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Sustainability Options for Retrofitting New Zealand Houses – theoretical cost benefit analysis

Final

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About This Report

Title

Sustainability Options for Retrofitting New Zealand Houses – theoretical cost benefit analysis

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Abstract

A theoretical cost benefit for options to retrofit for water and energy was carried out using ALF. At a national level, the following options have a theoretical internal rate of return greater than 5% making them worthwhile implementing from a financial perspective:

- Rainwater tanks (2,000 litre) for Auckland only (assuming 100% water retention)
- Low flow shower heads for high pressure systems
- Water efficient ("AAA") washing machines
- Water heating upgrade (if current water heating tank needs replacing)
  - Solar hot water heating
  - Heat pump hot water heating
  - Instant gas hot water heating
- Floor insulation
- Ceiling insulation

Reference

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1.1 Theoretical Cost Benefit Analysis

A theoretical cost benefit analysis was carried out on a range of options detailed in Section 3 for both water and energy efficiency retrofit levels of existing New Zealand houses. The energy benefits were based on modelling using the BRANZ ALF model, and the water and waste benefits were based on the experience from the Waitakere NOW Home®**.** As the improvements were not able to be quantified, the indoor environment quality and associated health improvements which result from insulation have not been included in these theoretical cost benefit analyses.

At a national level, the following options have a theoretical internal rate of return greater than 5% making them worthwhile implementing from a financial perspective:

- Rainwater tanks (2,000 litre) for Auckland only (assuming 100% water retention)
- Low flow shower heads for high pressure systems
- Water efficient ("AAA") washing machines
- Water heating upgrade (if current water heating tank needs replacing)
    - Solar hot water heating
    - Heat pump hot water heating
    - Instant gas hot water heating
- Floor insulation
- Ceiling insulation

1.2 Further Work

The work outlined in this report is the result of theoretical equations and modelling, not actual examples of retrofitting. In addition it does not consider the impacts on health which result from insulation retrofits in particular. Some potential next steps arising from this work are:

- to undertake research into actual retrofit outcomes and derive cost–benefit analyses from these, both from a national perspective, and also with consideration to regional differences; and
- to undertake research into the costs and benefits of insulation from an Indoor Environment Quality (health) perspective and review the theoretical cost benefit analyses in light of this research.

With regard to the TE106 retrofit project, these theoretical cost benefit analyses can be used to assist in development of a priority matrix for testing retrofit technologies, essentially providing the hypothesis which the research will address.

2 Introduction

Beacon Pathway Ltd is investigating the case for accelerating the retrofitting of sustainability measures into existing New Zealand homes to improve health, reduce energy and water consumption and minimise the environmental impact of energy use in the home.

This report is the second of two reports for the first stage of the retrofit program to provide input to the monitoring of 10 houses that will be retrofitted sustainably. A companion report which outlines a desktop study on energy retrofit research projects in New Zealand has also been completed. This report provides information to assist the decision making for the second stage of the Beacon Retrofit Program, being a cost benefit analysis focusing on energy, water and waste. The outputs will define achievable retrofit options that can be applied to the 10 houses to be retrofitted and identify the gaps indicating potential new opportunities for further research or technologies.

3 Theoretical cost benefit analysis of retrofit options

There are varying degrees of energy and water efficiency measures available in New Zealand today, some of which are designed to make a dwelling almost completely independent of the reticulated infrastructure. Many of the measures involved in achieving this sort of efficiency are not financially feasible with present energy and water prices. As the intentions of this analysis are to establish a cost effective way to retrofit from the homeowner's perspective, the analysis has been carried out in the following areas:

- Water Efficiency
  - Rainwater tanks
  - Low flow shower heads
  - Low flow taps/flow restrictors on taps
  - Dual flush toilets
  - Water efficient washing machines
- Energy Efficiency
  - Water heating – if replacement of old system is required.
    - a) Solar hot water
    - b) Heat pump
    - c) Instant gas
  - Glazing systems – both full replacement and alteration of existing frames.
  - Insulation
    - a) Timber floors
    - b) Walls – retrofitted from both interior and exterior
    - c) Ceiling
  - Compact fluorescent light bulbs
  - Energy efficient bundle (draught stoppers, hot water cylinder wraps and pipe lagging, thermal curtains with pelmets)
- Waste (costs only)
  - Worm farm
  - Compost

