TE106/13

Interim Performance Monitoring from Papakowhai Renovation Project

Report to Inform the Home*Smart* Renovations Project

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About this report

Title

Interim Performance Monitoring from Papakowhai Renovation Project

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Abstract

The Papakowhai Renovation Project has extensively monitored nine homes in the Porirua suburb of Papakowhai before and after sustainability intervention packages were applied to the homes. This report presents an analysis of monitored data from the May to September period of two consecutive years (2006 and 2007). The first year included the period before any interventions, and the second year included the period after interventions. Results are assessed against the HSS High Standards of Sustainability (HSS).

The report also includes New Zealand Home Energy Rating Scheme (HERS) star ratings for these buildings resulting from AccuRate modeling both before and after the interventions, using an interim version of the rating tool.

Reference

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1 Executive Summary

1.1 Preface

The Papakowhai Renovation Project has renovated nine existing homes in the suburb of Papakowhai, Porirua. The project goal was to identify the most cost-effective and easy to implement packages and combinations of renovation options that would significantly improve the standard of sustainability of the homes.

This report presents the interim monitoring results, while the companion report (Saville-Smith 2008) presents the social analysis of this data and the project's impacts on the households.

1.2 The Project

The suburb of Papakowhai, Porirua was chosen since it contained a large number of homes constructed in the same era (1970s) and was close to BRANZ Ltd. The choice of the same era was important so that similar issues would be faced in interventions. Ten homes were randomly selected from letters sent out to 355 households in this suburb, after the homes had been sorted by occupancy types. The homes were labelled from P01 to P10.

Monitoring equipment was installed in these 10 homes in 2006 to measure the energy use, and the temperature in the master bedroom and living room. In 2007, equipment to measure the master bedroom humidity and the water use by the household was installed. Data was monitored for a year before interventions were made in 2007. Subsequently the performance of the homes was monitored after the interventions. Ten homes were reduced to nine when P04 was sold, and this home was removed from the sample in early 2007.

1.3 The Interventions

These interventions were designed to improve the sustainability of the homes. A range of intervention packages were used with effects that were designed to be from minimal to significant:

- the Low intervention included improvements such as hot water cylinder wraps and ceiling insulation
- the Basic interventions included the Low interventions, and also used compact fluorescent lights, humidity reduction measures, and water and waste minimisation strategies
- the Standard used the same as the Basic, and added higher levels of ceiling insulation and floor insulation
- the High used all the Standard interventions and added wall and window insulation, and some other more costly improvements including solar water heating and space heaters.

The impact of interventions have been assessed against the Beacon HSS, which sets the performance expectations for temperature, energy use, water use, ventilation, relative humidity (RH), waste and material use.

The monitoring was continued after these interventions were completed. The differences in the winter performance before and after the interventions were analysed.

1.4 The Monitoring Results

Reticulated energy[1] consumption for all metered purposes was found to be the same or less after the interventions in all but one case. The only monitored increase in reticulated energy consumption was for the water heating in P05, where two instant gas hot water systems had been installed. The HSS for the total energy use was met in P02 and P03 using the 15% reduction in energy use that was initially used as the metric for the energy HSS.

The largest reductions in reticulated energy demand were for solar water heating systems.

In all cases the family room or bedroom temperatures were the same or higher after the interventions. The HSS was met for the temperatures in the master bedrooms of P03 and P06, and for the living room temperatures of P03, P08 and P10 for this winter period.

The largest energy and comfort improvements came from the homes with the most extensive interventions, labelled High.

All homes have improved thermal comfort levels, and in most cases also increased temperatures.

1.5 The HERS Results

The home performance was modelled with the AccuRateNZ software used as part of the New HERS, both before and after the interventions.

The HERS modelling results all show the same trend in improvement for the energy parameters from before to after the interventions, as seen in the actual monitoring work.

1.6 The Conclusions

- The Beacon HSS was achieved for some of the sustainability parameters investigated for the winter period.
- Insulation of the complete thermal envelope had the greatest effect on energy consumption and/or temperatures.
- Solar hot water systems provided large reductions in reticulated hot water energy demand.
- The High intervention package incurred very high capital costs ($75,000) in two of the three cases.

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[1] ***Reticulated energy is electricity supplied by the electricity network and natural gas supplied by underground pipe.***

2 Introduction

The New Zealand Government has recently implemented a range of measures to reduce energy use in the residential built environment. The two most important measures are: changes to the thermal insulation requirements of the envelope of new domestic dwellings;[2] and a rating scheme to assess the thermal performance of new or existing homes.[3] These changes address energy use, but do not answer the larger question of the sustainability of the residential built environment, which includes energy, water, waste and material use.

The Papakowhai Renovation Project has endeavoured to provide some information regarding the sustainability of the residential built environment. In particular, it has been concerned with finding the easiest to implement and most cost-effective, renovation options that will significantly improve the standard of sustainability of some existing homes.

This report is part of a series from the TE106 project that deals with a Beacon Pathway research project carried out by BRANZ Ltd in the Porirua suburb of Papakowhai. Interim results from monitoring of 10 homes for a winter period both before and after interventions are presented.

This required the detailed analysis of the monitoring results of the Papakowhai Renovation Project up to September 2007 to inform the Home*Smars* Renovations Project. The best and worst intervention options (cost versus efficacy) were identified, as were interventions that work better in combination. Issues which arise in relation to occupancy have been treated in this report and in the companion report (Saville-Smith 2008). Some interventions were carried out by the occupants, and some estimates in costs have therefore been made to include the cost of their labour. The context for the analysis is the Beacon HSS i.e. achieving multiple outcomes around energy, indoor environment quality (IEQ), water and waste (see Table 1).

The parameters for the Beacon HSS for existing homes are presented below, as extracted from Allen et. al. (2007).

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[2] ***These changes include the modifications to Clause H1 of the Building Code which have increased the level of insulation required in the walls, roofs, floors and glazing of new dwellings. See the compliance document for the Building Code Clause H1 Energy Efficiency (third edition) published on 31 October 2007, accessed on 28 May 2008 at: www.dbh.govt.nz/UserFiles/File/Publications/Building/Compliance-documents/clause-H1.pdf.***

[3] ***This is the Home Energy Rating Scheme (HERS) which currently includes a software tool (AccuRateNZ) for modelling the thermal performance of new or existing homes from plans or measurements.***

Table 1: Beacon HSS Benchmarks (Easton 2006)

		Benchmark in Climate Zone 1	Benchmark in Climate Zone 2	Benchmark in Climate Zone 3
Energy Use		New homes: 7,600 kwh/yr Existing homes: 9,050 kwh/yr	New homes: 8,500 kwh/yr Existing homes: 11,000 kwh/yr	New homes: 9,800 kwh/yr Existing homes: 12,000 kwh/yr
Water Use		180 litres/person/day (L/p/d)		
IEQ	Temperature	16°C bedroom mean min temp 18°C living room mean min temp		
	Ventilation	New homes: 0.4–0.6 air changes per hour Existing homes: 0.5–0.75 air changes per hour		
	Relative humidity (RH)	Mean RH 20–70% in bedrooms and living space		
	Checklist	Mechanical extract ventilation of kitchen, bathroom and laundry Windows with passive venting No unflued gas heaters Environmental Choice certified paints and finishes No air conditioning		
Waste		Provision for kitchen waste composting or storage space for kitchen waste collection Space for recyclables storage No in-sink waste disposal unit New building construction or renovation in accordance with REBRI construction guidelines		
Materials		<u>New homes</u>: materials which – promote good indoor air quality have minimal health risks during construction or retrofitting are durable and have low maintenance requirements incorporate recycled content or can readily be recycled re-use existing or demolished building materials or can readily be re-used are made from renewable or sustainably managed resources have low embodied energy including minimal impacts due to transport have low impact on landfill or are biodegradable minimal impact on the environment (air, water, land, habitats and wildlife) have third-party certification (e.g. NZ Environmental Choice, Forest Stewardship Council) <u>Existing homes:</u> Retrofit or renovation applies principles from materials checklist where appropriate		

Monitoring of the homes began in early 2006 to determine the amount of reticulated resources consumed, before interventions were made. Packages of sustainability interventions were selected that would develop understanding of how to meet the HSS. The interventions were made between February 2007 and October 2007, while the post-intervention monitoring has been performed on data obtained between May and September 2007.

Some of the interventions were incomplete during the post-intervention monitoring, meaning that only an indication of the effects of the intervention packages can be revealed at this stage. It is also expected that the householders' operation of the retrofitted homes and appliances will not have settled down in these results. Physical factors such as reduction in moisture content of the materials of the home may also take a year or more to stabilise. The full analysis will be presented as a report in December 2008, covering the differences in monitored conditions over the full pre- and post-intervention logging periods including both summer and winter.

2.2 Report Structure

The intention of this report is to present a detailed interim analysis of the data pertaining to the sustainability interventions that were undertaken for a winter period.

This report begins with an Executive Summary (Section 1) and an Introduction (Section 2), and then presents the selection of the homes (Section 3), followed by the selection of the interventions (Section 4). The interventions performed on each home are then covered in three ways. First, they are presented by home reference number (Section 5). Secondly, the detail of the impacts on the homes is assessed for the four areas of energy, IEQ, water and waste (Section 6). Thirdly, the impacts are assessed by intervention type (Section 7).

The next section (Section 8) of the report presents the star rating results of energy modelling performed with the HERS AccuRateNZ software package in March 2008 for the homes both before and after the interventions.

The final report (due in December 2008) will analyse a full year of data after the interventions and compare to a full year of data before the interventions. This will reveal the change in the selected sustainability indicators, and determine those parameters that have the most effect in the achievement of the HSS.

3 Selecting Homes

Ten homes were selected in Papakowhai to form the basis of this intervention study. Papakowhai is a middle-class area that was developed from the mid-1960s on the eastern side of Porirua Harbour, around 20 km north of Wellington.

All of the homes were owned by the occupiers, and included single, split-level and two-storey homes with a range of sizes, materials and designs, and variations in occupancy, as desired by the stakeholders.

3.1 Home Types

The homes were constructed between the late 1960s and the end of the 1970s. This was a period which was found to represent around 20% of the housing stock in New Zealand (Amitrano et. al. 2006).

This era of housing was expected to be difficult to retrofit since it contains a large number of split-level dwellings, skillion roofs, uninsulated concrete floor slabs, uninsulated concrete block walls, and old aluminium window frames.

3.2 Methodology

A letter was sent out to home 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 home from which they would continually reap the benefits in terms of improved internal environment, energy efficiency, and retaining any resulting profit upon sale of the home. Interested occupants/homeowners were asked to complete a form establishing the characteristics of the home and occupancy, methods of heating, and fuels used in the home to assist with the selection of the homes.

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 Papakowhai Renovation Project.

The information provided by the 148 positive responses was compiled, and the homes were sorted by occupancy types. Occupancy groups included families/high occupancy, small families/low occupancy (1+ spare bedrooms likely), and couples/non-families/low occupancy

(2+ spare bedrooms likely). The study homes were selected randomly from each occupancy group.

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

3.3 Issues

Before the sustainability interventions took place, one home was sold (P04), reducing the sample to nine. There were also some occupancy changes that occurred during the course of the project which are assessed in the companion report (Saville-Smith 2008). This is always a risk when carrying out long-term monitoring in homes for research purposes and it is not easily avoided by stipulating legal or any other requirements. Ideally protection against this eventuality should be built in by increasing the sample size, and is discussed in the 'Learnings' report (Buckett et. al. 2008). A further home was nominated by the Beacon Board as a 'Control Home' (P06) with minimal interventions being made.

4 Selecting Interventions

The sustainability interventions were chosen on the basis of a study that was performed as the first stage of this work (Amitrano et. al. 2006), together with the outcomes from other work commissioned by Beacon (Walford et. al. 2005). Discussions with stakeholders, and developments during the course of the project, also helped to establish those interventions that would advance the sustainability of the subject homes in the areas of energy, waste, IEQ and water.

The existing sustainability issues for each of the homes were found from an assessment of the homes, and are reported in the tables from Table 3 to Table 11 below. The date of installation, cost and resulting intervention package are nominated for each home in these tables.

The initial renovation report (Buckett et. al. 2007) described two different types of renovation packages which were proposed for this work, as follows:

1) A Basic or lower level package, which is expected to take the homes part, but not the whole way, towards a high standard of sustainability; and
2) A series of High sustainability packages which include features which are expected to enable the homes to achieve a high level of sustainability in relation to the key Beacon indices.

During the development of the interventions this process developed into the application of three different packages designed in an attempt to achieve differing levels of sustainability. These were:

- The **Basic** intervention: uses existing standard packages similar to some existing New Zealand intervention programs[4] plus non-energy interventions to attain an improved level of sustainability. Here energy saving (e.g. cylinder wraps and compact fluorescent lights) and humidity reduction measures (e.g. extraction fans) together with basic water-saving devices (e.g. low-flow showerheads) and solid waste minimisation (e.g. recycling and worm farms) were combined with insulation top-ups of accessible areas, or interventions to enhance the energy-oriented interventions funded and subsidised by local and central government agencies.
- The **Standard:** uses a heightened level of interventions to bring homes a reasonable way toward the Beacon HSS, as outlined below. Water saving, solid waste minimisation and energy saving measures were combined with higher levels of insulation than the Basic package, plus additional simple and moderately priced interventions. Some examples of these extra measures are efficient new light fittings, worm farms and low-flow shower heads.
- The **High Standard**: uses more extensive interventions to allow homes to achieve the Beacon HSS. This has all of the Standard solid waste reduction measures, water and energy-saving modifications, but with higher levels of insulation and incorporating more extensive, costly and difficult interventions. These include (but are not limited to) solar water heaters double glazing and sustainable high efficiency space heating.

During the intervention development, one of the homes (P06) was required by the Beacon Board to become a ‘Control Home’, which is referred to as a Low intervention, giving four levels of intervention nominated as High, Standard, Basic and Low. These labels are used in the tables in this report to better describe the intervention packages.

[4] ***The EECA and the Environment Canterbury (ECAN) upgrade programs are among such initiatives where ceiling, insulation, energy-efficient lighting and hot water cylinder wraps are some of the interventions used.***

5 Individual Home Interventions

The interventions applied to the sample homes are reported in the following section, on a home-by-home basis.

An overview of the intervention packages is provided in Table 2:

Table 2: Intervention Packages

Intervention Packages	
P01	High + Pellet Burner
P02	ECAN[4] + Waste + IEQ
P03	High + Solar Hot Water + Solid Fuel
P04	SOLD - No Interventions
P05	Standard + Gas Hot Water
P06	Low – 'Control'
P07	Standard + High Insulation
P08	High + Solar Hot Water
P09	Standard
P10	High + Solar + Solid Fuel + Wetback

Most of the interventions were energy measures. However, sustainability measures for water, IEQ and waste were also implemented. The final report will present the analysis of all the sustainability parameters and include the post-intervention waste survey.

5.1 P01

Figure 2: P01 Photo.

5.1.1 P01 – Original Home

P01 is a split-level three bedroom home constructed in the mid 1970s with a living area floor size of approximately 120 m^2. It has a skillion corrugated iron roof, and a mixture of sheet and weatherboard cladding around the outside. The lower storey has a concrete slab floor, while the upper floor over ground has a timber suspended floor with an exterior concrete perimeter wall. The home was thought to be entirely uninsulated, but was found to have fibreglass insulation in the skillion roof when the interventions began. Most of the windows were timber-framed, except for an aluminium ranch slider in the master bedroom and an aluminium window in the shower room, and all were single glazed. Draughts were noticeable at times.

