in late 2007 but that data was found not to be amenable to systematic analysis. Consequently, a semi-structured, conversational interview schedule was developed and implemented in February 2008. The interview burden on participants by this double interviewing was acknowledged to be high. For that reason, the second wave of interviewing was limited to the following topic areas:

- Motivations and expectations around involvement and retrofit benefits.
- Knowledge of the retrofit undertaken in their dwelling.
- Perceived impacts of the retrofit on dwelling performance
- Perceived achievements/benefits of retrofit both:
  - expected
  - unexpected.

- Issues around process and/or failure to achieve benefits.
- Taste for retrofit and retrofit expenditure.

The interview structure is attached as Annex A. Most interviews involved a senior CRESA or associated interviewer assisted by a note taker.

Analytic Limitations

It has already been noted that a wide variety of data has been collected, both quantitative and qualitative. That data allows from some triangulation and additional understanding of the monitoring data associated with each case. There are, however, some limitations on comparative analysis between cases. To allow clear comparative analysis, the cases would have had to have been selected to hold constant and reduce the variation on at least some characteristics across all of the selected dwellings and households. The cases essentially explore the dynamic between the:

- dwelling
- household, and
- renovation package.

It is unclear precisely what the analytic expectations were at the start of this research. It is not unusual for the focus to be changed or clarified over time. However, in terms of the current preoccupations of Beacon – a desire to explore the impacts, costs and the performance returns on different levels of retrofit – it would have been desirable for the dwelling type to be held constant. Households are notoriously difficult to hold constant over time, but the focus on renovation package assessment would have been facilitated if all the households had been selected with similar compositional and life stage characteristics. Table 1 indicates the considerable variability in relation to each of the three domains across the nine case study dwellings involved in the interviews.

Table 1: Key Characteristics of Cases in the Papakowhai Retrofit Programme

Dwelling Number	Household Characteristics	Dwelling Characteristics	Pre assessed Intervention Level	Retrofit Cost
P01	Couple and 1 pre-school and 1 primary school aged children	1.5 storey 3-bedroom 2-bathroom 1-living room Mixed cladding Mixed window frame Concrete slab lower floor Corrugated iron roof Skillion roof Good condition Residential and Work Use	Medium	$23,110
P02	Semi-retired couple	3 storey 4-bedroom 2-bathroom 1-living room Mixed cladding Timber window frame Concrete slab lower floor Corrugated iron roof Good condition Residential use only	Low	$2,120

P03	Couple and 2 school aged children and 1 secondary school aged child	1.5 storey 3-bedroom 2-bathroom 1-living room Mixed cladding Aluminium window frame Concrete slab Corrugated iron roof Mixed skillion and cavity ceiling Poor condition Residential use only	High	$72,990
P05	Retired couple	1 storey 3-bedroom 2-bathroom 1-living room Weatherboard and brick cladding Timber composite window frame Concrete slab Stonechip coated metal tile roof Excellent condition Residential use only	Medium	$10,680
P06	Semi-retired couple	2 storey 4-bedroom 1-bathroom 2-living room Mixed cladding Mixed window frame Concrete slab Concrete tile roof Good condition Residential use only	Basic	$1,380

P07	Couple	2 storey 4-bedroom 2-bathroom 1-living room Mixed cladding Mixed window frame Concrete slab Stone chip metal tile roof Poor to Good condition Residential use only	Medium	$7,540
P08	Couple	2 storey 4-bedroom 1-bathroom 2-living room Mixed cladding Mixed window frame Concrete slab Long run iron roof Good to Excellent condition Residential and work use	High	$24,610
P09	One person	2 storey semi-detached 2-bedroom 1-bathroom 2-living room Mixed cladding Concrete slab Concrete tile roof Reasonable condition Residential use only	Medium	$4,830

P10	Couple and 3 children including primary and secondary aged children	2 storey 4-bedroom 2-bathroom 1-living room Mixed cladding Mostly timber frame Concrete slab Concrete tile roof Poor condition Residential and work use	High	$38,030

Given that case controls were not established in the case frame, the analysis must largely be limited to:

- improving our understanding the householder experience in the context of the dwelling performance data
- illuminating the dwelling performance data in relation to the householder experience
- identifying any patterns between householders regarding:
- expectations of renovations
- achieved expected and unexpected benefits
- issues around renovation participation, and
- choices around retrofit and willingness to pay.

4 The Case Findings

Nine dwellings have both monitoring data and householder data. They are:

- P01
- P02
- P03
- P05
- P06
- P07
- P08
- P09
- P10

Key data related to each of those dwellings is presented in sections 4.1-4.9.

The case findings provide an overview of the dwelling and its household are the beginning of the retrofit process. It then lists BRANZ's record of interventions undertaken, market value and their assessment of the package level. It comments on the monitored performance of the dwelling and triangulates and illuminates those performance results by reference to the interview data. Finally, case data related to householder views of the retrofit process, benefits and costs are presented.

4.1. Dwelling P01

This dwelling is occupied by a couple and their two children. The dwelling is used as the basis for a part-time business. The children are pre-school and primary school age respectively. BRANZ's description of this dwelling is set out in Table 2. The interventions and BRANZ's estimate of the market value[1] of those interventions are set out in Table 3.

[1] ***All market value information has been supplied by BRANZ.***

Table 2: BRANZ Dwelling Description – P01

Age	Construction	Layout	Initial Condition
Early 70s	Mixture of sheet cladding and timber weatherboard, timber suspended floor on upper levels, uninsulated concrete slab under garage and utility areas downstairs. Corrugated iron roof. Single glazed, predominantly timber-framed windows, older aluminium in shower room and master bedroom.	Split level, living areas (containing woodburner/pellet burner) above garage, bedrooms and bathrooms down on split level to southeast. Three bedrooms, one living room and two bathrooms.	Overall good, although some draughts and no retrofitted insulation. Other features: Skillion roof with low value original insulation (approx R1), over upper two levels.

Table 3: Retrofit Interventions – P01

Issues	Actual Interventions	Approx. Market Value (exc GST)	Resulting Package
Draughty single-glazed timber-framed windows			
Skillion ceilings throughout with inadequate insulation	Lowered and insulated ceiling to R4.6 (R2.6 in places)	$12,770	
	Plasterboard (13mm) for ceiling	$570	
Draughts from downstairs around sliding door	Heavy draught stopping around door to garage	$100	
Uninsulated cavity walls			
Uninsulated underfloor	Insulated floor with R2 foil-backed bulk insulation, polythene put on ground	$1,960	
Uninsulated midfloor above garage			
Older Woodburner	Pellet Burner installed	$4,330	
Inadequately heated bedrooms	Ducted heat transfer kit with 3 outlets installed	$3,020	Medium

Food waste not being composted	Worm farm installed	$160	
Energy in-efficient lighting	Compact fluorescent bulbs put into high-use fittings	$30	
Plumbing quality unknown	Plumbing checked	$80	
High mains water use			
Leaky fridge seals			
Poorly insulated B Grade Electric Hot Water Cylinder	Hot water cylinder wrapped and pipes insulated with lagging	$90	
	TOTAL	$23,110	

These householders were attracted to the renovation project because it offered them opportunities to increase the value of their home while increasing its sustainability. They had some specific concerns about the performance of their house and household health. In particular, they found the house cold in winter – particularly in the children's bedrooms – and 'unbearably hot' in summer. They saw retrofitting as a way of saving money and a means by which they could better manage the conditions for family members suffering from asthma.