The materials for these were priced using discount rates that an average-sized residential building company should have available to them. This was achieved using a price guide from a major national building supplier, Rawlinsons, and local contractor rates for each region and appliance prices. Eight regions were selected to represent different areas of New Zealand, metro/city, urban and rural. These are:

Larger centres:

- Auckland
- Wellington
- Christchurch
- Dunedin

Smaller centres:

- Rotorua
- Gisborne
- Masterton
- Invercargill

The analysis in this report is based on three people living in a 150m^2 single storey building. It is intended to highlight where the most cost effective savings could be made.

The threshold set for water conservation and energy efficiency measures was an Internal Rate of Return (IRR) of at least 5%. This is because the expected return should be at least equal to a bank term deposit (currently about 7.5% less tax @ 33% i.e. a 5% return).

Internal Rate of Return (IRR)

The IRR is the return achieved in the extra initial expenditure, (i.e. more than code standard insulation) compared to the cost savings (i.e. extra energy savings compared to standard insulation). The calculations are based on a 20 year analysis period.

The formula is: $P=R*USPWF_{r/n}$

Where P = Extra initial cost
R = Value of the additional energy/water savings.
$USPWF_{r/n}$ = Uniform series discount factor for period n years and a discount rate of r.

The r value is trialled until the two sides of the equation are equal, giving the internal rate of return.

Simple Payback

An energy investment's simple payback period is the amount of time it will take to recover the initial investment in energy savings divided by the extra initial installed cost by the annual energy cost savings. For example, a heat pump HWC costs $3,728 more than a standard electric HWC; and saves $312 per year giving it a simple payback of 3,728 divided by 312 or 11.9 years.

$$\text{SIMPLE PAYBACK} = \frac{\text{Additional Extra Initial Costs}}{\text{Annual Savings}} = \quad \text{years}$$

3.1 Theoretical Cost Benefit for Water Efficiency

Table 1 is a summary of the amount of water that can potentially be captured annually from a 150m^2 roof. It also shows how many times (cycles) the captured rainwater could be used for each appliance if only used for that particular purpose. This is to show the total potential rain water captured.

The water costs per m^3 are derived from local council rates and where no water charges apply, estimates have been made using figures from nearby councils. (Of the centres used in this study only Auckland currently has water charges in place.) These have been included to show the regional variations in water costs and therefore potential savings made from installing a water tank vary. Some Regional Councils also have rebates in place to provide further incentives for households to install water storage tanks. For analysis purposes, rebates have been excluded.

Table 1 Rainwater Supply and Potential Use

Rainwater Usage & Potential Savings/yr		Auckland	Wellington	Christchurch	Dunedin	Rotorua	Gisborne	Masterton	Invercargill
Annual rainfall	mm/yr	1,240	1,249	648	812	1,401	1,051	979	1,112
150m^2 roof	L	186,000	187,350	97,200	121,800	210,150	157,650	146,850	166,800
		No. of cycles (times) possible using total amount of rainwater available from the roof							
Toilet flushes	5L/flush	37,200	37,470	19,440	24,360	42,030	31,530	29,370	33,360
Showers (6 min average)	5L/min low flow head	6,200	6,245	3,240	4,060	7,005	5,255	4,895	5,560
Loads of washing	@ 150L/load	1,240	1,249	648	812	1,401	1,051	979	1,112
Local rates water	\$/m^3	1.48	1.48	1.24	1.24	0.31	1.48	1.48	1.48

In reality, due to seasonal changes, evaporation, first-flush diverters, and tank size availability, the total rainfall is unlikely to be used. Table 2 shows the water savings for two tank sizes (2,000L and 7,500L). For the 2,000L rainwater tank, the total amount of rain captured from the roof is 50% and for the large tank (7,500L) it has been assumed to be 80%. The material cost of the water storage tanks allows for a low pressure water pump, but does not allow for the down pipes required to deliver the water to the tanks as each situation is different.