A woodburner was used to heat the open plan living areas in winter, while oil column heaters were used to heat the second and third bedrooms. Remnants of a disconnected diesel-fired furnace of around the same age as the home were found underneath the home.

5.1.2 P01 – Floor Plan

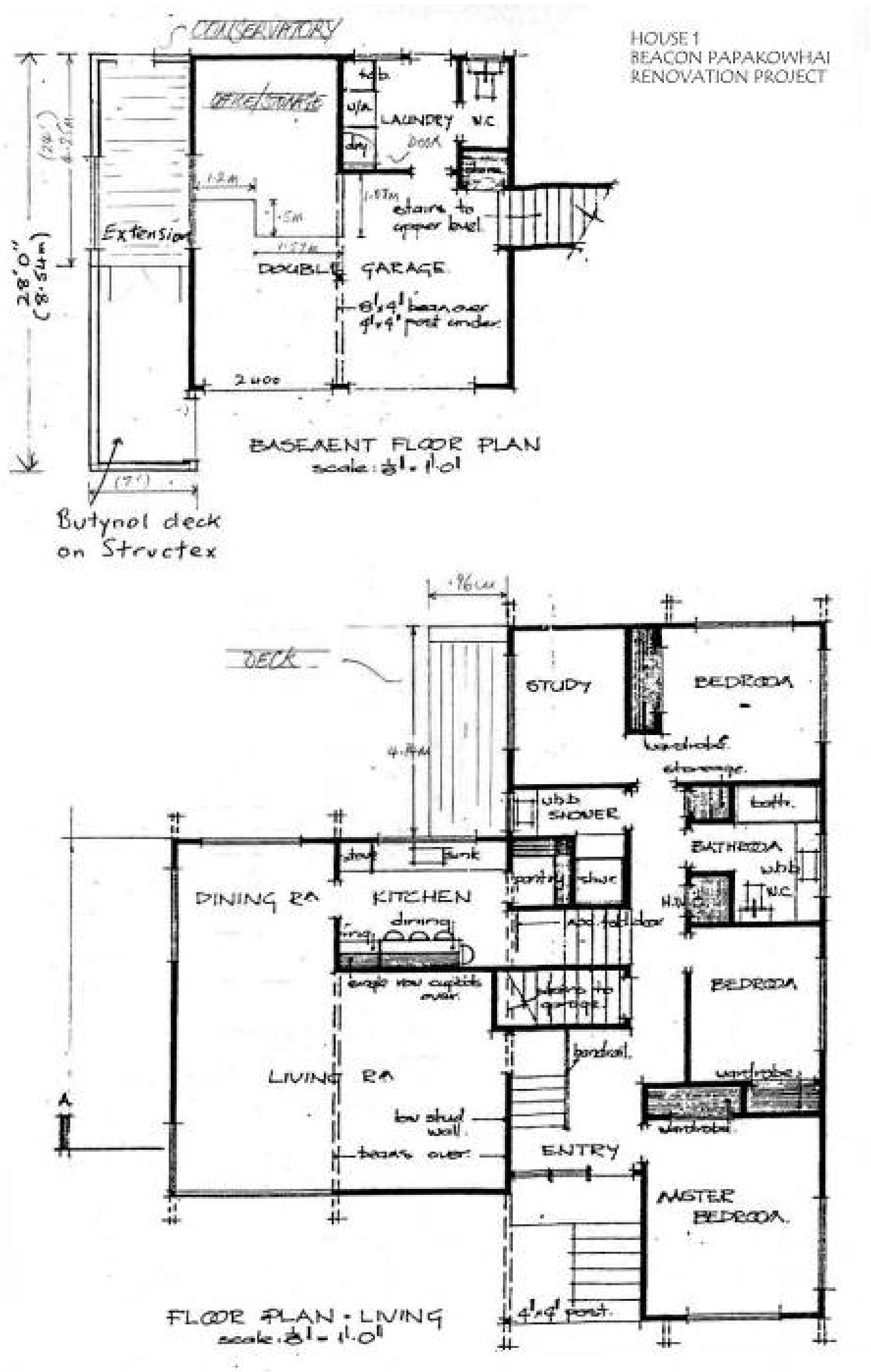


Figure 3: P01 Floor Plan.

5.1.3 P01 – Occupancy

The home is occupied by a young family of four. One parent works part-time and the other is self-employed with a second part-time job. The children are pre-school and school age. The home is occupied for much of the day.

5.1.4 P01 – Issues, Interventions and Costs

For P01, the issues that were identified in the pre-intervention information collection are presented in Table 3, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P01				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Draughty single-glazed timber-framed windows	[redacted]			Standard
Skillion ceilings throughout with inadequate insulation	Lowered and insulated ceiling to R-4.6 (R2.6 in places)	May 07	$13,270	
	Plasterboard (13 mm) for ceiling	May 07	$570	
Draughts from downstairs around sliding door	Heavy draught-stopping around door to garage	May 07	$100	
Uninsulated cavity walls	[redacted]			
Uninsulated underfloor	Insulated floor with R-2 foil-backed bulk insulation, polythene put on ground	Feb 07	$1,960	
Uninsulated mid-floor above garage	[redacted]			
Older woodburner	Pellet burner installed	July 07	$4,330	
Inadequately heated bedrooms	Ducted heat transfer kit with three outlets installed	May 07	$3,020	
Food waste not being composted	Worm farm installed	Sep 07	$160	
Energy inefficient lighting	Compact fluorescent bulbs put into high-use fittings	May 07	$30	
Plumbing quality unknown	Plumbing checked		$80	
High mains water use	[redacted]			
Leaky fridge seals				
Poorly insulated B Grade electric hot water cylinder	Hot water cylinder wrapped and pipes insulated with lagging	May 07	$90	
	TOTAL		$23,610	

Table 3: P01 – Issues, Interventions and Costs.

5.1.5 P01 – Monitoring Analysis

The monitoring analysis for the interim report was performed on data taken from a period where the installation of the pellet burner and the insulation of the ceilings were still being undertaken in this home. However, the following results have statistical significance. Analysis of data from a full year after the intervention (to be presented in the final report) is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis.

5.1.5.1 Energy

There was no statistically significant difference in energy consumption before and after the retrofit. The floor was insulated and the skillion ceiling lowered to allow for a greater thickness of insulation, together with a ducted heat transfer system. The existing storage electric hot water cylinder was wrapped and pipes lagged. For this home the retrofits have led to improvements in comfort without increasing total energy consumption, being an example of comfort take-back.

5.1.5.2 IEQ

The average 24 hour air temperatures over the winter period in the family room rose from 14.8°C to 15.7°C and in bedroom 1 from 13.2°C to 14.3°C, as shown in Table 12. In both cases this fell short of the HSS target for temperature of 18°C for living rooms and 16°C for bedrooms.

A heat transfer system was installed to allow heat from the pellet burner to be transferred to the bedrooms.

The average 24 hour humidity in the master bedroom was 68% RH for the second (2007) winter (see Table 14). The humidity in the 2006 winter was not monitored.

The application of heavy draught-stopping between the internal garage and the living space reduced the draughts that entered the home under the garage door.

5.1.5.3 Water

No changes were made to the water reticulation end-uses of this dwelling since the showers already had a low-flow rate, and the toilets were erroneously believed to already have dual-flush cisterns.

P01 had the highest equal water demand with P08, with an average total water use of 330 L/p/d between February and October 2007, as can be seen in more detail in Table 15.

5.2 P02

Figure 4: P02 Photo.

P02 is a two-storey colonial-style home with four bedrooms constructed in 1970. The home has a coated metal tile roof and a mixture of weatherboard and sheet cladding. The windows are mainly timber, with three new aluminium windows in the master bedroom, which was recently extended by around a metre. The lower storey appears to have been an addition put in soon after the home was built, and contains the garage, a bedroom and service rooms. It is smaller than the upper storey, and is set into a bank. The majority of the upper storey has timber suspended floors, some of which is over a subfloor space, while the lower storey and the new section of the upstairs master bedroom have a concrete slab floor.

The living rooms (kitchen, dining and lounge) and three of the four bedrooms are upstairs. Their floor area is approximately 140 m^2.

Fibreglass batts were installed throughout the ceiling cavity at least 24 years ago, and only the master bedroom had wall insulation to the 2000 New Zealand Building Code (the Building Code) minimums when it was extended in 2003/2004. The home still retains its original electric low-pressure hot water cylinder, which is located within the ceiling cavity.

The home is heated with a woodburner, and downstairs was heated with oil column heaters when adult children were home in 2006.

5.2.1 P02 – Floor Plan

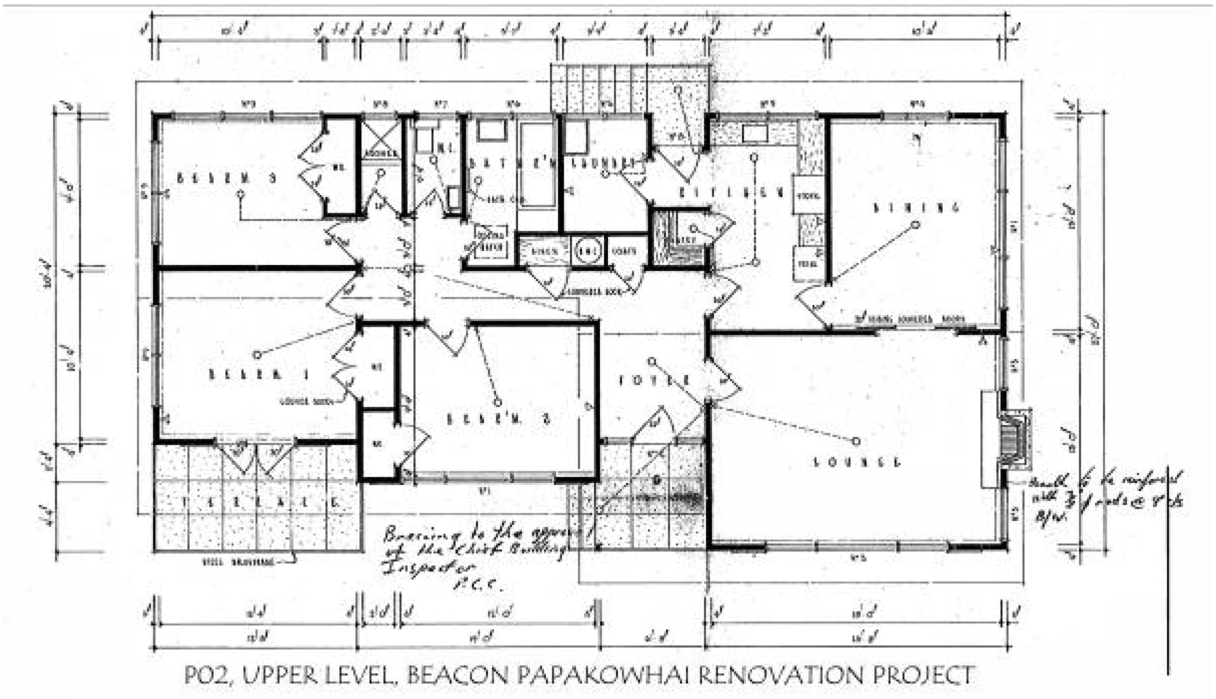


Figure 5: P02 Floor Plan (note that the lower level is not shown here).

5.2.2 P02 – Occupancy

The home is occupied by a semi-retired couple, both working part-time out of the house, and one working part-time from home. In 2006 two adult children and friends stayed in the home for extended periods.

5.2.3 P02 – Issues, Interventions and Costs

For P02, the issues that were identified in the pre-intervention information collection are presented in Table 3, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P02				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Single-glazed timber-framed windows in excellent condition, but require new stays	[redacted]	[redacted]	[redacted]	
Original D Grade electric hot water cylinder is poorly insulated	Hot water cylinder wrapped and pipes lagged	July 07	$90	
No underfloor insulation	Floor insulated with R-2 foil-backed bulk insulation, polythene put on ground	Feb 07	$1,290	
Dislodged ceiling insulation	Ceiling insulation re-laid, extra added where necessary	Feb 07	$110	
Food waste not being re-used	Worm farm installed	Sep 07	$160	
Extractor fan not working well	Extra fan added to heat transfer kit, ducting shortened	Jul 07	$280	Basic
Broken cat flap causing draughts from garage	New cat door installed	Jul 07	$50	
Energy inefficient lighting	Compact fluorescent bulbs put into high-use fittings	Jul 07	$30	
Plumbing of unknown quality	Plumbing checked	May 07	$80	
No smoke alarm	New smoke alarm installed	May 07	$30	
No significant water reuse methods or appliances	[redacted]	[redacted]	[redacted]	
Fridge seals old and probably leaky	[redacted]	[redacted]	[redacted]	
No wall insulation	[redacted]	[redacted]	[redacted]	
	TOTAL		$2,120	

Table 4: P02 – Issues, Interventions and Costs

5.2.4 P02 – Monitoring Analysis

The following results have statistical significance. However, analysis of data from a full year after the intervention will be performed in the final report, and is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, and will include summer data analysis.

5.2.4.1 Energy

P02 saw significant changes after the intervention. The existing storage electric hot water cylinder was wrapped and pipes lagged. The floor was insulated with R-2 foil-backed glass fibre insulation batts and ceiling insulation was re-laid and topped up to R-2.6. Total electricity and total energy consumption decreased, and so did the space and water heating. Overall energy consumption during the May–September period was about 20% lower after the intervention, although occupancy fluctuations are likely to be an influencing factor. See Table 12 for the presentation of the energy and temperatures by end use. This home was one of only two that meet the HSS benchmark for energy – based on total energy, not just reticulated energy.

5.2.4.2 IEQ

Family room and bedroom temperatures increased, as shown in Table 12. However, this may be partly due to occupancy patterns.

The occupancy patterns for P02 were varied and changed during the monitoring, affecting some results. A daughter visited in winter 2006, which increased energy consumption and temperatures. There were also more people living in the home in summer.

The average 24 hour RH level in the master bedroom of P02 was 64% in the second winter (see Table 14), but the average RH exceeds the 70% upper bound on occasion. Humidity was not measured in the 2006 winter.

5.2.4.3 Water

P02 used a total average of 280 L/p/d of water between February and October 2007 (as can be seen in Table 15).

5.2.4.4 Waste

The volume of household waste in a single month before the renovations is not currently available, but will be included in the final report.

5.3 P03

Figure 6: P03 Photo.

Originally purchased as a classic New Zealand doer-upper a few years ago, the new owners did not know where to start and it remained unchanged until this project began.

The home was built and owned by a builder in the 1970s and was framed with rimu timber. The exterior cladding is a mix of weatherboard and sheet cladding, with concrete block around the addition, and a small stone veneer façade at the front of the garage.

The lower floor has a concrete slab floor, while the upper floor has timber suspended floors. The original corrugated iron roof was in a state of disrepair and had been leaking – it was described by the homeowners as made water resistant only through the presence of a vast amount of duct tape. The roof is partly skillion, partly cavity. The windows were all older, unventilated single-glazed aluminium, which were badly degraded and in need of replacement.

The living area floor size is approximately 120 m^2 excluding the downstairs where the occupants ran a small business from home (note that this has since moved out). This resulted in difficulty in attributing energy uses since separate metering of the domestic and commercial areas could not be done. The home contains a large open plan living and dining area, and kitchen on the upper floor. The bedroom wing, located in the split-level, contains three bedrooms, a large foyer, bathroom and toilet. Downstairs there is a laundry, toilet and several offices. The addition of the large office at the rear of the home took place in the early 1980s.