Despite the considerable investment and range of interventions the householders still see the house as having performance problems. As Table 4 shows, the gains in indoor temperature are statistically significant.[2] The householders also believe family room and bedroom temperatures have risen during winter. Indeed, they are entirely satisfied with the winter family room temperatures despite the winter average still be substantially lower than WHO optimal temperatures at 15.7 ° C as a winter average. However, they find the thermal performance in summer is poor with excessive heat. In addition the children's rooms are still described – correctly given that the winter temperature is an average of 14.3° C – as cold.

[2] ***Statistical analysis in relation to this data was undertaken by BRANZ. Any references to findings being statistically significant in this report are based on analysis supplied by BRANZ. These findings have not been independently tested by CRESA.***

Table 4: Dwelling Performance Summary – P01

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	301	38	332	155	14.8	13.2	63.55 - 73.69
Post	297	31	305	159	15.7	14.3	

Table 5: Winter Average Temperature Ranges – P01

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	11.60	13.10	17.27	18.50
family room b	12.88	14.81	18.40	19.19
family room average	12.24	13.96	17.84	18.85
bedroom	11.22	12.18	16.47	17.10

It is notable in Table 5 that both minimum and maximum winter average temperatures have risen. However, the maximum bedroom temperature remains marginal to the healthy indoor temperature benchmarks.

The householders have increased the level of warming in the family room and this probably accounts for the lack of statistically significant reductions in energy use and the failure to reduce energy costs. The wood pellet burner is seen by the householders as extraordinarily efficient, convenient, ‘guilt free’ and safe. Typically the household reports running the pellet burner from 4 pm to 10.30 pm in winter. They did, however, find that the pellet burner was noisy and commented that costs associated with it were high. The householders reported that they used 60 bags of pellets at $12/bag over winter.

Heating does not appear to have addressed problems of humidity and condensation. Table 4 shows that humidity during winter was highest at night and morning reaching over 70 percent while the average winter humidity over 24 hours was measured as 67.88 percent.

These householders clearly believe that double glazing would have been a useful and effective intervention. They saw the pellet burner as providing the most benefits and would choose that intervention above all others. They also identified the worm farm as giving them very real

benefits. Overall, the householders saw themselves as expending around $20,000 on retrofit if it improved indoor temperature management.

The householders identified a number of process problems despite being appreciative of the opportunities and investments provided through the project. Those problems include:

- Uncertainties about the package to be provided.
- Unfulfilled expectations around interventions, particularly:
  - double glazing
  - wall insulation
  - dual flush toilet.
- Having to undertake work including:
  - installation of plasterboard
  - removal of old batts.
- Delays and disruption including:
  - significant gaps between successive stages
  - unreliable workmen
  - lack of planning of tasks and work sequence in consultation with the household.

4.2. Dwelling P02

A semi-retired couple reside in this dwelling. BRANZ's description of this dwelling is set out in Table 6. The interventions and market valuation of those interventions are set out in Table 7.

Table 6: BRANZ Dwelling Description – P02

Age	Construction	Layout	Initial Condition
Early 70s, downstairs addition added during the 70s, master bedroom extension done after 2000.	Timber weatherboard cladding on upper storey, sheet cladding on lower, all timber framing. Floor predominantly timber suspended upstairs, aside from small slab under extension on Master Bedroom. Downstairs the floor is uninsulated concrete slab. Corrugated iron roof, timber framed windows throughout, aside from three small aluminium framed windows in the Master Bedroom extension.	Living areas, bathroom and three bedrooms upstairs, woodburner located in lounge. Bedroom/rumpus, bathroom/laundry, and garage located downstairs, backing onto subfloor area. Four bedrooms, one living room, two bathrooms.	Good, little retrofitted insulation.

These householders were attracted to the renovation project for two reasons. Firstly, they were concerned to reduce expenditure on energy. Secondly, they saw the renovation project as aligned with their interest in getting 'eco-friendly'. They had no interest in the notion of increasing the capital value of their dwelling. They have been living in the house 28 years and see themselves living in it well into the foreseeable future.

The major performance problem that they had with the house was high levels of humidity and the necessity of using a dehumidifier. The year 2 winter performance measures for humidity show humidity to be 64.44 percent on average over 24 hours. The humidity range is low with a 63.33 percent average humidity in the evening to a 66.75 percent humidity recorded winter average in the morning. Those humidity levels have been achieved despite the householders giving away their dehumidifier.

Table 7: Retrofit Interventions – P02

Issues	Actual Intervention	Approx. Value (exc GST)	Resulting Package
Single-glazed timber framed windows in excellent condition, but require new stays			Low

Original D grade electric hot water cylinder is poorly insulated	Hot water cylinder wrapped and pipes lagged	$90	
No underfloor insulation	Floor insulated with R2 foil-backed bulk insulation, polythene put on ground	$1,290	
Dislodged ceiling insulation	Ceiling insulation relaid, extra added where necessary	$110	
Food waste not being re-used	Wormfarm installed	$160	
Extractor fan not working well	Extra fan added to heat transfer kit, ducting shortened.	$280	
Broken cat flap causing draughts from garage	New cat door installed	$50	
Energy in-efficient lighting	Compact fluorescent bulbs put into high-use fittings	$30	
Plumbing of unknown quality	Plumbing checked	$80	
No smoke alarm	New smoke alarm installed	$30	
No significant water re-use methods or appliances.			
Fridge seals old and probably leaky			
No wall insulation			
	TOTAL	$2,120	

The renovation investment in this dwelling has been low - $2,120. The largest single expenditure item has been the installation of the under floor insulation consisting of foil-backed bulk insulation and a polythene ground sheet.

There have been statistically significant decreases in energy use. There have also been statistically significant increases in temperature. In both the family room and the master bedroom. These rooms are still, however, relatively cold at 16.5° C and 14.5° C. The householders' view is that the temperature increases are more significant than average measurements. They suggest that

the family room is heated to 25° C in winter despite leaving doors open. They believe that they are receiving more benefit from their enclosed wood burner in which they burn pine, manuka and blue gum which has been seasoned for a year or more. They have found the basement drier and can walk around the house in bare feet without becoming chilled.