Low flow shower heads are a cost effective and simple way to lower water usage which have been evaluated on the basis of a straight replacement. For the cost benefit analysis, information from the HEEP data (Isaacs et al, 2004) was used. This stated the average mains pressure shower system uses approximately 12L/min which could be reduced to 5 to 7L with a low flow shower head. Therefore the savings were based on 6L/min with an average shower time of six minutes.

Water efficient washing machines (60L/wash) on the other hand have been evaluated under the basis that the washing machine in place is due for an upgrade and therefore the additional cost of $60 is that over a new standard washing machine (150L/wash). This assumption has been used because it is highly unlikely someone will buy a new washing machine whilst their current one is working.

The water savings provided in Table 2 show the amount of water used compared to not retrofitting a home with the selected water efficiency measure. For example, if in Auckland, a family installs a 2,000L rainwater tank, they could potentially collect and use about 50% of the rainfall from the roof which gives water savings of 93,000L. However, this amount of rainwater is not enough to provide for the total needs of their laundry, shower and toilet (109,500L) even with water efficiency measures in place for all three end uses. A 7,500L tank, however, can harvest more water (estimated at 80%) and therefore not only can provide water for all three designated end uses, but will have some left over for other uses such as watering the garden.

For the low flow shower heads and “AAA” washing machines, the total use is the amount used with the water efficient measure in place and the savings are the difference between this and a non-water efficient appliance or device.

Table 2 Water use analysis by region

Water tanks & efficient appliances	Water use assumptions	Material Cost ($)	Labour Cost ($)	Unit Cost ($)	Total water use* (L/yr)	Water Savings** (L/yr)	Water Cost*** ($/m^3)	Savings ($/yr)	Simple payback (years)	IRR (%)
AUCKLAND										
2,000L tank	Toilet, laundry, shower	1,225	496	1,721	109,500	93,000	1.48	138	12.5	5.0
7,500L tank	Toilet, laundry, shower	2,325	496	2,821	109,500	109,500	1.48	162	17.4	1.4
Low flow shower head	3 people, 6 min each	50	124	174	65,700	39,420	1.48	58	3.0	33.4
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.48	49	1.2	81.0
WELLINGTON										
2,000L tank	Toilet, laundry, shower	1,225	480	1,705	109,500	93,675	1.24	116	14.7	3.1
7,500L tank	Toilet, laundry, shower	2,325	480	2,805	109,500	109,500	1.24	136	20.6	-0.3
Low flow shower head	3 people, 6 min each	50	120	170	65,700	39,420	1.24	49	3.5	28.6
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9
CHRISTCHURCH										
2,000L tank	Toilet, laundry, shower	1,175	440	1,615	109,500	48,600	1.24	60	26.8	-2.6
7,500L tank	Toilet, laundry, shower	2,120	440	2,560	109,500	77,760	1.24	96	26.5	-2.6
Low flow shower head	3 people, 6 min each	50	110	160	65,700	39,420	1.24	49	3.3	30.4
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9
DUNEDIN										
2,000L tank	Toilet, laundry, shower	1,195	400	1,595	109,500	60,900	1.24	76	21.1	-0.5
7,500L tank	Toilet, laundry, shower	2,175	400	2,575	109,500	97,440	1.24	121	21.3	-0.6
Low flow shower head	3 people, 6 min each	50	100	150	65,700	39,420	1.24	49	3.1	32.5
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9