The walls contained glass fibre insulation which appeared to have been installed when the home was constructed, yet the cavity roof was uninsulated until the new owners installed R-2.6 glass fibre insulation in the ceiling cavity over the bedroom wing. The skillion roof above the living areas was found to have been insulated to what is a low level by today's standards when built. The underfloor area beneath the bedroom wing was uninsulated. Many homes built in the late 1970s and early 1980s may have this ad-hoc approach where some parts are insulated and others are not, making it even more difficult for assessors to accurately record insulation levels and for homeowners to decide what improvements are needed.

During the first monitoring period, the home was heated with two heat pumps: a large unit upstairs and a smaller, less efficient, unit downstairs in the offices. A fan heater was also used in the office area. An old woodburner was occasionally used in the lounge, and the children’s bedrooms were heated with oil column heaters. There is a heat transfer system from the lounge into the master bedroom.

5.3.1 P03 – Floor Plan

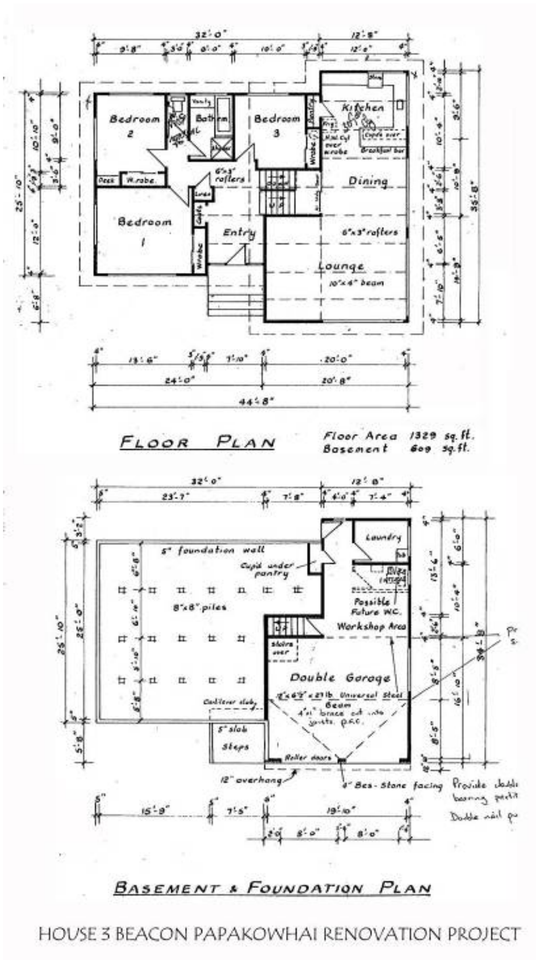


Figure 7: P03 Floor Plan (note that the office extension is not shown in this picture).

5.3.2 P03 – Occupancy

The home is occupied by a young family of five, with two primary school age children, and another who started attending school during the renovations. The parents worked from home during the day from the downstairs area (until February 2008) and have expanded their business from having two-and-a-half full-time equivalent employees at the start of the project, to five working there in the second monitoring period. This commercial operation was removed from the home in January 2008.

5.3.3 P03 – Issues, Interventions and Costs

For P03, the issues that were identified are presented in Table 5, together with the interventions designed to address these issues, costs, date of completion of the intervention, and the type of intervention package.

P03				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Old wall insulation in unknown state	Stripped, re-insulated and re-lined walls of thermal envelope to R-2.4 Pelmets rebuilt	Sep 07	$10,050	**High**
Old skillion ceiling insulation in unknown state – assume R-1	Lounge, dining and kitchen skillion ceilings lowered and insulated with R-3.6 glass fibre insulation	Feb 07	$5,930	
	Plasterboard for walls (10 mm) and ceiling (13 mm)	Feb/Sep 07	$1,450	
No underfloor insulation	Floor insulated with R-2 foil-backed bulk insulation, polythene put on ground	Feb 07	$2,020	
135l B Grade electric hot water cylinder serving family of five	Solar water heating system installed with 300l cylinder	May 07	$10,060	
Old woodburner past useful life	Occupant installed new NES[5] compliant woodburner		$3000	
Ceiling insulation in cavity needing to be re-laid	New ceiling insulation put over existing insulation in accessible places. Existing insulation re-laid, R-2.6 insulation put over top and over ceiling joists to remove thermal bridging	Feb 07	$1,080	
Plumbing in unknown state	Plumbing checked	May 07	$80	
No smoke alarm	New smoke alarm installed	May 07	$30	
Fridge seals potentially needing replacement	[redacted]			
Food waste not being reused	Worm farm installed	Sep 07	$160	
Extraction fan in kitchen out of commission	New rangehood in kitchen	Aug 07	$870	
High water use toilets	Two dual flush toilet cisterns installed	Sep 07	$90	

[5] *Ministry for the Environment's (MfE) National Environmental Standards (NES) for Woodburners. The NES are a nationwide regulation that restricts the discharge of particles into air from woodburners and requires that new woodburners installed on properties of less than 2 hectares must meet:*
a. A particle emission rate of less than 1.5 g/kg (grams of particulate per kilogram of wood burnt); and
b. A thermal efficiency of at least 65 per cent (percentage of thermal heat produced in comparison to the amount of energy available).

Old aluminium window frames past useful life	Windows replaced with standard clear double glazing and standard frames	Oct 07	$41,770	
	(Occupants replaced roof)	Feb 07	N/A	
	TOTAL		$76,590	

Table 5: P03 – Issues, Interventions and Costs.

5.3.4 P03 – Monitoring Analysis

The monitoring analysis for the interim report was performed on data taken from a period where the windows in this home were still being completed. This led to significant draughts being present around the windows through the winter months. However, the following results have statistical significance. Analysis of data from a full year after the intervention to be presented in the final report is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis.

There are likely to be significant impacts of the small business operating from downstairs. However, we currently do not have enough information to make appropriate assumptions about division of the energy use. A way to separate the domestic from the commercial resource use will be introduced in the final report. Some of these issues are addressed in the companion reports (Saville-Smith 2008) and (Buckett et. al. 2008) and include:

- implications for water use and heating patterns
- the additional thermal effect provided by the business premises outside the thermal envelope of the residential portion of the house
- the occupancy variation
- the interaction between the two spaces.

5.3.4.1 Energy

Despite interventions in this home being incomplete for the duration of the 2007 winter monitoring period, energy consumption for P03 dropped. Total energy and electricity consumption each dropped by approximately 15%, space heating by 33% and water heating energy by a very significant 60%. The solar hot water system was responsible for more than half of the overall decrease in total reticulated energy consumption. This home was one of only two that meet the HSS for reticulated energy use. Table 16 presents the reduction in hot water energy use, and the volume of water heated by the solar water heating system.

5.3.4.2 IEQ

Temperatures in the family room increased slightly (0.4°C), and by about 1.5°C in bedroom 1. See Table 12 for the presentation of the energy and temperatures by end use.

The average 24 hour RH in the master bedroom of P03 was the lowest of the nine homes with 57% in the second (2007) winter (see Table 14). However, there were some instances where the current HSS for humidity (70%) was exceeded, but this may change as the home dries out.

5.3.4.3 Water

P03 used a total average of 140 L/p/d of water between February and October 2007, being the lowest per person water use for any home in the sample (see Table 15). The solar water heating system heated around 6,000 L of water per month during the first four months of operation, being 39 L/p/d, as can be seen in Table 16,

5.4 P04

P04 was withdrawn from the project upon its sale in the first monitoring period.

5.5 P05

Figure 8: P05 Photo.

P05 is a one-storey three bedroom home constructed in 1978 just before insulation became mandatory under the Building Code. It has an open plan living areas and a sunken lounge. The home is clad with brick on the road frontage, and weatherboard around the rest of the house, with an enclosed subfloor perimeter wall. The timber-framed windows are in good condition, apart from having worn out stays leading to draughts, especially through the living areas. The home has a metal tile roof. The majority of the floor of the living areas is suspended timber, apart from the concrete slab floor of the sunken lounge and the attached garage. The living area floor size is approximately 130m^2.

The exterior walls of the home and the partition wall between the garage and the home were found to be insulated with R-1.5 batts when intervention work started. Ceiling insulation that varied from R-1.5 to around R-2.2 had been retrofitted into the ceiling cavity by an insulation installation company several years prior to this project. The timber suspended floors of the home were uninsulated. The 1978 hot water cylinder was wrapped and pipes lagged when the ceiling insulation was installed.

The home was heated with a flued open gas fireplace in the lounge and an electric convection heater in the dining room.

5.5.1 P05 – Floor Plan

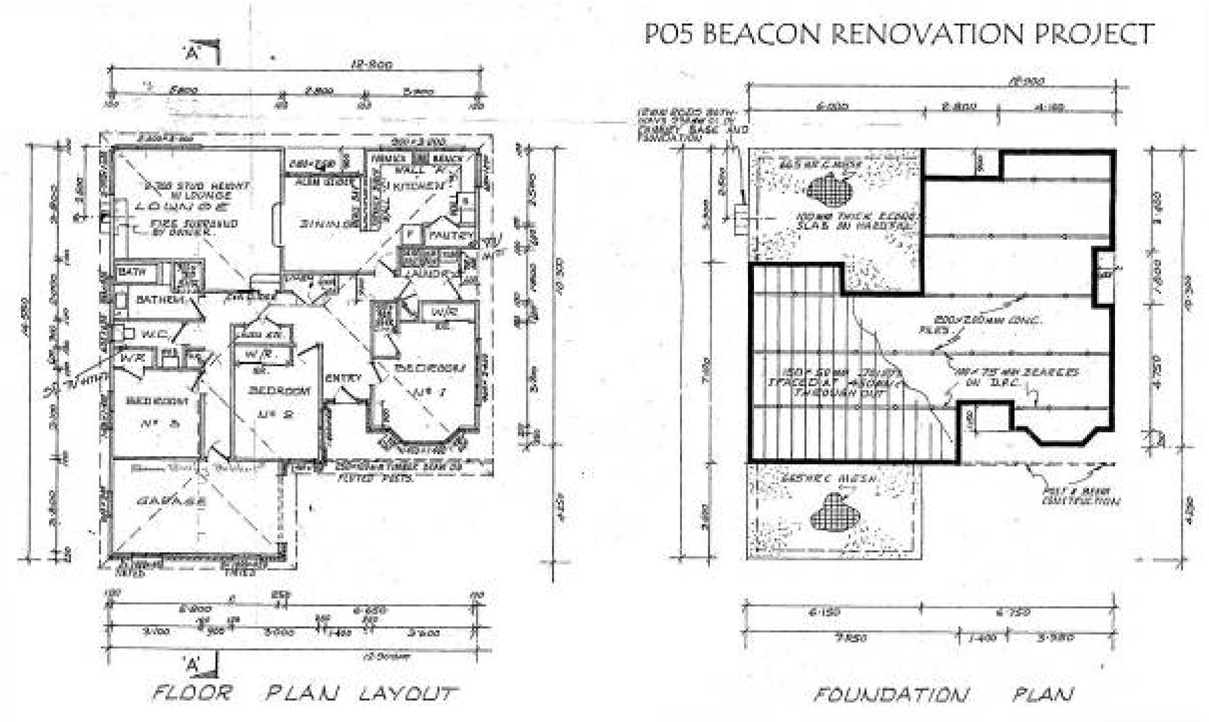


Figure 9: P05 Floor Plan.

5.5.2 P05 – Occupancy

The occupants of P05 are an active retired couple.

5.5.3 P05 – Issues, Interventions and Costs

For P05, the issues that were identified in the pre-intervention information collection are presented in Table 6, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P05				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention 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	Jul 07	$4,520	Standard
Lack of wall insulation making heat losses high	Plastering repairs to walls	Feb 07	$50	
Older ceiling insulation in unknown state	Ceiling insulation topped up with R-1.8 blanket	Feb 07	$1,190	
No underfloor insulation making heat losses high	Timber suspended floors insulated with R-2 foil-backed bulk insulation, polythene put on ground	Feb 07	$3,030	
No active heating in bedrooms	Ducted air transfer system installed to move warm air into hallway by bedrooms	Jun 07	$1,400	
Extraction fan vents moisture into roof cavity	Bathroom extraction fan ducted to outside	Jun 07	$70	
No significant water re-use methods or appliances	[redacted]			
Fridge seals in poor state				
Plumbing in unknown state	Plumbing checked	May 07	$80	
Draughty windows and sliding door in dining room contributing to heat loss	Sliding door draught-stopped	Jun 07	$50	
Large old recessed downlight in kitchen resulting in poor energy use and loss of insulation value	Two x CA-rated halogen downlights installed in kitchen	Jul 07	$110	
Energy inefficient lighting	Compact fluorescent bulbs put into high-use light fittings	May 07	$30	
Food waste going into the bin	Worm farm installed	Sep 07	$160	
	TOTAL		$10,690	

Table 6: P05 – Issues, Interventions and Costs.

5.5.4 P05 – Monitoring Analysis

The monitoring analysis for the interim report was performed on data taken from a period where interventions were being undertaken in this house. This data should therefore be viewed as indicative.

5.5.4.1 Energy

In P05 the total electricity consumption decreased by ~45%, and heating energy by ~10%. However, the water heating energy consumption nearly doubled, resulting in no overall change in total energy consumption (see Table 12).

5.5.4.2 IEQ

Temperatures in the family room and bedroom were unchanged within error bounds, not meeting the HSS.

The average 24 hour humidity level in the master bedroom of P05 was 69% in the 2007 winter (see Table 14). This does not meet the HSS for humidity of 20 to 70% under the definition used in this work.

5.5.4.3 Water

This home had two instant gas hot water systems installed, and this resulted in a reduction in electricity consumption, as electricity was no longer used for water heating. The increase in water heating energy consumption is most likely caused by an increase in hot water use. This is possibly in response to the greater supply and convenience of the instant gas hot water systems, although no comparison of the change in the volume of hot water use has been attempted.

Initially this home had a low-pressure water reticulation system, so flow restrictors were required to avoid damage to the system since the system operated at mains pressure. A low-flow shower head was fitted with the intention of improving the older style shower rose present, and a mixer was installed that would work with the unequal hot and cold water pressures.

P05 occupants used an average of 200 L/p/d of water between February and October 2007 (as can be seen in Table 15).

5.6 P06

Figure 10: P06 Photo.

P06 was constructed during the early 1970s. The home is mainly lightweight construction clad with weatherboards, with some sheet cladding around the lower part of the house. A family room was added around the 1980s, and is solid construction with concrete block walls. The majority of the home has timber suspended floors, with concrete slab floors in the garage and family room. The windows are half newer aluminium-framed single glazing on the southern side of the house, while on the northern side they are a combination of older aluminium and timber. The home has a large conservatory area which has been placed outside the thermal envelope in this work. This space is not believed to have been heated from a reticulated energy source.

The ceiling cavity had poorly laid and patchy glass fibre insulation throughout the home, with the exception of the family room ceiling cavity where there was no insulation at all. The home also has open downlights throughout, creating holes in the insulation and allowing additional heat loss. Glass fibre insulation was installed into the mid-floor cavity between the lounge and garage. The insulation had been pushed into place, and has folds and gaps throughout the cavity. The rest of the underfloor was not insulated, nor were the walls.

The home has a living area of approximately 190 m². The home was heated with a woodburner in the family room, oil column heaters in the bedrooms, and a portable LPG heater was moved where it was required.