Table 8: Dwelling Performance Summary – P02

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	134	138	276	61	14.6	13.0	63.33-66.75
Post	91	109	211	39	16.5	14.5	

Table 9: Winter Average Temperature Ranges – P02

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	12.14	12.94	22.84	24.62
family room b	12.50	12.76	19.03	18.82
family room average	12.32	12.85	20.94	21.72
bedroom	12.32	12.77	15.06	16.04

These householders are relatively low users of energy and their energy use has decreased – including hot water use. The householders believe that hot water use has stayed the same. When they heard that their hot water use had fallen, they explained this in terms of a decrease in the use of the laundry facilities by their children living away from home. Other than this change in dwelling use, the householders report that they did not change their behaviours or acquire or dispose of energy using appliances.

These householders believe that a number of other interventions such as a new hot water tank and new windows would be beneficial. They see themselves as undertaking those tasks into the future but report that they have been having difficulty getting skilled trades. The simplicity of smoke alarm installation, however, made them realise that they could undertake a number of improvements themselves. Nevertheless, the householders were ambivalent about the efficacy of some interventions. The cat door installed to reduce opening the door into the garage did not have that affect on their behaviour. The worm farm was unsuccessful. The householders removed the polythene ground cover in the basement because it appeared to cause a water build up. The two installations they believe to be most effective are:

- under floor insulation which they believe they would have installed earlier if they had known the benefits, and
- hot water cylinder.

The householders believe they would be prepared to $3,000 to have the windows sealed. Overall, they feel that the project would have been more effective if they had been allocated $10,000 and assisted to contract the retrofit process themselves with expert advice. The latter appears to reflect the householders' view that the project over promised and under delivered or, as they put it, "offered long and delivered short". There is a perception that the interventions did not fulfil what was promised in contracts.

4.3. Dwelling P03

This dwelling is occupied by a couple and their three children. The dwelling is the employment site for both parents. Two children are primary school age and one child is at secondary school. BRANZ's description of this dwelling is set out in Table 10. The interventions and market valuation of those interventions are set out in Table 11.

Table 10: BRANZ Dwelling Description – P03

Age	Construction	Layout	Initial Condition
Early 70s, office addition added around the 80s.	Split level, skillion ceiling (original with exposed rafters) over living areas and hallway, cavity ceilings above bedrooms. Timberframed with timber suspended floors and timber weatherboard cladding around upper levels. Bottom floor has an uninsulated concrete slab floor, mainly timberframed walls with sheet cladding with some brick veneer around bottom level, with a newer (1980s?) concrete block office addition out the back. The roof is corrugated iron, and the windows are older single glazed aluminium.	Living areas located above garage and office areas, bedrooms, entrance and main bathroom located on split level. For the purposes of this project, the bottom level has been ignored in this project as it contains a business run from the home, and the garage is used for business storage purposes. Three bedrooms, one living room, two bathrooms	Poor. The roof was described as being made water resistant only through vast amounts of duct tape. The aluminium windows were past their useful life and required replacement. The original woodburner had been under a leak and had rusted. The underfloor vents on one side of the bedroom wing were buried. The painted weatherboards and bargeboards were peeling, some were split. The hot water cylinder, while being under a decade old, was too small for a family of five at 135 litres capacity. The décor was much the same as it was when the house was first built.

These householders were attracted to the renovation project because it offered them opportunities to increase heat efficiency and saw a professional and personal interest in monitoring for increased warmth and energy efficiency. They saw it as an opportunity to modernise the house with lowered ceilings and new lighting as well as improve dwelling performance. Issues of noise, cold and excessive condensation were of concern to the householders.

Table 11: Retrofit Interventions – P03

Issues	Actual Intervention	Approx. Market Value (exc GST)	Resulting Package
Old wall insulation in unknown state	Stripped, reinsulated and relined walls of thermal envelope to R2.4. Pelmets rebuilt.	$10,050	
Old skillion ceiling insulation in unknown state	Lounge, dining and kitchen skillion ceilings lowered and insulated with R3.6 batts.	$5,430	
	Plasterboard for walls (10mm) and ceiling (13mm)	$1,350	
No underfloor insulation	Floor insulated with R2 foil-backed bulk insulation, polythene put on ground.	$2,020	
135l B grade electric hot water cylinder serving family of 5	Solar water heating system installed with 300l cylinder.	$10,060	
Old woodburner past useful life	Occupant installed new MEPS compliant woodburner.	N/A	
Ceiling insulation in cavity needing a relay	New ceiling insulation put over existing insulation in accessible places. Existing insulation relaid, R2.6 insulation put over top and over ceiling joists to remove thermal bridging.	$1,080	
Plumbing in unknown state	Plumbing checked.	$80	
No smoke alarm	New smoke alarm installed.	$30	
Fridge seals potentially need replacement			
Food waste not being re-used	Wormfarm installed.	$160	
Extraction fan in kitchen out of commission	New rangehood in kitchen.	$870	
No significant water re-use methods or appliances.	Two dual flush toilet cisterns installed.	$90	
High water-use toilets	Windows replaced with standard clear double glazing and standard frames.	$41,770	High

Old aluminium window frames past useful life	Occupants replaced roof	N/A	
	TOTAL	$72,990	

This dwelling was in a poor condition and the project interventions involved extensive retrofitting and renovation as well as the householders re-roofing the house, replacing the wood stove and installing a ducted heat pump system. Because of the long time frame over which those interventions occurred, the monitoring data around performance is difficult to interpret. There appears to be statistically significant falls in energy consumption.

There are distinct increases in the average temperatures in the family room and master bedroom (Table 12). The extent of that change is best understood by reference to the minimum average winter temperatures which have risen from very minimal levels to acceptable minimum temperatures. Increases in minimum average winter temperatures have in some cases exceeded 3.5°C.

Table 12: Dwelling Performance Summary – P03

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	342	100	414	95	17.7	15.7	55.69-59.01
Post	293	67	350	38	18.1	17.1	

Table 13: Winter Average Temperature Ranges – P03

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	12.74	16.01	20.88	20.28
family room b	13.10	15.67	19.13	19.22
family room average	12.92	15.84	20.01	19.75
bedroom	12.25	15.74	15.95	18.36

The householders ascribe the fall in energy consumption to the installation of the solar water heating system. The double glazing is also cited as the major reason for temperature increases, although it appears that the greatest benefit around the windows was related to draft reduction. There is now some concern about potential over heating and the householders intend to install sunscreens. The householders believe that their hot water use is decreasing, but this appears to be contradicted by the monitored data and other comments by the householders themselves. The latter report that because the hot water is costing less to heat they have unlimited water and do not need to 'nag' the children about getting out of the shower.

The changes exceeded the expectations of the householders. They find that the wood burner combined with the heat transfer system heats the whole house. The problems with condensation have been entirely eliminated along with the mould problem. The solar hot water has been very effective, although the neighbours find that the panels interrupt their view. Unexpected benefits have been:

- Noise reduction of sounds generated inside the house and sounds generated outside the house.
- A feeling that the house is healthier.
- The modernised look of the house.