ROTORUA										
2,000L tank	Toilet, laundry, shower	1,225	496	1,721	109,500	105,075	0.31	33	52.8	-7.9
7,500L tank	Toilet, laundry, shower	2,325	496	2,821	109,500	109,500	0.31	34	83.1	-10.9
Low flow shower head	3 people, 6 min each	50	110	160	65,700	39,420	0.31	12	13.1	4.4
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	0.31	10	5.9	16.1
GISBORNE										
2,000L tank	Toilet, laundry, shower	1,225	480	1,705	109,500	78,825	1.24	98	17.4	1.3
7,500L tank	Toilet, laundry, shower	2,325	480	2,805	109,500	109,500	1.24	136	20.6	-0.3
Low flow shower head	3 people, 6 min each	50	100	150	65,700	39,420	1.24	49	3.1	32.5
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9
MASTERTON										
2,000L tank	Toilet, laundry, shower	1,225	440	1,665	109,500	73,425	1.24	91	18.3	0.9
7,500L tank	Toilet, laundry, shower	2,325	440	2,765	109,500	109,500	1.24	136	20.3	-0.2
Low flow shower head	3 people, 6 min each	50	90	140	65,700	39,420	1.24	49	2.9	34.8
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9
INVERCARGILL										
2,000L tank	Toilet, laundry, shower	1,195	400	1,595	109,500	83,400	1.24	103	15.4	2.6
7,500L tank	Toilet, laundry, shower	2,175	400	2,575	109,500	109,500	1.24	136	18.9	0.5
Low flow shower head	3 people, 6 min each	50	100	150	65,700	39,420	1.24	49	3.1	32.5
"AAA" washing machine	1 load/day	1,599		60	21,900	32,850	1.24	41	1.5	67.9

* Total amount of water used assuming water efficient measures have been retrofitted.
** Water saved by using a rainwater tank or installing a water efficiency measure (reduced shower flow or water efficient washing machine).
*** Note 1m^3 is equivalent to 1,000L.
Note: Low flow shower heads reduce normal head flow rate from 10L/min to 6L/min

3.1.1 Cost benefit

The results of the cost benefit analysis show that homes in all regions, with the exception of Rotorua, choosing to install a water efficient washing machine when replacement is needed and a low flow showerhead, achieve a financial benefit from retrofitting. In Rotorua, only the washing machine replacement has an IRR over 5%, although the low flow shower head was close, with an IRR of 4.4% (albeit a payback period of 13.1 years). The reason for this is the very low unit cost for water in Rotorua.

The only region where rainwater tanks meet the 5% IRR (at payback of 12.5 years) was in Auckland for the 2,000L tank (the 7,500L tank IRR equals 1.4%). With a payback period at best over 10 years, it is not surprising the harvesting of rainwater through installation of tanks has been minimal. Rotorua had the worst payback at -10.9%. In some areas councils provide subsidies for homeowners to install rainwater tanks and it seems likely this will be necessary (or a considerable increase in the price of water) for consumers to take this up without any regulation.

However, given the likelihood that water shortages are going to become more of an issue in the future and water metering is likely to increase in many areas, the cost of water should be expected to increase. With this in mind, it could be assumed these calculations are on the conservative side. Outside of Auckland a range of other councils (Nelson, Tauranga, and soon Kapiti Coast) also charge a significant amount for water, and the IRR of 5% may well be achieved in these areas if retention approaches 100%.

3.2 Theoretical Energy Conservation Through Retrofit

The savings represented in this report are based on three people living in a 150m^2 single story building with a 3:1 wall to window ratio facing solar noon. A three person house is the closest full number to the average household in New Zealand of 2.9 persons and 150m^2 is representative of a typical existing house. However there is no 'typical or representative' amount for north facing glazing. The energy benefits of insulation have been simulated using ALF3. Each level of the above measures was simulated one at a time using the following as base levels:

- Glazing – Single glazing R0.16
- Timber floors – no insulation as this is the state of approximately 65% of New Zealand houses.
- Walls – no insulation as this is the state of approximately 55% of New Zealand houses.
- Ceiling – R0.3 no insulation because approximately 36% of New Zealand houses have less than 50mm insulation.

It must be noted that adding the benefits of each measure together will overstate the level of savings achieved from multiple measures. To cover the variability in both pricing and climate, the four main centres (Auckland, Wellington, Christchurch and Dunedin) and four smaller regions (Rotorua, Gisborne, Masterton and Invercargill) were used for the cost benefit analysis calculations.

Water Heater Replacement Due to the expense of replacing a hot water cylinder (HWC), the analysis of hot water heating has been calculated on the basis that the existing cylinder is in need of replacement, similar to the washing machine. The feasibility of each system is then compared to that of a standard HWC on day rates. The extra material cost incurred in electric night store HWCs is due to the need for an extra meter to be installed for night rates if one is not already in place. Due to differences in power prices from region to region, it is more cost effective in some locations to leave the HWC on day rates. The fuel prices for gas fired water systems are based on the cheapest options for each region. For the North Island this is mostly reticulated natural gas. Where natural gas is not available, 45kg LPG bottle prices have been used. The energy savings gained through the adoption of solar water heaters were calculated using a program designed by RetScreen International[1]. The coefficient of performance for the heat pump water heaters were estimated using figures from a report by Carrington[2].