5.6.1 P06 – Floor Plan

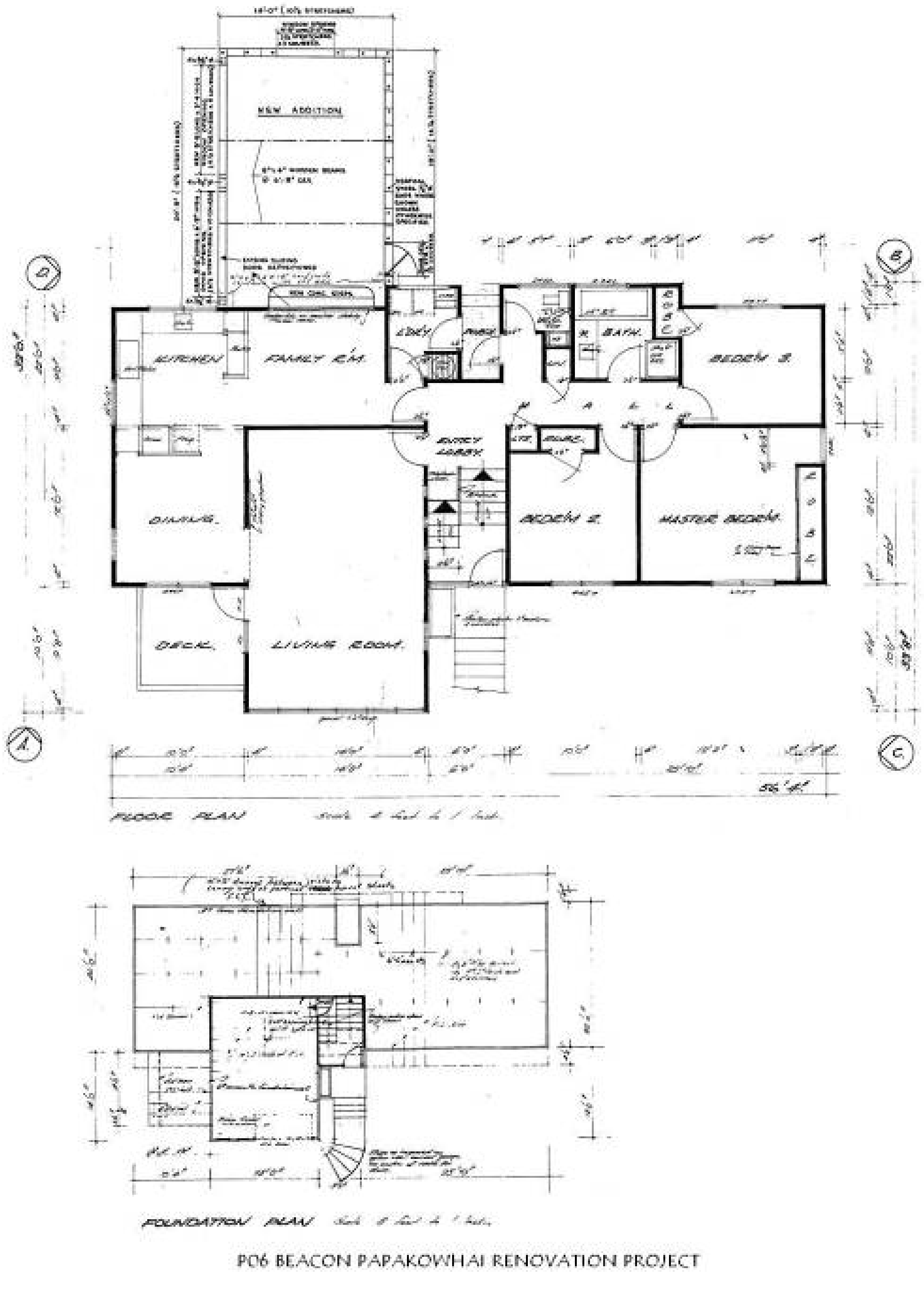


Figure 11: P06 Floor Plan.

5.6.2 P06 – Occupancy

The home was occupied by a family of three professionals throughout the initial monitoring period, with two adult children residing there on a transitional basis. From around the end of the interventions, the owners revealed that one adult had moved out, and another two adults were again living at the home on a transitional basis. This will need to be taken into account when the full data monitoring analysis is performed.

5.6.3 P06 – Issues, Interventions and Costs

For P06, the issues that were identified in the pre-intervention information collection are presented in Table 7, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P06				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Poor insulation in ceiling	Ceiling insulation topped up with R-2.6	Jul 07	$1,380	Low
No wall insulation	[redacted]	[redacted]	[redacted]	
New single-glazed aluminium windows across south side of home with poor insulation value	[redacted]	[redacted]	[redacted]	
No underfloor insulation	[redacted]	[redacted]	[redacted]	
B Grade hot water cylinder losing excessive heat	[redacted]	[redacted]	[redacted]	
Food waste going into the bin	[redacted]	[redacted]	[redacted]	
No significant water re-use methods or appliances	[redacted]	[redacted]	[redacted]	
Large old downlights leaking air and interrupting insulation	[redacted]	[redacted]	[redacted]	
Plumbing in unknown state	[redacted]	[redacted]	[redacted]	
	TOTAL		$1,380	

Table 7: P06 – Issues, Interventions and Costs.

5.6.4 P06 – Monitoring analysis

P06 was originally planned to receive interventions, but this was changed before the interventions to be a ‘Control Home’. However, the householders indicated that unless they received some intervention they would pull out of the project. Consequently, ceiling insulation was installed throughout the main ceiling cavity of the home in August 2007.

This was the only home possessing an unflued gas heater in the remaining nine houses.

This data should be seen as purely indicative due to the monitoring analysis of this home for this interim report being performed on post-intervention data taken from a period of about a month.

5.6.4.1 Energy

P06 had a top-up of ceiling insulation to R-2.6, which is a very low level of intervention. The occupants were away for much of the winter on an overseas holiday and only one person was at home on a transitional basis during this time. This is addressed in the companion report.

As a result, there was no significant change in energy consumption seen in the short time (approximately one month) after the intervention (see Table 13).

5.6.4.2 IEQ

There were no significant changes in the temperatures found in this house.

The average 24 hour humidity level in the master bedroom of P06 was 61% in the second winter (2007) as shown in Table 14, but does not meet the range of the HSS for humidity as in Table 14.

5.6.4.3 Water

Hot water energy consumption dropped by ~30%, which cannot be explained by the interventions. There was a change from the usual occupancy over the winter period which may have been the cause.

P06 did not have water metered since access to the mains water supply was not readily available.

5.7 P07

Figure 12: P07 Photo.

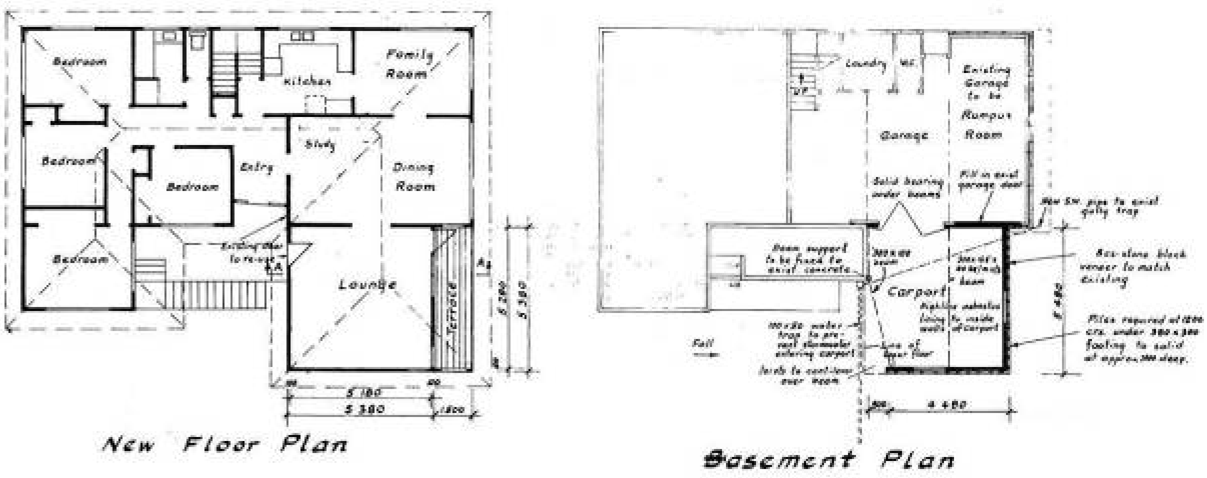
The original part of P07 was built around 1970. The home is mainly clad in weatherboard, with some sheet cladding. The home has a ventilated concrete perimeter wall, a suspended timber floor upstairs, and an uninsulated concrete slab floor downstairs in the garage, utility and rumpus areas. The home has a coated metal tile roof. The older aluminium windows in the upper part of the home were recently replaced with 10 mm laminated glass and new frames with the intention of reducing noise and providing better insulation. Downstairs (which was not considered to be part of the living spaces of the home in this project) the windows are a mixture of timber and aluminium, all in poor condition. Over the past few years, the living areas of the home have been insulated, re-lined and new windows put in. A lounge was added on top of the garage and the wall and ceiling insulation appropriately meets the 1996–2007 Building Code minimum levels for Zone 2. The living area floor size is approximately 160 m².

The ceiling cavity is insulated with material that conformed to the 1996–2007 Zone 2 Building Code minimums in the living areas (R-1.8), and has macerated paper insulation in varying states of condition and settlement throughout the rest of the house. The floor of the lounge over the garage does not have mid-floor insulation. The roof space is low and difficult to work in. The home has a multitude of halogen downlights, requiring many holes in the insulation throughout the living areas and combining to leave a significant amount of the ceiling effectively uninsulated. The walls of the living areas were insulated at the start of the project, and the underfloor area was uninsulated.

The home contains four bedrooms, a bathroom, toilet, open plan kitchen/dining/family room/lounge area upstairs, and a rumpus room, bathroom, toilet, laundry, workshop, storage and garage downstairs.

The living areas are heated with a large, recently installed enclosed woodburner in the lounge. An air transfer system had also recently been installed to pull warm air from the lounge up to the top of the hallway by the bedrooms. However, the thermostat was located in the unheated hallway, so was rarely switched on to transfer warm air.

5.7.1 P07 – Floor Plan



P07, BEACON PAPAKOWHAI RENOVATION PROJECT

Figure 13: P07 Floor Plan.

5.7.2 P07 – Occupancy

The occupants are a middle-aged couple, both employed full-time. The 2007 BRANZ interview revealed that one of the two occupants does contract work overseas at times, meaning that the home is usually occupied by a single adult, with transient visits from adult children and grandchildren.

5.7.3 P07 – Issues, Interventions and Costs

For P07, the issues that were identified in the pre-intervention information collection are presented in Table 8, together with the interventions to address these issues, costs, date of completion of the intervention, and the type of intervention package.

P07				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Low to medium levels of insulation in ceiling	Ceiling insulation topped up with R-2.6, existing insulation tidied up	Apr 07	$1,940	Standard
No wall insulation in bedroom wing	R2.4 wall insulation installed by occupants in bedroom wing	May 07	$1,940	
	Plasterboard for walls	Jun 07	$480	
No underfloor insulation	Timber suspended floors insulated with R-2 foil-backed bulk insulation, polythene put on ground	Feb 07	$1,770	
B Grade electric hot water cylinder not insulated	How water cylinder wrapped, pipes lagged	Feb 07	$90	
Heat transfer system not working, bedrooms not actively heated	Relocated heat transfer thermostat into lounge, extended ducting to bedrooms	Jun 07	$810	
Extraction fan vents moisture into roof cavity	Bathroom extraction fan ducted to outside Shower dome installed	May 07	$370	
New single-glazed aluminium windows throughout family areas offer poor insulation value	Occupants retrofitted rest of home with single-glazed tinted laminated aluminium windows	Dec 06	N/A	
No significant water re-use methods or appliances	[redacted]			
Plumbing in unknown state	Plumbing checked	May 07	$80	
Food waste going into the bin	Worm farm installed	Sep 07	$160	
	TOTAL		$7,640	

Table 8: P07 – Issues, Interventions and Costs.

5.7.4 P07 – Monitoring Analysis

The monitoring analysis for the interim report was performed on data taken from a period where in some cases the retrofits where still being undertaken in this house. However, the following results have statistical significance. The analysis of data from a full year after the intervention will be presented in the final report. This is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis.

5.7.4.1 Energy

There was no statistically significant change in the energy consumption of P07 after the intervention, despite the installation of wall insulation in the bedroom wing and the floor insulation.

5.7.4.2 IEQ

Family room temperatures increased slightly, but there was no statistically significant change in bedroom temperatures. This household had an unusual heating pattern and personal communication with the principal occupant revealed that they only heated during the weekends, so space heating energy consumption was already low. See Table 12 for the presentation of the energy and temperatures by end use.

The average 24 hour RH in the master bedroom of P07 was 72% in the second winter (see Table 14), exceeding the HSS humidity range of 20 to 70%.

5.7.4.3 Water

Due to lack of access to the water mains, P07 did not have water use metered. Water going through the solar water heating system was metered, with 5–6,000 litres used per month from May to September 2007 (see Table 16). This will be further analysed in the final report.

5.8 P08

Figure 14: P08 Photo.

P08 is the oldest home in the sample, having been constructed around 1968. The home is predominantly lightweight construction. The upper split-levels of the home are mainly clad in timber weatherboards, with some sheet materials below the apex of the long-run iron roof. The lower part of the home is clad in sheet material, and the back wall of the downstairs gym is uninsulated concrete block.

The home has been very well-maintained. The majority of the window frames have been replaced with aluminium frames, and the glazing was replaced with tinted single glazing just before the project began.

The gym part of the downstairs area (in the higher part of the split-level) was added around 2004. The two windows in this area are double glazed with standard aluminium frames, and the exterior walls were insulated to meet the minimum levels of the Building Code for Zone 2 at that time (R-1.5). The floor in this area is concrete slab on a continuous concrete block footing. The rest of the living areas of the home have suspended timber floors, while the garage has a concrete slab floor. The living area floor size is approximately 200m^2.

At the start of the project, there was insulation throughout the ceiling cavity, with larger than necessary gaps for recessed halogen lights in the bathroom and the living areas. The exterior walls were uninsulated, aside from the exterior walls of the downstairs gym. The underfloor was entirely uninsulated at the start of the project.

P08 contains three bedrooms in the uppermost level, along with a bathroom and toilet, and attaches to a garage without internal access. The lower split of the top level contains the foyer and open plan lounge, dining and kitchen areas. In the upper split of the downstairs level is a gym, while the lower split contains the laundry, rumpus room and fourth bedroom.

The home is heated with two nightstore heaters, one in the hallway of the bedroom wing upstairs and one in the rumpus room downstairs. There is manually controlled electric underfloor heating in the family room and multiple dehumidifiers, although the 2007 survey found that use of one dehumidifier had been discontinued.