Despite the performance and other benefits, the householders identified a number of process problems including:

- Poor sequencing of work and long delays
  - the children had to stay elsewhere for a number of weeks.
  - joinery sat outside for 3-4 weeks and was weather damaged

- windows delivered early and blew over and frames broken.

- Poor workmanship and installation practices:
  - Double glazing was installed three times.
  - Installation of flashings was not to specification.
  - Cylinder was incorrectly placed.
  - Plasterboard needed to be patched.
- Confused communication from multiple parties.
- Non-completion, particular the household is awaiting:
  - curtains
  - sealing

The householders reported that if the work had not been free of charge they would have ‘spat the dummy’ because of process issues. However, they also reported that they would be prepared to pay up to 20 percent of the house value in improvements. Of particular benefit was the solar water heating and insulation. The householders saw double glazing as appropriate in new houses but had doubts about their retrofit value.

4.4. Dwelling P05

This dwelling is used by a retired couple. BRANZ's description of this dwelling is set out in Table 14. The interventions and market valuation of those interventions are set out in Table 15.

Table 14: BRANZ Dwelling Description - P05

Age	Construction	Layout	Initial Condition
1978	Timber framed construction, timber weatherboard cladding around three sides, brick veneer on road frontage, all insulated to a relatively low level by today's standards. Predominantly timber suspended floors aside from sunken floor in the living room, and the garage floor which are uninsulated concrete slabs. Stonechip coated metal tile roof, and timber composite windows in excellent condition, requiring new sashes.	Single level throughout, aside from slightly sunken lounge. Three bedrooms, one living room, two bathrooms.	Excellent, insulation topped up to a moderate level several years ago and the original 1978 low pressure electric hot water cylinder insulated. Underfloor was uninsulated. Cladding in excellent condition, recently painted. Roof in excellent condition.

These householders were attracted to the retrofit project to increase the warmth of their house. They had no interest in the notion of increasing the capital value of their dwelling. They see themselves living in their current dwelling well into the foreseeable future. The householders believe the house to be warm and it is but only marginally and the result is not statistically significant. They also believe that their hot water use is less. The energy expended on hot water use has, however, increased according to the monitoring data. The impression that hot water use has decreased may reflect the effects of installing a low flow shower head.

The renovation investment in this dwelling has been reasonably sizeable – $10,680. The largest expenditure items are the under floor insulation and the replacement of the electric hot water system with a gas instant hot water system respectively. It has been the insulation of under floor and ceiling areas that the householders feel has made the most difference. The householders also associate the reduction of noise with draught stopping the sliding door.

Table 15: Retrofit Interventions – P05

Issues	Actual Intervention	Approx. Value (excl GST)	Resulting Package
Original D grade (wrapped) electric hot water cylinder poorly insulated	Replaced electric storage hot water cylinder with gas instant hot water units, one a high efficiency condensing model, at the two service areas. Low flow shower head installed.	$4,520	Medium
Lack of wall insulation making heat losses high	Plastering repairs.	$50	
Older ceiling insulation in unknown state	Ceiling insulation topped up with R1.8 blanket.	$1,190	
No underfloor insulation making heat losses high	Timber suspended floors insulated with R2 foil-backed bulk insulation, polythene put on ground.	$3,030	
No active heating in bedrooms	Ducted air transfer system installed to move warm air into hallway by bedrooms.	$1,400	
Extraction fan vents moisture into roof cavity	Bathroom extraction fan ducted to outside.	$70	
No significant water re-use methods or appliances			
Fridge seals in poor state			
Plumbing in unknown state	Plumbing checked.	$80	

Issues	Actual Intervention	Approx. Value (excl GST)	Resulting Package
Draughty windows and sliding door in dining room contributing to heat loss.	Sliding door draughtstopped.	$50	
Large old recessed downlight in kitchen resulting in poor energy use and loss of insulation value.	CA rated halogen downlights installed in kitchen.	$110	
Energy in-efficient lighting	Compact fluorescent bulbs put into high-use light fittings.	$30	
Food waste going into the bin	Wormfarm installed.	$160	
	TOTAL	$10,680	

These householders are relatively high users of energy and their energy use has only marginally decreased with their hot water energy increasing and off-setting their total electricity reductions. Nevertheless, the householders reported being prepared to expend up to $30,000 on retrofit.

Despite this apparent willingness to pay for retrofit at relatively high levels, the householders expressed dissatisfaction with the performance of some installed items. The installation of the bathroom duct is believed to be faulty by the householders and they associate this with mould and condensation problems in the shower. The new lighting is considered too dim. The dual flush toilet has proved unsatisfactory on the half flush. The water pressure is seen as inadequate.

Table 16: Dwelling Performance Summary – P05

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	132	324	501	51	16.4	12.9	66.75-71.23
Post	73	293	510	95	16.8	13.2	

Table 17: Winter Average Temperature Ranges – P05

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	12.45	13.70	20.68	22.33
family room b	12.48	13.48	17.60	18.03
family room average	12.47	13.59	19.14	20.18
bedroom	11.41	12.07	13.59	14.36

Average temperature gains (Table 16 and Table 17) have been relatively small in this dwelling. However, there has been a distinct upward movement in winter average minimum temperatures. This has also been accompanied by increased average maximum temperatures.

4.5. Dwelling P06

The dwelling is used by a semi-retired couple. The occupancy of the house varies considerably with up to seven adults living in the house at times. BRANZ's description of this dwelling is set out in Table 18. The interventions and market valuation of those interventions are set out in Table 19.

These householders were attracted to the retrofit project because it offered them opportunities to increase heat efficiency and saw their own house as typical of the area. They saw the project as addressing the warmth and dryness of the house and increasing its liveability into their retirement. They also saw the project as giving them ideas on what they could do to with the house to both increase its thermal performance and to increase its value.

Table 18: BRANZ Dwelling Description – P06

Age	Construction	Layout	Initial Condition
70s, family room added around the 80s.	Timber framed with weatherboard cladding, aside from concrete block walls around the family room and sheet cladding around the garage and workshop downstairs. Timber suspended floors throughout, aside from uninsulated concrete slab floor in family room and garage. Concrete tile roof. Half of the windows are the original timber-framed single glazing, while the other half is predominantly newer single glazed aluminium windows, with some older single glazed aluminium windows.	The liveable areas of the house are on the second storey, while a garage and workshop are located downstairs. The family room floor level is slightly lower than that of the upper floor. Four bedrooms, two living rooms, one bathroom.	Good. Little retrofit insulation had been put in, with a Do-It-Yourself insulation job in the ceiling where fibreglass batts had been laid in a thin layer throughout the ceiling cavity. The underfloor was entirely uninsulated. New windows had been installed along the southern face of the house to reduce draughts. Exterior decoration was generally in good condition, although some painting was underway where new windows had been put in.