Glazing types Other than the glazing units that have been retrofitted into rerouted timber frames, all glazed windows have been analysed on the basis that the windows require replacement due to rot, settling of the building or general replacement. All frame prices are for standard aluminium frames fitted back into the same sized opening and rearchitraved. Note that no painting of architraves or window sills has been allowed for.

Table 3 below shows the percentage change from a standard aluminium frame window to an alternative with a more energy efficient frame. For example, the additional capital cost of using a composite aluminium frame instead of a standard aluminium frame when installing double glazing in Wellington is 71%. These more efficient frames were not included in the main analysis as the additional cost was not justifiable.

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[1] ***http://www.retscreen.net***

[2] ***Carrington G., Demonstration of a hot water heat pump system. Report 102, New Zealand Energy Research and Development Committee.***

Table 3 Cost increase of window frame with the same glazing type compared to a standard aluminium frame, expressed as a percentage increase

Percentage change of window prices for alternative frame types	Auckland (%)	Wellington (%)	Christchurch (%)
Composite aluminium frame			
Single glazing	143	128	130
Double glazing	78	71	99
Double glazing low-e	63	49	85
Double glazing argon fill/low-e	61	46	81
Thermally broken aluminium frame			
Single glazing	na	na	na
Double glazing	36	33	51
Double glazing low-e	29	17	44
Double glazing argon fill/low-e	28	15	42
PVC frame			
Single glazing	93	81	79
Double glazing	61	39	69
Double glazing low-e	47	22	65
Double glazing argon fill/low-e	46	19	60

The minimum Building Code level of insulation is used for each region, which varies between the North and South Islands. From there, the levels of insulation are increased by a factor of 1.5 and 2, which are then matched to the closest R-value of an actual insulation product currently available in New Zealand. However in the South Island, for the walls, it was not possible to use a double code R-value, due to inadequate cavity space in a standard 100x50 framed building.

Timber Floor Insulation The floor insulation has been calculated on the basis that there is sufficient access and crawl space (600mm) under the building to fit the insulation. Underfloor foil with fibre cement sheet is more expensive than two layers of expanded polystyrene foam as the labour required to fit the product for the latter is much less.

Wall Insulation The cost of insulating the walls of the dwellings have been calculated in two different ways; firstly by tearing down the interior plasterboard linings, insulating and then fitting new plasterboard, skirting and scotia followed by painting. Secondly, if the dwelling has weatherboard cladding that requires repainting or replacement of rotten boards, the insulation can be fitted by pulling off the weatherboards and fitting the insulation from the exterior. The external weatherboard analysis has been broken down into three groups: 10, 20, and 30% replacement of old weatherboards which are damaged during removal and need to be replaced. The costs allow for new building paper, cavity battens and fixing of weatherboards on a single storey house on a flat section (does not allow for scaffolding). Painting costs are not included, as these would have been incurred by the owner as repainting was already required. Also, some weatherboards may be rotten and need replacing in any case. This cost has not been included in the analysis. Although the second option is more expensive, less waste is produced in this application as the majority of weatherboards are re-used.

Ceiling Insulation As mentioned earlier the base line level of insulation is R-0.3, because BRANZ Ltd research has shown that 36% of houses in New Zealand have less than 50mm of insulation in place.

3.2.1 Auckland Cost Benefit

In the Auckland region the theoretical cost benefit analysis for any retrofit space heating savings is well below the desired IRR of 5%. This is primarily due to the warmer climate than in the rest of the country. Benefits arising from improvements to indoor environment quality and improved health have not been considered as part of the equation. With the proportionally large number of houses in the Auckland region, this suggests any market transformation on space heating savings alone will need to be different for the Auckland region (and north of Auckland) compared to the rest of the country as the financial drivers are not as strong. It is likely other drivers such as comfort and health benefits outweigh the financial ones.