5.8.1 P08 – Home Plans

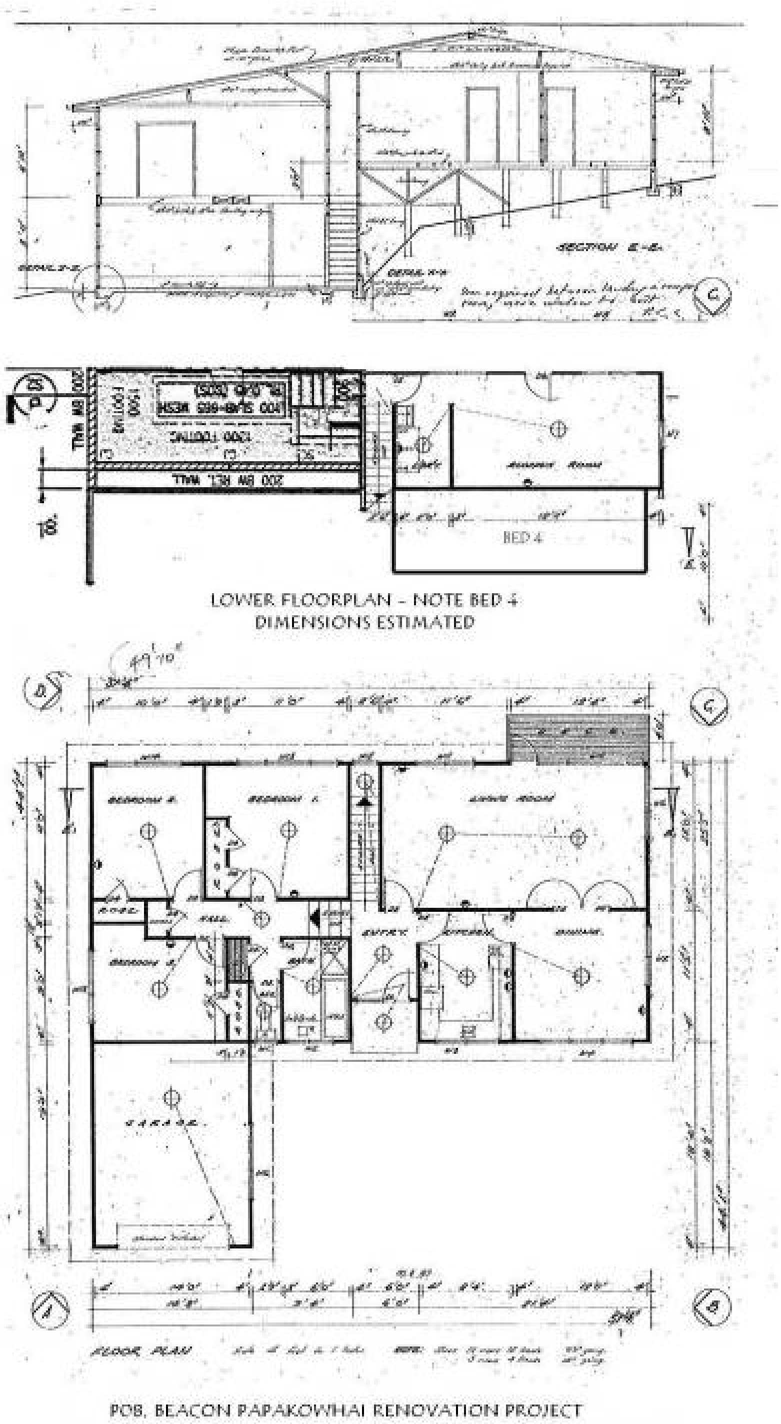


Figure 15: P08 Home Plans.

5.8.2 P08 – Occupancy

The occupants of the home are an adult couple; this has decreased from three occupants before early 2007. Both adults work full-time with one working from home. A further change has seen one adult residing elsewhere over weekends.

5.8.3 P08 – Issues, Interventions and Costs

For P08, the issues that were identified in the pre-intervention information collection are presented in Table 9, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P08				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Ceiling insulation at moderate level but needs re-laying in places	Ceiling insulation re-laid, second layer of R-2.6 put over existing and across ceiling joists, removing thermal bridging, raising insulation to approx R-5	Feb 07	$940	High
No wall insulation	Rear wall of bedroom 4 (R-2.4 batts) and gym backing onto underfloor (R-1.2 masonry) insulated	May 07	$390	
No underfloor insulation	Floor insulated with R-2 foil-backed bulk insulation, or foil, polythene put on ground	Mar /May 07	$2,160	
B Grade electric hot water cylinder with excessive heat loss	Solar water heating with 300l cylinder installed	May 07	$9,870	
New aluminium framing with single-glazed panes do not provide good insulation	Double-glazing panes retrofitted into existing aluminium frames (including scaffolding)	Jun 07	$10,700	
No significant water re-use methods or appliances	[redacted]	[redacted]	[redacted]	
Fridge seal replacement potentially needed	[redacted]	[redacted]	[redacted]	
Condensation and mould in bathroom	Shower dome installed	May 07	$310	
Plumbing in unknown state	Plumbing checked	May 07	$80	
Food waste going into the bin	Worm farm installed	Sep 07	$160	
	TOTAL		$24,610	

Table 9: P08 – Issues, Interventions and Costs.

5.8.4 P08 – Monitoring Analysis

The results below have statistical significance, and analysis of data from a full year after the intervention is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis. This will be presented in the final report.

5.8.4.1 Energy

The total electricity consumption for P08 decreased by about 20%. Total heating energy consumption of this home was unchanged. P08's total energy consumption decreased by around 20% in the second monitoring period. Reticulated hot water energy consumption decreased by around 80%, due to the solar hot water system. See Table 16 for the presentation of the energy used by the solar hot water system.

5.8.4.2 IEQ

While the average temperatures in the family room and bedroom 1 met the HSS benchmarks before the project began, temperatures have increased by 0.8°C to 19.0°C in the family room, and 0.4°C to 17.8°C in bedroom 1 (see Table 13). The average 24 hour humidity level in the master bedroom of P08 was 64% in the second winter (see Table 14).

5.8.4.3 Water

P08 used an average total of 330 L/p/d of water as can be seen in Table 15. The consumption per person in P08, which matches that of P01, is the highest of the sample. The solar water heating system heated an average of 65 L/p/d of water for the four months analysed (see Table 16). We cannot determine whether the installation of the solar water heating system led to an increase in overall potable water consumption.

5.9 P09

Figure 16: P09 Photo.

P09 is a timber-framed double-storey townhouse built in 1976. The lower storey is clad in sheet material and has a concrete slab floor, while the upstairs is clad in fibre-cement weatherboards and has a timber suspended floor, some of which is over a subfloor space. The windows are all single glazed with older aluminium frames. This semi-detached townhouse has a concrete block firewall on the western wall between it and the neighbouring unit. The roof is clad with concrete tiles. The thermal envelope of this dwelling is different from the other homes in this study given that it has a shared wall. The heat transfer (or effective insulation value) of this wall is therefore affected by the amount of heating that is performed in the adjacent space, which was not monitored in this work. It is assumed that if the neighbouring occupants do heat their dwelling, P09 will benefit from the heat that is lost through the shared wall. However, considering the adjacent rooms are bedrooms (the HEEP study revealed few New Zealand bedrooms are heated), the real benefit is expected to be slight. The living area floor size is approximately 95 m^2.

The upstairs area contains an open plan kitchen, dining and family room area as well as two bedrooms, a bathroom and a laundry. Downstairs has a single internal garage below the master bedroom, a large rumpus room and an unused sauna.

The walls and ceiling of the home were insulated with older glass fibre insulation, while the underfloor area was uninsulated.

The heat pump in the family room was installed in October 2006 after the 2006 winter monitoring period finished. A fan heater is used for short periods to heat the master bedroom, as is a portable halogen radiant heater and a fan heater downstairs in the rumpus room.

5.9.1 P09 – Floor Plan

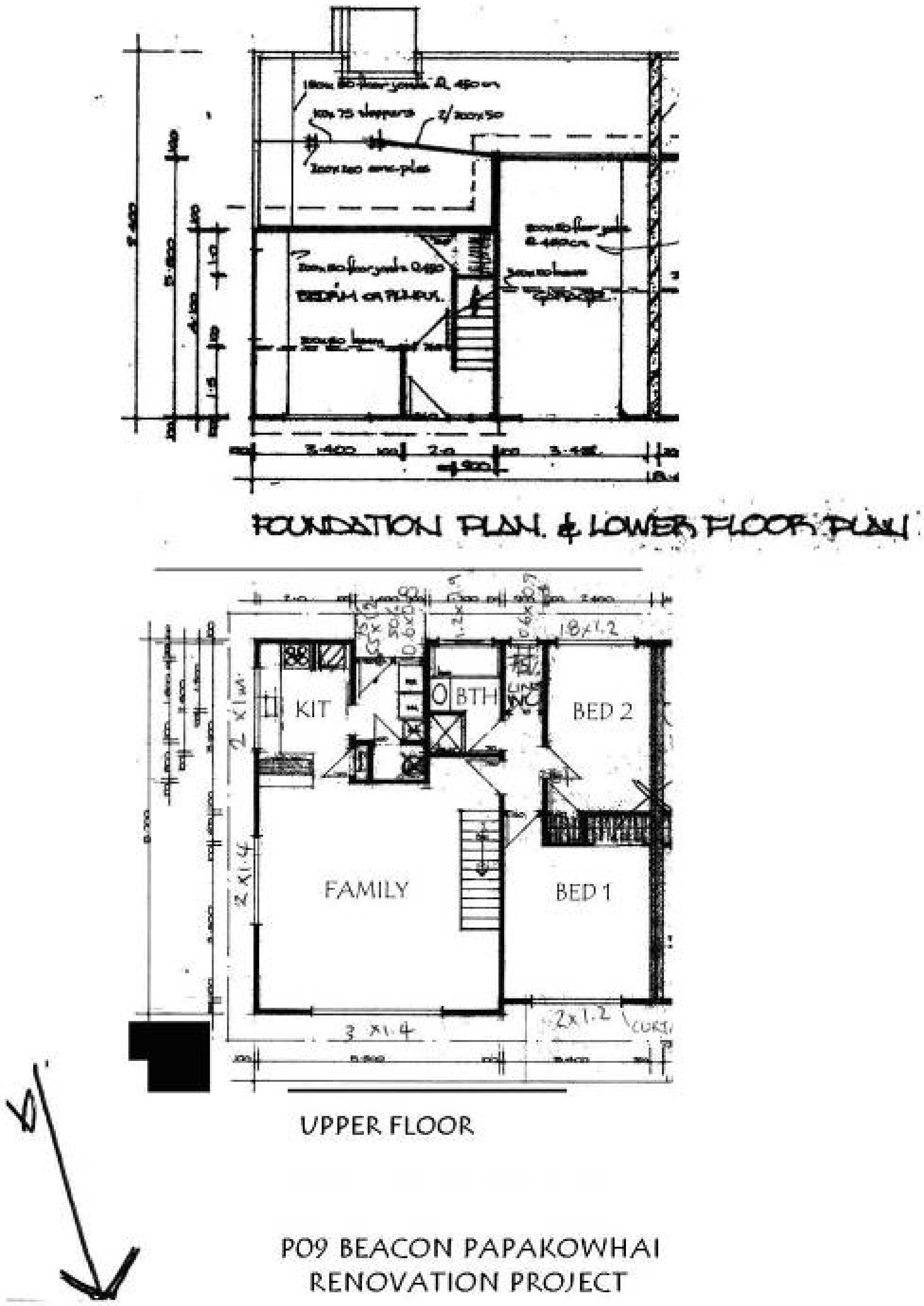


Figure 17: P09 Floor Plan.

5.9.2 P09 – Occupancy

The home is occupied by one adult who works full-time.

5.9.3 P09 – Issues, Interventions and Costs

For P09, the issues that were identified in the pre-intervention information collection are presented in Table 10, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P09				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Ceiling insulated to a low-moderate level	Layer of R-2.6 put over top of existing insulation, and over ceiling joists to remove thermal bridging, raising insulation to approximately R-4	Feb 07	$710	Standard
No underfloor insulation	Floor insulated with R-2 foil-backed bulk insulation, polythene put on ground	Mar 07	$490	
Floor of main bedroom is above uninsulated garage	Mid-floor insulation installed between garage and main bedroom	Mar 07	$2,270	
	Plasterboard (13 mm) for garage ceiling	Mar 07	$320	
Wall between garage and stairwell/rumpus, rumpus/underfloor uninsulated	Wall insulation on rear of wall to underfloor and garage installed	Apr 07	$180	
Slight mould in bathroom	Shower dome installed	May 07	$310	
No fixed heating	Homeowner installed heat pump	Mar 07	$3000	
	Heat pump rewired	Mar 07	$150	
Draught from garage sliding door into living area	Sliding door to garage draught-stopped	May 07	$40	
Single-glazed aluminium windows throughout with poor insulation performance	[redacted]	[redacted]	[redacted]	
B Grade electric hot water cylinder with poor insulation performance	Cylinder wrapped, pipes lagged	Feb 07	$90	
Energy inefficient lighting used	Compact fluorescent bulbs put into high-use fittings	Apr 07	$30	
No significant water re-use methods or appliances	[redacted]	[redacted]	[redacted]	
Old fridge/freezer and downstairs chest freezer may have dodgy seals				
Plumbing in unknown state	Plumbing checked	May 07	$80	
Food waste is not recycled	Worm farm installed	Sep 07	$160	
	TOTAL		$7,830	

Table 10: P09 – Issues, Interventions and Costs.

5.9.4 P09 – Monitoring Analysis

The following results have statistical significance, and analysis of data from a full year after the intervention is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis. This will be presented in the final report.

5.9.4.1 Energy

In P09 the total electricity consumption decreased by ~20%, and the total hot water consumption decreased by ~15%. It was not possible to estimate the change in the heating as a monitored fixed heating source (air-source heat pump) was installed in October 2006. Before this, plug-in type heating was monitored as part of the total electricity load, and therefore a direct comparison to pre-renovation space heating cannot be drawn. It is likely that a decrease in space heating consumption was the cause of much of the decrease in electricity consumption.

5.9.4.2 IEQ

There was no statistically significant difference in family room temperatures, but the temperature in bedroom 1 increased slightly (~0.4°C) to 15.5°C, remaining below the HSS bedroom temperature benchmark. See Table 12 for the presentation of the energy and temperatures by end use.

The average 24 hour humidity level in the master bedroom of P09 was 61% in the second winter (see Table 14). Humidity had not been monitored in the first winter.

5.9.4.3 Water

P09 had the lowest household water consumption, although not the lowest per person, at 230 L/p/d (see Table 15).

5.10 P10

Figure 18: P10 Photo.

The householders purchased P10 as a renovation project in 2005. The home seemingly had not been touched since it was built in the early 1970s. The home had been poorly (or not) maintained. The original timber window frames had rotted through in places and were overall in need of immediate replacement. The new owners dealt with drainage problems (including a relatively minor flood of the lower storey in the first few months of living there), and leaks in the building envelope. The owners then started progressively re-lining and insulating walls in parts of the bedroom wing of the house, and installed double-glazed window units in the bedroom wing during the summer of 2006–2007, between the monitoring periods.

The upper level of the home contains an open plan kitchen, dining and family room wing, connected by a sunken foyer/stairwell to the bedroom wing containing three bedrooms, a laundry and a bathroom. The lower storey contains a fourth bedroom or rumpus room, a storage room and an internally accessible garage. The upper level of the home is clad in sheet materials with timber-framed windows and timber suspended floors. The lower level has a concrete slab floor and concrete walls. The roof of the home is concrete tiles. The living area floor size is approximately 150 m².

The ceiling cavity has some older glass fibre insulation which was thin and patchy, and has been lifted and piled up in places leaving large areas without insulation. The walls are uninsulated apart from downstairs, where battening and new plasterboard lining has provided an air gap insulating the concrete walls of the downstairs bedroom or rumpus room. The floor was uninsulated throughout.

The home was heated with an older recessed enclosed woodburner in the lounge and oil column heaters in the bedroom wing.