Table 19: Retrofit Interventions – P06

Issues	Actual Intervention	Approx. Value (exc GST)	Resulting Package
Poor insulation in ceiling	Ceiling insulation topped up with R2.6 to approximately R4	$1,380	Basic
No wall insulation			
New single glazed aluminium windows across south side of house with poor insulation value			
No underfloor insulation			
B grade hot water cylinder losing excessive heat			
Food waste going into the bin			
No significant water re-use methods or appliances			
Large old downlights leaking air and interrupting insulation			
Plumbing in unknown state.			
	TOTAL	$1,380	

The house was seen as being in good condition but with some persistent performance problems. In particular, they had one bedroom which was persistently damp and cold. They realised the impact of damp and cold on their own and other people's health when they had a daughter who was prone to illness sleeping in the cold, damp, mouldy bedroom. The installation undertaken as part of the project was basic but supplemented by the householders wrapping the hot water cylinder and lagging the hot water pipes.

Apart from a decrease in hot water energy and associated fall in electrical energy the impacts of the basic retrofit are minimal. Hot water use has, according to the householders increased, and it must be concluded that the benefits of hot water cylinder wraps are significant. The householders also report that occupancy levels have varied significantly over the monitoring period. While the householders were away for an extended period of they report both very low levels of occupancy

over that time and very high levels of occupancy subsequently. It is difficult to establish, then, whether energy consumption improvements are being under or over stated in the monitored energy measurements. However, indoor temperatures have fallen slightly, although the fall is not statistically significant. Temperatures are unhealthily cold.

Table 20: Dwelling Performance Summary – P06

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	162	72	215	53	14.4	12.9	76.91-79.43
Post	131	72	184	37	14.2	12.6	

Table 21: Winter Average Temperature Ranges – P06

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	12.91	11.81	19.31	15.96
family room b	12.96	12.18	16.96	15.18
family room average	12.94	12.00	18.14	15.57
bedroom	12.62	11.57	14.71	13.12

This household has a high level of dissatisfaction with the project. They had expected more to be done to the house and/or advice on how to improve the comfort and energy efficiency of the dwelling. They emphasised the need for information on information identifying what interventions were likely to give them the greatest ‘bang for the buck’. They see the house as still being cold and damp. They feel that they can not heat the house adequately and rely on electric blankets and spot heating. They see persistent sickness among household members as reflecting poor house performance. They are frustrated that the project is monitoring the house but they do get significant information about alternative interventions.

The householders report that they would be prepared to spend the equivalent cost of moving house to ‘putting the house right’. They estimate that sum to be in the region of $15,000. However, they are concerned that they do not have the information they need to make decisions

about appropriate, quality and affordable interventions. They see the provision of credible information as a desirable key outcome of the project.

4.6. Dwelling P07

This dwelling is the residence of a professional couple. One of the residents is away from home for extended periods. BRANZ's description of this dwelling is set out in Table 22. The interventions and market valuation of those interventions are set out in Table 23.

Table 22: BRANZ Dwelling Description – P07

Age	Construction	Layout	Initial Condition
70s, lounge addition done after 2000.	Timber framed, mainly clad in weatherboard with some sheet cladding around the new addition, around most of the lower level. Downstairs has a concrete slab floor while upstairs has a timber suspended floor. The roof is stone chip coated metal tiles.	Living areas and bedrooms are located on the upper level, while the utility areas are located on the lower level. Four bedrooms, one living room, two bathrooms.	Good to poor. The original living areas had been relined and insulated (walls and ceiling), and new windows were put in when the lounge was added onto the house. The rest of the house was in original condition (aside from the décor).

These householders were attracted to the retrofit project because they were already considering renovations. They wanted to achieve a warmer house which they describe as being like a 'fridge'. They had already undertaken insulation of half of the house and installed 10 meters of what they described as 'thick glass' and had perceived a significant difference in thermal comfort from doing so.

Table 23: Retrofit Interventions – P07

Issues	Actual Intervention	Approx. Market Value (exc GST)	Resulting Package
Low to medium levels of insulation in ceiling	Ceiling insulation topped up with R2.6, existing insulation tidied up.	$1,940	
No wall insulation in bedroom wing	R2.4 wall insulation installed by occupants in bedroom wing.	$1,840	
	Plasterboard for walls	$480	
No underfloor insulation	Timber suspended floors insulated with R2 foil-backed bulk insulation, polythene put on ground.	$1,770	
B grade electric hot water cylinder not insulated	How water cylinder wrapped, pipes lagged.	$90	
Heat transfer system not working, bedrooms not actively heated	Relocated heat transfer thermostat into lounge, extended ducting to bedrooms.	$810	
Extraction fan vents moisture into roof cavity	Bathroom extraction fan ducted to outside. Shower dome installed.	$370	
New single glazed aluminium windows throughout family areas offer poor insulation value	Occupants retrofit rest of house with single glazed aluminium windows.	N/A	
No significant water re-use methods or appliances			
Plumbing in unknown state	Plumbing checked.	$80	
Food waste going into the bin	Wormfarm installed	$160	Medium
	TOTAL	$7,540	

The householders perceive a fall in electricity consumption. This is consistent with the monitoring data but the fall is not statistically significant. The householders ascribe the fall in energy consumption to not having to use a dehumidifier in winter. The ducting is seen as spreading warmth into the bedrooms, however, the householders report that the family room temperature is much the same. The monitoring data suggests a statistically significant temperature increase of 1.1° C in the family room. By way of contrast, the householders believe bedroom temperatures are rising although the monitoring rise of 0.3°C is not statistically significant.

Table 24: Dwelling Performance Summary – P07

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	185	70	239	49	13.7	12.6	70.48-70.48
Post	168	87	243	39	14.8	12.9	

Table 25: Winter Average Temperature Ranges – P07

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	11.78	13.95	17.07	17.82
family room b	11.90	13.21	16.29	16.29
family room average	11.84	13.58	16.68	17.06
bedroom	10.96	11.66	14.40	14.76

The perception of temperature improvement may be generated by the relatively substantial increase in average winter temperatures experienced in the family room and master bedroom (Table 25).

The householders identified a number of expected and unexpected benefits. In relation to expected benefits, the householders find the house drier and warmer with less condensation in the bathroom. They use the worm farm and associate this with a decrease in rubbish. The warmth in the master bedroom is higher than expectation. The musty smell has disappeared and they have ceased using a dehumidifier.

The contacts with all the organisations involved have been positive despite the householders recognising the potential for the extended contact with the project to be intrusive. The householders describe people working as part of the project as 'fantastic'. They were disappointed that some expected interventions did not occur but accepted that the project had 'run out of money'.

4.7. Dwelling P08

This dwelling is the resident of a professional couple one of whom uses the dwelling as their workplace. BRANZ's description of this dwelling is set out in Table 26. The interventions and market valuation of those interventions are set out in Table 27.