5.10.1 P10 – Floor Plan

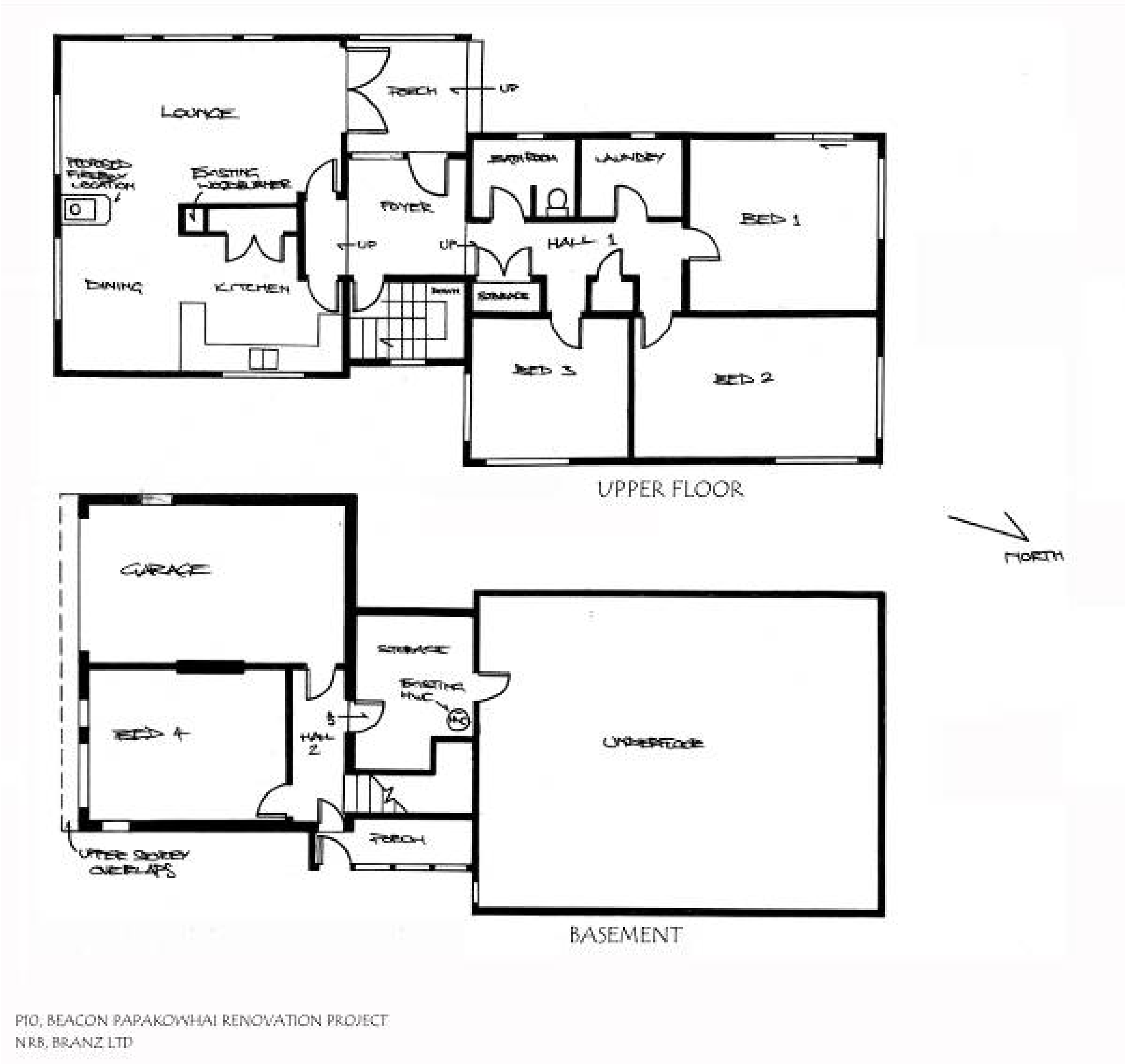


Figure 19: P10 Floor Plan.

5.10.2 P10 – Occupancy

The occupants of the home are a working couple with three primary school aged children.

5.10.3 P10 – Issues, Interventions and Costs

For P10, the issues that were identified in the pre-intervention information collection are presented in Table 11, together with the interventions to address these issues, costs, date of completion of the intervention, and a nomination of the level of intervention package.

P10				
Issues	**Interventions**	**Date**	**Approx. Market Value (exc GST)**	**Intervention Package**
Ceiling insulation thin and patchy	Two layers of R-2.6 put over old insulation, top layer put over ceiling joists to remove thermal bridging	Feb 07	$2,100	**High**
No underfloor insulation	Timber suspended floors above subfloor and garage insulated with R-2 foil-backed bulk insulation, polythene put on ground in subfloor	Apr 07	$2,380	
Flat roof above foyer uninsulated	Flat roof insulated with R-3.6 mid-floor glass fibre insulation and lined (13 mm)	Feb 07	$540	
No wall insulation	Walls stripped, insulated with R-2.4 and re-lined (10 mm) throughout thermal envelope, except downstairs bedroom	Apr 07	$7,810	
	Plasterboard for flat roof and walls	May 07	$1,230	
Original electric hot water cylinder (wrapped) losing excess heat	Solar water heating system installed on foyer roof	May 07	$10,040	
Old inbuilt woodburner past useful life	New high efficiency woodburner installed with wetback pumped to hot water cylinder	May 07	$4,050	
Old timber window frames in poor condition and rotted through in places	Double-glazing units and window frames installed throughout home by homeowner	Nov 07	$45,000	
Standard incandescent bulbs in high-use fittings	Compact fluorescent bulbs put into high-use fittings	Jul 07	$30	
No extraction fans in bathroom and laundry	Householders installed extraction fans into bathroom and laundry	Apr 07	$380	
Desire to reduce discharge to sewage system	[redacted]	[redacted]	[redacted]	
Desire to reduce stormwater runoff and mains water use	[redacted]	[redacted]	[redacted]	
Draughty door to garage losing heat	Garage door draught-proofed	Jul 07	$50	
Older fridge/freezer seals may be leaking	[redacted]	[redacted]	[redacted]	
Plumbing in unknown state	Plumbing checked, vanity moved for re-lining, leaky tap fixed	May 07	$300	
Food waste not effectively dealt with	Worm farm installed	Sep 07	$160	
	TOTAL		$74,070	

Table 11: P10 – Issues, Interventions and Costs.

5.10.4 P10 – Monitoring analysis

The monitoring analysis for the interim report was performed on data taken from a period where in some cases the retrofits were still being undertaken in this house. However, the following results have statistical significance, and analysis of data from a full year after the intervention is likely to reduce the uncertainty in the measurements and confirm the changes identified in this analysis, as well as include summer data analysis. This will be presented in the final report.

5.10.4.1 Energy

For P10 the total electricity consumption decreased by ~45%, and the total energy consumption by ~7%. There was no statistically significant difference in the heating energy consumption, but the total reticulated hot water energy consumption decreased by ~10% (See Table 16).

For P10 the intervention resulted in a substantial increase in internal space temperatures, and an increase in hot water service. Electricity consumption decreased, but total energy consumption did not decrease much, as the new wetback connection replaced electric water heating with solid fuel water heating. The combination of the solar and wetback hot water system proved very effective at reducing reliance upon reticulated energy. In combination with occupant behaviour the electric boost was used little, with reticulated energy providing only around 10% of the energy for the solar/wetback hot water system.

Although the reduction in total energy consumption was small, the reduction in reticulated energy consumption was large, and will be explored in the final report. See Table 12 for the presentation of the energy and temperatures by end use.

5.10.4.2 IEQ

The family room and bedroom temperatures increased considerably, by ~1.8°C, with the family room meeting the HSS for temperature.

The average 24 hour humidity level in the master bedroom of P10 was 68% in the second winter (see Table 14), whereas humidity was not monitored in the first (2006) winter.

5.10.4.3 Water

P10 used 160 L/p/d of water for the metered period between January and October 2007. This was the second lowest per person consumption of the nine houses, and meets the HSS benchmark for water use.

6 Analysis of Papakowhai Renovation Data

This work required detailed analysis of the monitoring results of the Papakowhai Renovation Project up to September 2007. The analysis of pre- and post-intervention data identified key aspects to inform the development of the Home*Smart* Renovation Project. This included trying to identify the best and worst intervention options (cost versus efficacy),[6] whether some things work better in combination, issues which arise in relation to occupant behaviour and other factors. The context for the analysis is the Beacon HSS i.e. achieving multiple outcomes around energy, IEQ, water and waste, to inform the development of the Home*Smart* Renovation Project.

Where the data is presented as averages, it is the average over the May to September period which is reported. This five month period is referred to as the winter, and covers the winter heating season.

Units from the Beacon HSS metric are used where possible, although where use of these figures could mislead, other figures are used. The metrics used for assessing the HSS were being confirmed during the preparation of this report. Consequently, meeting the HSS for energy use was assessed against the change in use of the reticulated parameters as a percentage (15%), rather than as an actual performance. The humidity parameter was also assessed in a particular way, as addressed in Section 6.2.1. The final report will assess against the performance figures, rather than against the percentage changes.

6.1 Energy

The Papakowhai Renovation Project energy data has been analysed to give a preliminary indication of the extent of changes resulting from the interventions. The analysis of reticulated energy and non-reticulated energy will be separated in the final report.

It is important to compensate for differences in climate from the 2006 year to the 2007 year. To do this, the analysis was done by correlating the energy consumption of various end uses (total electricity, total energy, heating and hot water) with the average weekly external temperature (as opposed to degree days). Previous HEEP analysis has shown that the average external temperature is an important driver of energy consumption, and generally has a strong correlation to energy consumption for total, heating, and hot water and for average 24 hour internal temperatures. An example of the correlation of average external temperature to energy consumption is given in Figure 20.

The total electricity consumption is shown for the pre- and post-intervention periods in Figure 20. The pre-intervention data is in blue and the post-intervention data in red. It can be clearly seen in this example that the electricity consumption is much lower in the post-intervention home. This particular home (P09) had a Standard renovation, with a heat pump installed by the owner to replace electric heating, so the reduction in electricity consumption in this particular

[6] ***Note this is a cursory cost versus efficacy assessment, not a full cost-benefit analysis.***

case is very high. However, this may not have been the case had the occupant's heating behaviour changed.

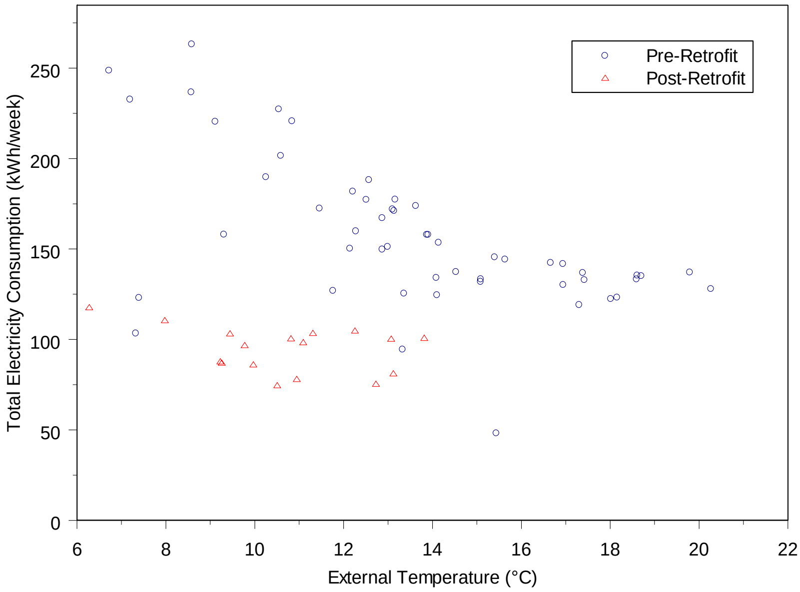


Figure 20. Example of the Pre- and Post-intervention Total Electricity Consumption by Weekly Average External Temperature.

To estimate the electricity consumption during the winter period, lines were fitted to the pre- and post-intervention data using linear regression. The parameters of these lines were then used to predict what the electricity consumption would be if the external average temperature was 9.5°C (the historic average for Wellington for May–September). For this example, the prediction for the pre-intervention consumption was 164 kWh/week and 134 kWh/week for the post-intervention consumption.

This process was repeated for all end uses – including total electricity, energy, hot water and heating (where possible) – in each of the nine Papakowhai Renovation Project homes.

Ideally, this procedure would be applied to the entire year. However, at this stage there is not enough post-intervention data available to reliably predict summer energy consumption. The estimates provided are for the May–September period, and at this stage cannot be extrapolated to a full year. The differences during the warmer months of the year are likely to be less, as there is less heating used.

6.1.1 Energy Results

The total electricity, heating energy and total hot water energy (except for the solar contribution) for the period between May and September are given in Table 12, together with the average 24 hour temperature for the family room and bedroom 1 in the same period.

Reticulated energy consumption was the same or less after the intervention in all but one case. The only increase in energy consumption was for the end use of water heating for P05, where two instant gas hot water systems were installed and this led to increased energy consumption.

In all cases the family or bedroom 1 temperatures were the same or higher after the intervention.

Note that for some of the results in Table 12 the occupancy varied, as discussed in the companion report.

Table 12: Energy and Temperatures by End Use (May to September).

Home No.	Pre- or Post-Intervention	Total Electricity (MWh)	Monitored Heating (MWh)	Total Energy (MWh)	Total Hot Water Energy Less Solar Contribution (MWh)	Average 24 Hr Family Room Temps (°C)	Average 24 Hr Bdrm 1 Temps (°C)	*Intervention Cost (NZ$ exc GST)*
P01	Pre	6.52	0.83	7.19	3.36	14.8	13.2	$23,610
P01	Post	6.43	0.67	6.61	3.45	15.7	14.3	
P02	Pre	2.90	2.99	5.98	1.32	14.6	13.0	$2,120
P02	Post	1.97	2.36	4.57	0.85	16.5	14.5	
P03	Pre	7.41	2.17	8.97	2.06	17.7	15.7	$76,590
P03	Post	6.35	1.45	7.58	0.83	18.1	17.1	
P05	Pre	2.86	7.02	10.85	1.10	16.4	12.9	$10,690
P05	Post	1.58	6.35	11.05	2.06	16.8	13.2	
P06	Pre	3.51	1.56	4.66	1.15	14.4	12.9	$1,380
P06	Post	2.84	1.56	3.99	0.80	14.2	12.6	
P07	Pre	4.01	1.52	5.18	1.06	13.7	12.6	$7,640
P07	Post	3.64	1.88	5.27	0.85	14.8	12.9	
P08	Pre	13.15	4.48	13.15	1.67	18.2	17.4	$24,610
P08	Post	10.55	4.27	10.55	0.35	19.0	17.8	
P09	Pre	3.55	--	3.55	0.98	16.5	15.1	$7,830
P09	Post	2.90	--	2.95	0.83	16.4	15.5	
P10	Pre	4.12	1.68	6.09	2.25*	16.4	14.0	$74,070
P10	Post	2.30	1.77	5.68	1.97*	18.0	15.8	

*Includes wetback water heater contribution.

The changes in the energy and temperatures are presented in Table 13. The term 'Less' has been used for when the renovation resulted in a lower consumption, 'More' for when the renovation resulted in a higher consumption, and 'Unchanged' for when the renovation resulted in no statistical difference in the output of the linear models used – within a 95% confidence interval. The final analysis will separately discuss the solar energy contribution and confirm whether the HSS levels have been met. The effect of the three solar hot water systems is shown in Table 16.

Table 13: Changes in Energy and Temperatures.

Home No.	Cost	Total Electricity	Monitored Heating	Total Hot Water	Total Energy	Family Room Temperatures	Bedroom Temperatures
P01	$23,610	Unchanged	Unchanged	Unchanged	Unchanged	Higher	Higher
P02	$2,120	Less	Less	Less	Less	Higher	Higher
P03	$76,590	Less	Less	Less	Less	Higher	Higher
P05	$10,690	Less	Less	More	Unchanged	Unchanged	Unchanged
P06	$1,380	Unchanged	Unchanged	Less	Unchanged	Unchanged	Unchanged
P07	$7,640	Unchanged	Unchanged	Unchanged	Unchanged	Higher	Unchanged
P08	$24,610	Less	Unchanged	Less	Less	Higher	Higher
P09	$7,830	Less		Less	Less	Unchanged	Higher
P10	$74,070	Less	Unchanged	Less	Less	Higher	Higher

This interim analysis shows that three of the nine homes reach the HSS for temperature target of 18°C in the family rooms after the interventions. These homes are P03, P08 and P10, although P08 met this temperature HSS (being above 18°C at 18.2°C) before the interventions.

The same three homes have also seen a rise in the bedroom temperatures, with P10 just falling below the 16°C for bedrooms required by the HSS after the intervention (at 15.8°C). P03 and P08 exceeded this temperature after the interventions, with only P08 exceeding the requirement before the renovations. The companion report (Saville-Smith 2008) develops this a little further, while the final report due in December 2008 will present a full assessment of the achievement of the HSS across all parameters.

6.2 Indoor Environment Quality

The markers assessed as part of the IEQ analysis were the humidity and temperature from physical measurement, with some other social markers captured in the companion report (Saville-Smith 2008). The temperature aspects are covered in the energy section above (Section 6.1.1), with humidity covered in the section below (Section 6.2.1). Ventilation was not measured, although some interventions to improve indoor air quality were made (draught-stopping, heat transfer systems, extract fans, rangehood). Some of these interventions were also intended to reduce humidity levels (extract fans, rangehood). The companion report (Saville-Smith 2008) assesses the level of non-energy benefits and improved IEQ that are contributed through the provision of ventilation.

6.2.1 Humidity

Humidity has been monitored in the Papakowhai Renovation Project homes since early 2007. No data is available for comparison to the previous year. However, there are expected to be changes observed in the final report reflecting the homes 'drying out' over the post-intervention period. Table 14 shows the 24 hour RH levels and the 24 hour average temperatures at which they are measured. During the preparation of this report, the metric used for assessing humidity against the HSS has been refined. In this work, meeting the HSS for humidity has required the average hourly measurements to not fall outside of the range of 20 to 70%.

Table 14: 24 Hour Average Humidity Levels Taken in the Master Bedrooms of the Papakowhai Renovation Project homes from May to September 2007.

Beacon Papakowhai NOW Home® Renovation Project Year Two May to September 2007 24 Hour Average Bedroom 1 Humidity Levels		
Home No.	24 Hour Average RH (%)	Temperature (°C)
P01	68%	14.3
P02	64%	14.5
P03	57%	17.1
P05	69%	13.2
P06	78%	12.6
P07	72%	12.9
P08	64%	17.8
P09	61%	15.5
P10	64%	15.8

The home with the lowest 24 hour average humidity levels observed in the study was P03, at 57%, which was also one of the warmest. P03 met the HSS for temperature in both bedroom 1 and the living room. It did not always fall within the 20 to 70% range for humidity. P03 was one of the homes with a high amount of heating, which may be a contributing factor. P03 also has large amounts of north and west-facing glazing. This home had a high level of interventions installed, including full thermal envelope insulation for the conditioned areas (excluding the mid-floor between lounge and garage), double-glazed windows and a new, high output woodburner to heat the lounge and supply heat via the heat transfer unit to the bedrooms.

The highest humidity levels in the sample were observed in P06 with 78%, which also had the lowest bedroom 1 temperature of 12.6°C. The occupancy in this home was highly variable over the period of analysis, likely resulting in less heating and ventilation. This home had a low level of intervention since it was converted into a 'Control Home' during the project, at the request of the Beacon Board.

6.3 Water

Seven of the nine homes in the Papakowhai Renovation Project have had their water use monitored since early 2007. Water meters were installed between December and March of 2007, with reliable readings obtained from February 2007. Two of the homes did not have access to the main water pipe coming into the property. Two other homes also had poor access to the main water pipe from outside, so meters were put into walls where the pipe entered the homes.

Table 16 shows the water use of the nine households, both for the home as a total and per occupant, in L/p/d. Data was collected approximately once a month and read off standard water meters.

Table 15: Water Meter and Per Person Water Use (L) in Papakowhai Renovation Project homes from February to October 2007. (Homes P04, P06 and P07 did not have water meters installed.)

Papakowhai Renovation Project Water Usage (February to October 2007)											
	Pre-intervention				Post-intervention						
Home No.	Feb-07 (1000L)	Mar-07 (1000L)	Apr-07 (1000L)	May-07 (1000L)	Jun-07 (1000L)	Jul-07 (1000L)	Aug-07 (1000L)	Sep-07 (1000L)	Oct-07 (1000L)	Average monthly usage by home to October 2007 (1000L)	Average usage per person to October 2007 (L/day)
P01	--	52	51	38	32	35	29	47	37	40	330
P02	22	27	28	19	11	8	11	12	15	17	280
P03	--	25	25	21	19	14	22	23	24	22	140
P05	14	14	20	10	9	7	10	13	15	12	200
P06											
P07											
P08	--	25	28	20	26	14	14	15	16	20	320
P09	5	9	8	5	6	5	6	6	8	7	220
P10	28	29	27	21	29	18	22	18	28	24	160

The benchmark water use per person per day for the HSS is 180 L/p/d. As can be seen in Table 15, five of the seven homes monitored exceeded this amount during the monitoring period, with only two of the homes meeting the HSS for reticulated water use. The two homes which used less water per occupant were homes with five occupants, three of them being children in each case. The volumes of water heated by the solar hot water systems are provided in Table 16. The two households with five occupants used a similar amount of water, while the two person household used approximately two-thirds that amount.

The young family of four in P01 were the highest potable water users between February and October 2007, both per person and in overall measurement. Initial and post-intervention BRANZ interviews discovered that two members of the household have at least two showers per day, while another two have at least one shower per day. Both adult occupants have jobs which require frequent clothes washing. One part-time job involves a commercial fishing boat, which has been washed at the home after each outing. This has been contributing to the high water use.

Table 16: Water and Water Heating Energy for the Solar Water Heating Systems.

Papakowhai Renovation Project Solar Water System Water Usage and Water Heating Energy Use Change						
Home No.	**Jun-07**	**Jul-07**	**Aug-07**	**Sep-07**	**Average daily usage to date per person (L/p/d)**	**Reduction in energy for heating water (%)**
	Water usage in litres (L) per month					
P03	6000	4000	7000	8000	39	60
P08	6000	3000	4000	4000	66	80
P10	6000	6000	5000	6000	39	10*
***Energy figures include wetback water heating contribution**						

There was no measurement of the volume of hot water usage before the installation of the solar hot water systems. However, it can be seen in Table 16 that the demand for reticulated energy for heating water reduced considerably following the interventions.

7 Individual Interventions

As can be seen in the home-by-home sections, numerous different interventions were applied to the Papakowhai Renovation Project homes. The interventions were designed to generate improvements in four areas: IEQ, energy, water and waste.

The energy savings and temperature differences in the homes with only floor and ceiling insulation are exceeded by three homes (P03, P09 and P10). In P03 and P10, the walls were insulated, and in P09, a lower level of wall insulation already existed. This indicates that the insulation of the full envelope (excepting the glazing) transfers significant benefits. It is expected that these results will be verified by the 2008 analysis, showing higher temperatures, lower humidity and some energy savings. However, it is possible that these may be reduced by comfort take-back, as occupants use the reduction in power bills to pay for additional heating.

Unfortunately, there is no way to accurately extract the effect of all the individual interventions from the complete package of Basic, Standard and High since multiple interventions interact to alter energy consumption profiles.

The intervention packages installed to P03 and P10 in this work were designed to meet a high level of sustainability, but cost a lot and are unlikely to provide a realistic economic payback period. The companion report (Saville-Smith 2008) indicates that the householders were more interested in the comfort and environmental benefits. During the study, the authors saw some changes in the Rateable Valuation of the homes, although this project has not analysed whether any of this change was due to the interventions. However, if these non-energy benefits are taken into account with any potential gain in capital value, the results may differ.

7.1 Effectiveness of Interventions

A cost-benefit study has not been performed in this work. In keeping with the project brief, a summarised assessment of the effectiveness of the individual interventions is included below.

7.1.1 Most Cost-effective Intervention Package

It is difficult to determine the most cost-effective outcome without a cost-benefit study, although superficially the lowest cost intervention in P02 achieved improvements in all the measured parameters for $2,120, although the HSS has not been achieved in any of the parameters measured. The attributing interventions are most likely to be the ceiling and underfloor insulation.

7.1.2 Least Cost-effective Package

The least cost-effective package also cannot be determined without a cost-benefit analysis, but superficially P01 had the lowest effect. In this home, $24,000 was used to make no statistically significant difference to the energy parameters, and the home retained the highest per person water use. However an increase of 1°C in the average bedroom and family room temperatures was made. As can be seen from Table 2, this home received a Beacon High intervention plus a pellet burner to replace a solid fuel burner that was close to the end of its useful life. The skillion ceiling was lowered and insulated, a heat transfer kit was installed, and underfloor insulation was placed. No interventions were made to the windows or the walls which meant that the persistent draughts from around the windows continued. The companion report (Saville-Smith 2008) indicates that the occupants have perceived non-energy benefits.

7.1.3 High Interventions

The highest cost intervention of $76,000 in P03 did achieve the HSS for the temperatures and total energy, and resulted in improvements in all the other parameters measured. (Water use was not measured before the interventions, so no conclusion could be made about this.) The principal contributing factor was likely to be the solar hot water heater. Likewise the $74,000 cost in P10 improved all the sustainability markers, meeting the temperature target for the HSS of the family room, although the air temperature in the master bedroom was 0.2 °C lower than the HSS (in its 24 hour average), as can be seen in Table 12. The installation of double glazing in new aluminium framing was the single largest cost factor in both these interventions, with the skillion roof lowered and insulated in P03, and the underfloor and walls insulated in P10. These were both High interventions, but had very high economic costs for the benefits that ensued. The occupant in P10 purchased and installed the double-glazed windows, having stripped all the interior linings from the home himself, contributing significantly to the project. The estimated labour costs at market rates have been included in the totals for this home.

The other High intervention in P08 may have had the best overall outcome (not accounting for cost) where $25,000 was spent. Improvements were seen in all but one of the parameters assessed in Table 12, with the HSS met for both the family room temperatures and the bedroom temperatures. This is in spite of the fact that the thermal performance of the high level of ceiling insulation was significantly reduced due to the large number of recessed downlights that penetrated the ceiling insulation.

The authors are unable to determine any obvious interventions that, in isolation, were able to offer the most cost-effective solution. However, significant benefits were provided by the solar hot water heating, retrofit double glazing and the inclusion of wall insulation where ceiling and underfloor insulation existed.

7.1.4 Wall Insulation

Wall insulation interventions cost $8,000 and $11,500 to insulate the walls in the thermal envelope of P10 and P03, respectively. Where they were accessible from roof spaces or subfloor spaces, portions of the walls of other homes were also insulated for between $180 and $400. The bedroom walls of P07 were insulated for $2,500. The performance of ceiling and underfloor insulation appears to be optimised by also insulating exterior walls of the thermal envelope of the home. (This same result is seen in the interim star ratings from the HERS modelling in Section 8.)

7.1.5 Ceiling and Underfloor Insulation

Amongst the simplest, least invasive and fastest insulation interventions were the ceiling and underfloor insulation packages. Costs varied from $109 (where existing glass fibre insulation batts were re-laid and spaces filled where necessary), to an average cost of $1,330 for ceiling insulation (predominantly partial top-up and re-laying, at least to R-2.6 and some to R-5.2), and $1,850 for underfloor insulation (predominantly R-2 foil-backed bulk insulation under sections of timber suspended floors). These costs nearly doubled where the full living areas of the homes were insulated (P05 for underfloor and P10 for ceiling). However, these were to R-2 and R-5.2 for the underfloor and ceiling respectively – high by New Zealand standards. Laying an extra layer of R-2.6 glass fibre insulation batts over the ceiling joists (at 90° to the existing run-direction of the insulation between the joists) was a simple intervention where space allowed. This counteracted the thermal bridging effect of the joists, which otherwise limits the insulation value that can be achieved through purely laying insulation between the joist lines.

7.1.6 Lowered and Insulated Ceiling

Lowering and insulating skillion ceilings proved to be possible in P01 and P03, although the cost in P01 of $13,000 may not be easy to justify. The incurred cost in P03 of $6,000 for lowering the ceiling of just the living area has contributed to this home achieving the HSS for temperature. However, the result has not been separated from the other interventions which cost a further $70,000. While there was a moderate cost involved with this intervention, the task was quite straightforward, and labour was contributed by capable handypersons for the task of stripping one ceiling and battening between the rafters of the other. The cavities allowed at least R-3.6 insulation to be installed, which in one case was in addition to the insulation provided by the original ceiling that was left intact above the new ceiling. This was estimated to provide an additional R-1 to the R-3.6 product installed. Lowering the skillion ceilings also allowed the opportunity to eliminate recessed light fittings, although this was not done.

7.1.7 Hot Water Cylinder Wrap and Pipe Lagging

This intervention cost $90 in the five homes that received it. These homes had reduced hot water energy use following the renovation. The companion report reveals how one occupant reported lowering the setting of the hot water lever in the shower in response to the higher air temperatures in the shower cubicles when a shower dome was installed. The use of shower domes may help reduce hot water energy use.

7.1.8 Full Window Replacement

By far the most expensive interventions, with an estimated value of around $42,000, were the double-glazed windows and new aluminium frames in P03, and the same intervention in P10 for around $45,000.

The benefits are expected to be substantial, both from an energy and a comfort and health point of view. While the full economic costs of this intervention are unlikely to be recouped in energy savings within the lifetime of the home, the windows were due for replacement, so the cost-benefit on the marginal costs may be different.

7.1.9 Glazing-only Replacement

Where double-glazed panes were retrofitted into existing frames, the cost of the new glass units, labour and scaffolding (e.g. $10,700) was significantly less than the cost for replacement of the full windows (e.g. $45,000). This cost is unlikely to be recouped through energy savings, but the non-energy benefits may render this worthwhile. The companion report notes the improvement to the acoustic environment that was achieved through the installation of the IGUs (Saville-Smith 2008).

7.1.10 Instant Gas Water Heating

An original D Grade electric storage hot water cylinder was replaced with a standard instant gas hot water heater and a condensing instant gas water heater to service demand at opposite sides of one home. While the pipe losses are less with units located close to hot water outlets, the flow rate was reported to be much higher by the occupants in the BRANZ interview. A flow restrictor had been installed. However, the infinite supply of hot water may be encouraging higher water use. The final report will take a more detailed look at this aspect. The cost of this intervention was $4,500 for two instant gas water heaters.

7.1.11 Solar Water Heating System

The three solar hot water systems cost approximately $10,000 each installed, although the area of solar collector provided was approximately twice the minimum area that is installed as standard. All three of the households found a reduction in the reticulated energy used for hot water heating, which is reported in Table 16. The companion report describes how the occupants favour the use of this technology and would install it even if it was not cost-effective on an economic basis, as is likely to be the case here. Given that the monitoring of the solar hot water usage has only been for the winter period when solar gains are low, this work is unable to present significant conclusions regarding the performance of the solar water heating until after summer monitoring data is available. However, the winter monitoring has shown a significant effect where P03, P08 and P10 have seen reductions of 60%, 80% and 10% in winter reticulated energy for water heating.