Table 26: BRANZ Dwelling Description – P08

Age	Construction	Layout	Initial Condition
1965, with a downstairs rumpus room addition done soon after the house was built, and the rumpus room addition built around 2004.	Principally timber framed with timber weatherboard cladding, sheet material cladding on eaves, and around lower levels. Two of the gym walls are concrete block walls, and the gym and garage floors are uninsulated concrete slab. The rest of the house has timber suspended floors. The roof is long-run iron.	Double, split level. Living areas are located in the lower split level above the rumpus room, laundry, fourth bedroom and subfloor, while the three bedrooms are located in the higher split level above the gym and subfloor. Four bedrooms, two living areas, one bathroom.	Good to excellent. The house was well maintained, with a recent exterior paint, and around moderate ceiling insulation laid (to a reasonable standard, although with some large gaps and holes) by one of the homeowners over a decade ago. The interior of the house was in excellent condition. Underneath the house, subsidence around the new rumpus room addition had caused a clay downpipe sump to break, leading to a small stream of water trickling under the house and pooling underneath the rumpus room and fourth bedroom. A waste pipe under the house was also leaking a little. The roof is in good condition and was relatively recently repainted.

This couple wanted to achieve capital gain on their property as well as reduce their energy costs through solar water heating. The retrofit interventions were extensive with a value of around $24,610. The household still, however, operates three dehumidifiers although the frequency with which the dehumidifiers are emptied is reported to have reduced.

Table 27: Retrofit Interventions – P08

Issues	Actual Intervention	Approx. Value (exc GST)	Resulting Package
Ceiling insulation at moderate level but needs relaying in places.	Ceiling insulation relaid, second layer of R2.6 put over existing and across ceiling joists, removing thermal bridging, raising insulation to approx R4	$940	
No wall insulation	Rear wall of bedroom 4 (R2.4 batt) and gym backing onto underfloor (R1.2 masonry) insulated.	$390	
No underfloor insulation	Insulated with R2 foil-backed bulk insulation, polythene put on ground	$2,160	
B grade electric hot water cylinder with excessive heat loss	Solar water heating with 300l cylinder installed	$9,870	
New aluminium framing with single glazed panes do not provide good insulation	Double glazing panes retrofitted into existing aluminium frames (including scaffolding)	$10,700	
No significant water re-use methods or appliances			
Fridge seal replacement potentially needed			
Condensation and mould in bathroom	Shower dome installed	$310	
Plumbing in unknown state	Plumbing checked	$80	
Food waste going into the bin	Wormfarm installed	$160	High

Issues	Actual Intervention	Approx. Value (exc GST)	Resulting Package
	TOTAL	$24,610	

The householders report a marked difference in the comfort of the dwelling. They report reducing their heating hours and they report significantly reduced electricity usage despite increasing hot water use. Those perceptions are consistent with the monitored data. It is notable that the dwelling was even before the renovation relatively warm. Bedroom temperatures in winter are now averaging 17.8°C.

Table 28: Dwelling Performance Summary – P08

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	607	207		77	18.2	17.4	62.97-66.68
Post	487	197		16	19.0	17.8	

Table 29: Winter Average Temperature Ranges – P08

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	NA	NA	NA	NA
family room b	14.11	15.58	19.75	21.84
family room average	NA	NA	NA	NA
bedroom	15.97	16.52	19.77	19.53

The monitoring data around reductions in energy consumption need to be treated with caution. This household has had changes in occupancy patterns over the monitoring period. Firstly, a daughter moved out of home about the time that the project started. Secondly, one household member is increasingly spending each weekend at the couple's second house. It is clear that the monitored house has become more likely to be completely unoccupied at weekends over the monitoring period. The fall in energy consumption, although not the improvements in temperature, may in part be attributed to changing occupancy patterns.

For these householders thermal comfort benefits have been supplemented by unexpected benefits around sound control. Members of the household no longer hear train noise filtering up from the main trunk line. The Government valuation of the property has also increased, although one of the householders attributes this to a generalised increase in property values which was experienced by all the dwellings in the district.

The impact of insulation has been particularly impressive for the householders. They were originally led to believe that their interior walls would be insulated but this was not done because they were told the project 'ran out of money'. However, they are thinking about doing that themselves although they are wary of removing the plasterboard and associated repainting costs. If confronted with undertaking a renovation in their house, this experience has meant that the householders would prioritise insulation in the roof and the floor and the installation of solar water heating. They report that they would not undertake double glazing in an existing house.

4.8. Dwelling P09

This house is a semi-detached unit with one resident. BRANZ's description of this dwelling is set out in Table 30. The interventions and market valuation of those interventions are set out in Table 31. The package of interventions is valued at $4,830.

Table 30: BRANZ Dwelling Description – P09

Age	Construction	Layout	Initial Condition
1976	Timber framed, fibrecement weatherboard cladding upstairs with sheet cladding downstairs. There is a concrete block firewall between the townhouse and its neighbour. The lower level has an uninsulated concrete slab floor, while the upper level is suspended timber. The roof is concrete tiles.	The kitchen, laundry, bathroom, toilet, and part of the second bedroom are above the subfloor area, while the rest of the living areas, majority of the hallway and master bedroom are above the lower level. The master bedroom is situated above the garage. Two bedrooms, two living areas, one bathroom.	Reasonable. The walls of the house were insulated to a low level (by today's standards) when it was built, and a low to moderate level of ceiling insulation existed throughout. No underfloor insulation was present. The weatherboard cladding requires some maintenance and possibly replacement in places.

The householder was attracted by the project because of a broader interest in energy, energy efficiency and a concern about rising costs. This householder is not interested in capital gains because the householder has no intention of moving. The attraction of renovation lay in increasing the warmth of the dwelling, reducing cold related health problems and reducing energy costs.

Table 31: Retrofit Interventions – P09

Issues	Actual Intervention	Approx. Market Value (exc GST)	Resulting Package
Ceiling insulated to a low-moderate level	Layer of R2.6 put over top of existing insulation, and over ceiling joists to remove thermal bridging, raising insulation to approximately R-4.	$710	
No underfloor insulation	Insulated with R2 foil-backed bulk insulation, polythene put on ground	$490	
Floor of main bedroom is above uninsulated garage	Midfloor insulation installed between garage and main bedroom	$2,270	
	Plasterboard (13mm) for garage ceiling	$320	
Wall between garage and stairwell/rumpus, rumpus/underfloor uninsulated	Wall insulation on rear of wall to underfloor and garage installed	$180	
Slight mould in bathroom	Shower dome installed	$310	
No fixed heating	Homeowner installed heat pump	N/A	
	Heat pump rewired	$150	
Draught from garage sliding door into living area	Sliding door to garage draughtstopped	$40	
Single glazed aluminium windows throughout with poor insulation performance			
B grade electric hot water cylinder with poor insulation performance	Cylinder wrapped, pipes lagged.	$90	Medium

Energy in-efficient lighting used.	Compact fluorescent bulbs put into high-use fittings	$30	
No significant water re-use methods or appliances			
Old fridge/freezer and downstairs chest freezer may have dodgy seals			
Plumbing in unknown state	Plumbing checked	$80	
Food waste is not recycled	Wormfarm installed	$160	
	TOTAL	$4,830	

The householder rightly believes that electricity consumption is lower. This is associated with lower hot water energy use. The householder is satisfied that winter temperature problems have been resolved but find that the house overheats in summer. The monitoring data is consistent with the view that Family Room and bedroom temperatures have increased. The increase is only significant in relation to master bedroom temperatures. There have been increases in average winter minimum temperatures.