7.1.12 Woodburner

A woodburner was installed by a homeowner in this project for the cost of around $3,000, with an existing flue. The woodburner was used to supplement the performance of the living room heat pump, but the period where both were monitored during the 2007 winter was too small to determine their combined effects.

7.1.13 Woodburner, Wetback and Solar Hot Water

The intervention of the woodburner with wetback, coupled to a solar hot water heater with internal storage tank, cost $14,000 and allows non-reticulated energy to be used to heat water in both winter and summer. The companion report analyses the social effects, since it will be difficult to have a positive economic outcome from this intervention. No conclusions are presented in this interim monitoring report since the solar contribution has not been separated from the solid fuel and electrical energy contributions.

7.1.14 Pellet Burner

The installation of this space heating intervention had a capital cost of $4,300 and assisted in allowing the household to increase the temperature of both the master bedroom and the living space. It was a necessary replacement due to the maintenance need of the existing heater, but was one of the examples of fuel switching that resulted in changes to purchased energy.

7.1.15 Ducted Heat Transfer Systems

The cost of these varied from $1,400 (P05) to $3,000 (P01) for a system to transfer heat to the bedrooms, to $810 for an extension to an existing system. The temperature in the master bedroom of P01 increased, although this may not have been solely due to the heat transfer system. The companion report addresses some of the non-energy benefits of this intervention.

7.1.16 Heavy Draught- stopping

None of the measurements used were able to attribute physical benefit to the draught-stopping that was undertaken in this program, which ranged in cost from $50 to $100. In one case a new door was installed to prevent draughts from the garage entering the home. The companion report does address some of the non-energy benefits that may be attributed to draught-stopping, which should be a home maintenance issue.

While the replacement of the windows has a direct effect on the R-value of the thermal envelope, it also has the effect of modifying the draughts that pass through the joints in the windows themselves. New windows are rated as allowing either 2 $L/s/m^2$, or 8 $L/s/m^2$ air infiltration under test conditions, whereas older windows (particularly deteriorated windows) may well exceed this air leakage level.

In several cases there was insufficient airtightness between internal garages and the living spaces of the homes. This potentially allowed garage fumes to penetrate into the living areas when vehicles were run in the garages.

7.1.17 Polythene Ground Cover

Polythene is placed on the ground to prevent moisture from rising from the soil into the subfloor space, which then may infiltrate into the home above. This moisture needs to be removed from the subfloor space by ventilation before it is absorbed into the subfloor materials – including floors, joists and other framing timbers – and is transferred into the living spaces. The cost of this intervention was bulked into the cost of underfloor insulation (see Section 7.1.5), as it is recommended by EnergySmart that polythene should always be installed wherever possible in conjunction with underfloor insulation. This intervention is likely to have had an effect on the humidity within the homes.

7.1.18 CA-rated Lamps

In one case existing downlights were replaced with CA-rated (closed-abutted) downlights, which allow minimal air infiltration. Lamps rated to this level also allow insulation in the ceiling space to be abutted against the heat-can surrounding the lights. The cost of this intervention was $110, since the chosen lights were able to use the existing ceiling penetration with larger discs used to cover the larger holes from the penetration. (However, this is not always possible). While the actual light quality was found to not provide the desired effect, the intervention reduced the air infiltration into the ceiling cavity and improved the insulation of the space.

7.1.19 Compact Fluorescent Lamps

Up to five compact fluorescent lamps (CFLs) were installed into high-use fittings of all homes that did not already have this technology. The cost for these lamps (five) including installation was $30. An attempt was made to source the next generation LED lights, but the cost was around $30 per unit, which was beyond the scope of the budget. One issue that needs some more investigation is the reduction in space heating provided by moving from standard incandescent bulbs to fluorescent lights, which may need to be made up with purchased space heating energy. The compact fluorescent lamps use less power, so improve the design energy use of the dwelling.

7.1.20 Smoke Alarms

These were installed in the two homes that did not already have them, and cost $30 installed.

7.1.21 Extract Fan

Extract fans were installed for a price ranging from $30 (for the direct replacement of an existing fan) to $200 for the purchase and installation of a fan where a penetration was required in the building envelope. The installation of the extract fans were designed to improve the indoor air quality, although only the humidity was measured in bedroom 1 as an assessment of this.

7.1.22 Rangehood in Kitchen

One home installed a rangehood at their own cost rather than an extract fan. This cost $870 rather than the $70–200 for the installation of an extract fan, and was desired for other reasons. Rangehoods are thought to be more effective at capturing moisture and odours from cooking and were the preferred option, but did not fit into the budget.

7.1.23 Shower Domes

This was the most intriguing intervention, since it is a recent technology invented in New Zealand, and claimed (by its inventor) to be the "greatest bathroom invention since the tap".[7] It cost between $310 and $370 installed, but since there were no humidity measurements made in the bathroom, its influence cannot be measured easily, although we may witness reduced condensation and mould in the bathroom. It serves to trap most of the steam inside the shower cubicle, which condenses on the dome and walls, and runs back to the drain. It is expected that it will significantly reduce the moisture levels in the bathroom. It has been reported anecdotally by one occupant that the shower water temperatures used were lower, although another complained about the changed environment within the shower.

7.1.24 Plumbing Check

In several cases the plumbing check revealed hidden issues which were rectified outside of this project. One significant problem was found where a waste pipe was leaking in the subfloor area, creating a potential human health problem, and a leaking potable water supply was causing pooling under P08. The plumbing check cost $80, and had the potential to find water leaks, and consequent issues with elevated soil moisture, humidity and structural deterioration.

[7] ***Product literature from Showerdome.***

7.1.25 Low-Flow Shower Heads

It is recognised in the Beacon National Value Case (Allen et. al. 2007) that low-flow shower heads can form part of a significant water use reduction package. In all the solar hot water interventions, flow reducers were used rather than low-flow shower heads since the whole home needed flow reduction. Only one $85 low-flow shower head was installed in this project since most homes were on low-pressure hot water and flows were already low.

7.1.26 Dual Flush Toilet Cisterns

Two of these units were installed in one home for a $90 installation fee, with all but one of the other homes already possessing this technology, given that they became standard installation in the 1970s.

7.1.27 Worm farms

A low-cost intervention was the worm farms. It is anticipated that the benefit of these will be revealed when the post-intervention waste audit is performed and recorded in the final report. These cost around $160 each including installation. However, the reduction in waste is expected to be significant in most of the homes. The compost and fertiliser generated is expected to be of benefit to gardening householders and/or their neighbours. Most householders in this sample use kerbside bin collection services rather than council rubbish bags, so while the reduction in the volume of waste may not save them money, less waste should be going into the landfill.

7.2 Synergisms

This report does not differentiate pure synergistic effect from the convenience of two interventions working together. The final report may be able to define this better.

1. *Insulating walls and replacing windows*. Where window frames are to be replaced, the cost of upgrading single glazing to double glazing is marginal, compared to the cost of retrofitting later. Also, as internal wall linings are disturbed during this process, it is a natural time to strip, insulate and re-line exterior walls. By insulating walls and installing double glazing, the thermal performance of the exterior wall systems is optimised and the air leakage through the joints can be addressed. It is thought that this will provide a synergistic effect.

2. *Re-roofing and insulating ceilings*. Where roof replacement is appropriate, roofing contractors should be employed to install appropriate insulation products as they go, especially where inaccessible skillion and isolated cavity ceilings exist. The maximum practicable insulation levels should be sought, allowing both the roof and the insulation to work together.

3. *Underfloor insulation and laying polythene*. In all cases, polythene ground cover and underfloor insulation should be installed together where there is exposed ground in the subfloor area. Polythene reduces the influence of high soil moisture and high RH levels in the subfloor area, thereby reducing the amount of moisture rising into the fabric of the building. It also potentially reduces the build-up of salt deposits and oxidization on

the top layer of foil insulants. (This can lead to premature corrosion of the reflective foil and reduction in its performance.)

4. *Removing downlights when laying ceiling insulation*. When installing, re-laying or topping up insulation in existing ceilings, all open downlights should be removed and replaced with either non-recessed lights or CA-rated downlights. By removing recessed downlights, there becomes no need for holes in the ceiling insulation. Where recessed lights are chosen, putting in CA-rated downlights allows insulation to butt up against downlights, leaving only a small hole in the insulation and reducing the uninsulated area of the ceiling.

8 NZ HERS AccuRate Modelling

The HERS scheme was launched on 17 December 2007. The HERS energy modelling software AccuRateNZ was used to model the space conditioning energy requirements of the Papakowhai Renovation Project homes. Two sets of models were created, one with parameters reflecting their physical descriptions before the interventions and one after. The results for the space conditioning of the conditioned area only are shown below in Table 16. AccuRateNZ does not allow for the modelling of non-energy benefits, so the contribution of changes in the IEQ, water and waste are not assessed.

The type of space heater used in the homes is not taken into account in the modelling, but the modelling is based on the construction, solar gain, insulation etc, and uses a 24 hour standardised heating schedule with specific set points for each zone.

Note: the software tool to perform the modelling was upgraded after the modelling (late May 2008) and star rating bands have changed, so results may change.

Table 17: Simulated Space Conditioning Energy Use Before and After Interventions for the Papakowhai Renovation Project, Modelled in the New Zealand HERS Version of AccuRate, Current as at 5 March 2008.

New Zealand HERS AccuRate Modelled Space Conditioning Energy Use Pre- and Post-intervention for the Papakowhai Renovation Project homes

Home No.	Heating MJ/m^2/annum			Cooling MJ/m^2/annum			Total MJ/m^2/annum		
	Pre	Post	% change	Pre	Post	% change	Pre	Post	% change
P01	724	635	12%	15.4	14.4	6%	739	650	12%
P02	472	428	9%	3.8	6.2	-63%	476	434	9%
P03	463	228	51%	11.1	0.8	93%	475	229	52%
P05	426	367	14%	15.1	0.2	99%	441	367	17%
P06	605	567	6%	6.3	5.8	8%	611	573	6%
P07	518	395	24%	0.6	0.6	0%	519	396	24%
P08	503	381	24%	1.4	0.8	43%	505	382	24%
P09	264	207	22%	25.1	35.1	-40%	289	242	16%
P10	622	223	64%	1.2	0.7	42%	623	224	64%

Measured in MJ/m^2/annum based on floor area (increased energy use is shown as negative).

Table 18: Intervention Packages and Potential Star Ratings (Interim Rating Tool Used).

Home No.	Intervention	Potential HERS Star Rating Before Intervention	Potential HERS Star Rating After Intervention
P01	Standard + Pellet Burner	1	1.5
P02	EECA + Waste + A Higher Standard of Underfloor Insulation & Fixing Heat Transfer Kit	2.5	2.5
P03	High + Solar Hot Water + Wood Burner (installed by owner) + Waste + IEQ + Water	2.5	5
P05	Standard + Gas Hot Water + Air Transfer System + Waste + IEQ	2.5	3.5
P06	Ceiling Insulation Top-up	1.5	1.5
P07	Standard + Wall Insulation + IEQ + Heat Transfer + Waste	2	3
P08	High + Solar Hot Water + IEQ + Waste	2	3
P09	Standard + Heat Pump (installed by owner) + IEQ + Waste	4.5	5
P10	High + Solar Hot Water + Wetback + Woodburner + IEQ + Water + Waste	1.5	4.5

As can be seen in Table 17, all homes in the study were modelled to have reduced space conditioning energy requirements after the interventions had been performed. The most significant changes in modelled space conditioning energy consumption were in homes P03 and P10.

There has been not much change in the modelled space conditioning energy use in P01, likely due to high levels of infiltration, the walls not being insulated, and the glazing being untouched. The HERS package does account for airtightness, allowing assumptions to be made about improved airtightness that were due to the interventions.

P02 had interventions including underfloor insulation and ceiling insulation top-up. Air infiltration, window insulation and wall insulation were not changed. This resulted in a small reduction in simulated space conditioning energy consumption from 476 MJ/m²/annum to 435 MJ/m²/annum.

P03 already had wall and ceiling insulation (although the R-1 ceiling insulation needed to be re-laid), but there was a substantial reduction in space conditioning energy due to the High package of extra insulation.

P05 had improved ceiling insulation and underfloor insulation, which reduced the modelled space conditioning energy requirements. The windows were not improved, but wall insulation (although old) was present.

P06 only had a ceiling insulation top-up, which led to a small simulated space conditioning energy reduction.

P07 improved by one star in the interim HERS rating due to the insulation package which included the insulation of the walls. The replacement of the clear single glazing with tinted single glazing has reduced the solar gain, and is responsible for the smaller improvement in this home that would have been expected.

P08 did not have its walls insulated. However, there was still an improvement in its modelled HERS star rating from 2 to 3.

P09 already had insulated walls and ceiling in its pre-intervention condition. The glazing was not touched, but a small area of floor insulation was added (mid-floor between bedroom 1 and garage) and a ceiling insulation top-up was performed leading to a star rating improvement from 4.5 to 5.

P10 received all the energy interventions offered, with R-2.4 wall insulation, double glazing, R-5.2 insulation in roof and R-2 underfloor. This led to a substantial reduction in the simulated space heating energy, leading to a 3 star improvement from 1.5 to 4.5.

The high modelled reduction in space conditioning energy requirements in P03 and P10 (52% and 64% respectively) were expected, as both had the exterior walls of the thermal envelope of the home insulated, as well as high levels of ceiling insulation and underfloor insulation installed. New aluminium window frames with double-glazed panes were installed into both homes.

P08's modelled reduction in space condition energy use was slightly lower, as no insulation was installed into the exterior walls of the living area of the home.

The smallest modelled reduction in required space conditioning energy (6%) was in P06, where only ceiling insulation was installed.

9 Conclusions

This report presents the findings from detailed analysis of the monitoring results of the Papakowhai Renovation Project up to September 2007. This included assessing the changes in the energy use, temperature, humidity and water in the subject homes.

It has shown that there have been improvements in nearly all of the sustainability parameters analysed. However, this is an interim result since it is from the winter period only when some of the interventions were still being completed.

It is clear that the highest energy savings and/or comfort improvements can be expected in the homes with the most extensive interventions (High interventions), including full insulation of the thermal envelope, solar water heating and new solid fuel burning appliances. All homes have improved thermal comfort levels and usually also increased temperatures.

As discussed in the companion report, the householders generally do not see energy savings as the principal outcome of the interventions. Instead more emphasis is placed on living environment improvements, such as increased warmth and decreased noise. One householder even commented on improved safety.

The specific aspects from the analysis of the pre- and post-intervention data that may be identified to inform the development of the Home*Smart* Renovation Project are:

- The Beacon HSS was achieved for some of the sustainability parameters investigated for the winter period.
- Insulation of the complete thermal envelope had the greatest effect on energy consumption and/or temperatures.
- Solar hot water systems provided large reductions in reticulated hot water energy demand.
- The High intervention package had significant capital costs of up to $75,000 in two of the three cases.

This work has identified some of the better-performing and poorer-performing intervention options (cost versus efficacy), whether some things work better in combination, and issues which arise in relation to occupant behaviour.

With only nine homes in the study, and the large variety in house construction, occupants and interventions, it has not been generally possible to isolate the effect of single interventions. However, it is clear that the largest improvements have occurred with the most extensive interventions. The various insulation packages give improved performance with increasing cost. Insulation of the walls and fitting double glazing are both highly effective at further improving performance over the basic package of roof and floor insulation. However, the costs are high. These interventions appear to be best left to when major renovation or maintenance are required, where the marginal cost would be low.

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