Table 32: Dwelling Performance Summary – P09

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	164	-	-	45	16.5	15.1	58.66-62.54
Post	134	-	-	38	16.4	15.5	

Table 33: Winter Average Temperature Ranges – P09

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	14.12	14.31	21.09	20.34
family room b	13.82	13.92	19.12	20.10
family room average	13.97	14.12	20.11	20.22

bedroom	13.70	14.43	16.55	17.23

The householder is satisfied with the process although not getting double-glazing was a disappointment. The householder is prepared to pay an additional $5,000 to put in double-glazing upstairs. Insulation is seen as the most effective option by the householder. Overall the householder was satisfied that expectations were not raised unnecessarily and the monitoring process has not been intrusive.

4.9. Dwelling P10

This dwelling was in poor condition and houses five people – a couple with three children ranging from primary school to secondary school ages. BRANZ's description of this dwelling is set out in Table 34. The interventions and market valuation of those interventions are set out in Table 35.

Table 34: BRANZ Dwelling Description - P10

Age	Construction	Layout	Initial Condition
Early 70s	Timber framed walls with sheet cladding upstairs, and reinforced concrete walls downstairs. Uninsulated concrete slab floor downstairs, timber suspended floors upstairs. There were mostly original timber framed windows when the project started, with one window replaced with a new aluminium ranchslider. The roof is concrete tiles, with the exception of the bitumen flat roof over the foyer and stairwell.	Living areas located above garage, lower hallway and fourth bedroom/rumpus. The foyer (with a floor level one step below the living and bedrooms wings) is located over the storage area/hot water cylinder room between the lower hallway and the subfloor. The bedroom wing containing three bedrooms, the main bathroom and laundry are located above the subfloor area. Four bedrooms, one living room, two bathrooms.	Poor. The house was in essentially original condition. The paint was coming off the exterior claddings, the window frames were rotten through to the extent where the outside could be seen in places, and the drainage had just been fixed after a flood of the bottom of the house soon after the occupants had moved in. There were strong draughts coming in around some of the windows. The roof had just been patched, repaired and repainted. The décor remained as it had been when the house was first built, and the recessed woodburner was original. The hot water cylinder was also original, although the new owners had wrapped it and lagged the hot water pipes.

The retrofit interventions for this dwelling were relatively intensive at a value of around $38,030. The householders have been intending extensive renovations but have been severely constrained by their low income. They were attracted to the project because it gave them the opportunity to 'kick-start' things that they had already planned on doing. Their primary concerns with the house were:

- cold
- damp
- mould.

Because of their concern about the cold in their children's bedrooms they had already started to double glaze the children's rooms prior to the project.

Table 35: Retrofit Interventions – P10

Issues	Actual Intervention	Approx. Market Value (exc GST)	Resulting Package
Ceiling insulation thin and patchy	2 layers of R2.6 put over old insulation, top layer put over ceiling joists to remove thermal bridging.	$2,100	
No underfloor insulation	Timber suspended floors above subfloor and garage insulated with R2 foil-backed bulk insulation, polythene put on ground in subfloor.	$2,380	
Flat roof above foyer uninsulated	Flat roof insulated with R3.6 midfloor batts and lined (13mm).	$240	
No wall insulation	Walls stripped, insulated with R2.4 and relined (10mm) throughout thermal envelope, except downstairs bedroom.	$7,010	
	Plasterboard for flat roof and walls	$1,030	
Original electric hot water cylinder (wrapped) losing excess heat	Solar water heating system installed on foyer roof.	$10,040	High

Old inbuilt woodburner past useful life	New high efficiency woodburner installed with wetback pumped to hot water cylinder.	$4,050	
Old timber window frames in poor condition and rotted through in places	Double glazing units and window frames provided for installation into living wing ONLY. Installation costs included (estimated)	$10,640	
Standard incandescent bulbs in high use fittings	Compact fluorescent bulbs put into high-use fittings.	$30	
No extraction fans in bathroom and laundry	Householders install extraction fans into bathroom and laundry.	N/A	
Desire to reduce discharge to sewage system			
Desire to reduce stormwater runoff and mains water use			
Draughty door to garage losing heat	Garage door draughtproofed	$50	
Older fridge/freezer seals may be leaking			
Plumbing in unknown state	Plumbing checked, vanity moved for relining, leaky tap fixed.	$300	
Food waste not effectively dealt with	Wormfarm installed	$160	
	TOTAL	$38,030	

Although the householders were prompted by a desire to increase the warmth of their dwelling, they have found the cost savings associated with reduced energy consumption a very real benefit. Electricity use is down although heating is slightly increased. The latter increase is not statistically significant. The fall in electricity consumption appears to be largely attributable to the fall in energy consumption associated with hot water use. This, in turn, appears to be associated with the installation of solar water heating and a wetback on the installed wood-burner. The fall in hot water energy consumption is despite the householders reporting that they have increased their use of hot water.

Increased hot water use is also matched by the householders reported increase in water use generally. This is associated with the family establishing an extensive vegetable garden and planting trees in September and October 2007. They expect to reduce their outdoor water use once the trees are established. The householders are particularly pleased with the fertiliser derived from the worm farm.

Table 36: Dwelling Performance Summary – P10

Pre/post Retrofit	Total Electricity (kWh/wk)	Monitored Heating (kWh/wk)	Total Energy (kWh/wk)	Total Hot Water (kWh/wk)	Family Room Temps (°C)	Bedroom Temps (°C)	Winter Humidity Range %
Pre	190	77	281	104	16.4	14.0	62.04-65.1
Post	106	81	262	91	18.0	15.8	

Table 37: Winter Average Temperature Ranges – P10

Room	Temperatures °C			
	Min Year 1	Min Year 2	Max Year 1	Max Year 2
family room a	14.21	16.59	22.60	24.39
family room b	12.54	13.91	16.83	17.69
family room average	13.38	15.25	19.72	21.04
bedroom	11.50	14.40	14.68	16.87

Reductions in electricity and total energy consumption have been accompanied by increased indoor temperatures. This is particularly apparent in the Family Room which now has an average of 18°C. The average bedroom temperatures have also increased by a considerable 1.8°C. This is statistically significant. Despite that considerable increase the bedroom average temperatures are still low at 15.8°C. However, it is notable that there have been substantial increased in minimum average winter temperatures in all the monitored areas of the house. No heat transfer system was installed and the householders believe that this would ensure that heat generated in the family room was more effectively spread around the house.

The renovations met their expectations around improved warmth. The unexpected benefits were the very considerable cost reductions they were able to achieve with solar water heating and the wetback. They had originally been sceptical about solar water heating but if they were faced with

the same situation again they would place solar water heating at the top of their priority list. The heating combined with insulation they saw as having the most impact on temperatures. The double glazing, while welcomed, they saw as a secondary issue.

The most unexpected consequence of the renovation for the householders was the enormous sense of well-being derived from being able to progress the work and improve their living conditions. The warmth in particular and the reduction of noise from the double glazing and window repair have been particularly important for the family.

The householders were enormously appreciative of the opportunities to progress their house renovations through the project. They were hesitant to report on issues around process. When pressed to do so, they commented that two problems arose:

- Poor sequencing of work and long delays. It was reported that the full sets of tasks needed to undertake some work did not seem to be identified until after work was initiated. This tended to create problems around who was to take responsibility for some tasks.
- Poor quality workmanship and/or materials. This was particularly the case with the double glazing.

4.10. Some Conclusions

This research was expected to address a number of questions about the renovation of existing dwellings. In particular:

- What renovation packages have significant impacts on the performance of dwellings and at what cost?
- What prompts householders to renovate?
- What retrofit components and benefits do householders value?
- What are the barriers to renovations?

It should be noted that at present:

- none of the dwellings showed performance levels unequivocally consistent with the High Standard of Sustainability (HSS)
- the level of renovation (basic, low, medium and high) is not clearly related to:
  - either the cost of the renovation
  - or the dwelling performance subsequent to renovation (Table 38).

Table 38: Renovation Package by BRANZ pre-assessed dwelling condition & cost of retrofit

Renovation Package	House Condition	Value of Retrofit
Basic	Good	$1,380
Low	Good	$2,120
Medium	Reasonable	$4,830
	Poor to Good	$7,540
	Excellent	$10,680
	Good	$23,110
High	Poor	$38,030
	Poor	$72,990

What is clear from the research, however, is that, irrespective of the nature of the renovation itself, householders do recognise benefits dwelling performance benefits from retrofitting. Indeed, some householders actively change their behavioural patterns because of those perceived benefits. The most typical changes in behaviour are increased hot water use, and changes in heating patterns. Increased winter warmth and the reduction of damp were consistently identified by householders as expected and important benefits.

Notably renovation was not motivated primarily by ideas around capital gain or even reduced operating costs although the latter were appreciated by some householders when they emerged. The attraction of the renovation programme lay in householders' desire to:

- improve the performance of their homes in terms of comfort and health
- upgrade their homes for future use
- get access to expert advice as well as funding for renovation.

Unexpected benefits identified by a number of householders included:

- indoor noise reduction associated by householders with double glazing and/or increased insulation, and
- reduced household stress associated with warmer winter indoor environments and, for those with solar water heating, increased access to hot water.

The renovation components that tended to be consistently valued were:

- under floor insulation
- ceiling insulation
- efficient wood burners or pellet burners.

Alternative hot water heating, either through wet backs or solar water heating, were valued. Householders views of double-glazing were more ambivalent. While those that had double-glazing installed appreciated its benefits, double-glazing was not seen as a renovation priority for those householders compared to other retrofit components including solar water heating. Notably, however, those householders that felt that they had 'missed out' on double-glazing tended to see it as a key pathway to improved house performance.

With regard to the process of research engagement and the installation of the retrofit packages themselves, there is considerable consistency of view across the householders. All the householders that participated in the interviews appreciated the opportunity to be involved. Most householders identified a number of problems associated with participation, however. The most important of those are:

- uncertainty, and in some case unmet expectations, regarding the nature of the package installed
- poor specification and sequencing of installation leading to:
  - extended disruption of the household
  - unexpected requirements to provide a 'sweat' contribution
  - difficulties around managing the quality of work.

5 Retrofit and Measuring Dwelling Performance

The data from the monitoring of dwelling performance and the household interviews should be used iteratively. The problem with the current study is the power of the monitoring data is limited by the diversity of the sample and the small number of cases. Three consistent conclusions can be drawn, however, from the analysis of the monitoring data in the context of the householder interviews. They are that the:

- Householders feel changes in indoor comfort even when changes are relatively small.
- Householders do change their behaviours when previous constraints are released. This is most noticeable among those households that have expanded their supply of hot water through solar hot water heating. It is not clear whether this generates total increases in water use.
- Changes in performance may be under- or over- stated where changes in occupancy are not taken account. Consequently, physical monitoring data in itself is not enough to evaluate the impact of renovation packages.

In addition, it is also clear that relationship between house condition as measured by BRANZ at Papakowhai, the market value of the renovation package, the BRANZ specified level of renovation, and the benefits to householders are related in complex ways. Certainly, there is no obviously alignment between them. This can be interpreted in one of two ways. One interpretation is that there is not relationship between those variables. This appears to be unlikely. The second interpretation is that ways in which those variables have been defined and operationalised is inadequate.

6 Renovation Packages

It is difficult to identify from the monitoring data what packages are the most cost-effective. However, the householder interviews do provide some learnings that impact on package design, and package installation.

There is considerable variability around the willingness to pay for retrofit. Householders in the case studies ranged from around $3,000 to around $30,000. There is, however, less variation about the priorities of householders. Those may be summarised as winter warmth and the reduction of damp.

Operating cost reduction is also valued, but in an unsystematic way. That is, there is no evidence that return on investment in classical economic terms represents the value householders put on certain amenities or performance improvements. Solar water heating is an obvious example of this. Those householders who had solar water heating installed were aware that reductions in energy costs gave relatively low returns on investment. However, those householders valued it so highly that they would prioritise solar water heating immediately after underfloor and ceiling insulation and effective heating. The non-monetary value of solar hot water heating lay in improved availability as well as affordability of hot water, satisfaction with using the sun's energy, and a sense of independence and certainty around energy supply.

In short, the issue of affordability is important to householders but the rate of return appears to be less of a consideration. The language of 'return on investment' and 'pay-off periods' when householders do refer to them, appear to be simply a superficial adoption of the language and pre-occupations of public policy and investment decision-makers.

However, householders do want to ensure that they make the 'right' decisions. They want to know what is most effective in relation to the performance outcomes they value. They want to ensure that limited disposable income is used to make the most effective choices. There are three aspects of this that have emerged from the householder interviews:

- Firstly, householders want advice on effective investment at different price levels.
- Secondly, householders want advice on how to assess their needs and the sequencing of product/package installation. That is, given that affordability issues might mean that retrofit/renovation is likely to take place over time, they want to know what is the most cost-effective approach to achieving improved dwelling performance.
- Finally, they want to be assured that necessary standards of workmanship are being adhered to.

For Beacon this means that:

- Packages need to be developed to meet affordability limits. This implies a mix of 'single-point' packages and 'over-time' packages.
- The rationale for packages and package installation processes must be transparent.
- Beacon can support the industry to provide credible assessment and product/package installation processes.