The theoretical energy saving from water heating options that are financially feasible include instant gas hot water and solar hot water. Heat pump hot water systems are just below the 5% threshold at IRR 4.6%.

Table 4 Theoretical Energy Efficiency Cost Benefit Analysis – AUCKLAND

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	150	0	1.00	2,665	0.183	0	487	0		
Electric night store HWC		1,230	150	135	1.00	3,197	0.151	-533	482	4	31.3	-3.9
Gas Instant 26L		1,332	320	408	0.90	2,261	0.086	404	333	154	2.7	37.6
Gas Storage		3,439	320	2,814	0.90	2,961	0.086	-296	393	93	30.1	-3.6
Solar		4.720	1,500	5,275	1.00	311	0.183	2,354	57	430	12.3	5.2
Heat pump HWC		4,657	500	4,213	1.00	871	0.183	1,794	159	328	12.9	4.6
Glazing types – min. code = R-0.26		unit										
Single	R-0.16	6,442				3,561						
Rerout & fit DG units in ex timber frame		3,355	4,388	7,742		3,243		318		58	22.3	-13.8
Double, 4-12-4	R-0.35	9,093	1,935	11,028		3,243		318		58	78.8	-10.6
Double Low-E, 4-12-4	R-0.52	11,307	1,935	13,242		3,172		389		71	95.5	-11.8
Double Low-E Argon, 4-12-4	R-0.62	11,604	1,935	13,539		3,020		541		99	71.7	-9.9
Insulation, joists at 450 centres		150m^2	150m^2									
FLOOR TIMBER												
No insulation						2,554						
Sisalation 100mm sag	code R-1.3	279	996	1,275		2,167		387		71	18.0	1.0
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,980	3,314		2,140		414		76	43.7	-6.5
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		2,029		525		96	37.2	-5.3
WALLS												
No insulation						3,561						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	146	5,533		3,265		296		54	102.1	-12.2
2. 2 94mm ultra wall pink batts	code *1.5	5,497	146	5,643		3,231		330		60	93.4	-11.6
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	146	6,508		3,190		371		68	95.9	-11.8
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	6,728	8,369		3,265		296		54	154.5	-14.6
	code * 1.5	1,752	6,728	8,480		3,231		330		60	140.4	-14.1
	code * 2.0	2,617	6,728	9,344		3,190		371		68	137.6	-14.0
20% replacement in weatherboards	code R-1.5	2,098	6,728	8,826		3,265		296		54	162.9	-14.9
	code * 1.5	2,208	6,728	8,936		3,231		330		60	148.0	-14.4
	code * 2.0	3,073	6,728	9,801		3,190		371		68	144.4	-14.2
30% replacement in weatherboards	code R-1.5	2,555	6,728	9,282		3,265		296		54	171.4	-15.2
	code * 1.5	2,665	6,728	9,392		3,231		330		60	155.5	-14.7
	code * 2.0	3,530	6,728	10,257		3,190		371		68	151.1	-14.5
CEILING												
1.050mm degraded insulation						3,561						
1.8 75mm ceiling pink batts	code min 1.9	893	225	1,118		3,191		370		68	16.5	1.9
3.2 135mm ultra ceiling pink batts	code * 1.5	1,371	225	1,596		3,122		439		80	19.9	0.1
4.0 170mm ceiling pink batts	code * 2.0	1,884	225	2,109		3,100		461		84	25.0	-2,0

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 5 Theoretical Energy Efficiency Cost Benefit Analysis - WELLINGTON

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	108	0	1.00	2,665	0.188	0	501	0		
Electric night store HWC		1,630	108	535	1.00	3,197	0.121	-533	385	115	4.6	21.1
Gas Instant 26L		1,332	288	418	0.90	2,261	0.086	404	399	102	4.1	24.0
Gas Storage		3,439	288	2,740	0.90	2,961	0.086	-296	459	42	65.8	-9.4
Solar		4.720	1,500	5,233	1.00	543	0.188	2,122	102	399	13.1	4.4
Heat pump HWC		4,657	500	4,171	1.00	943	0.188	1,722	177	324	12.9	4.6
Glazing types – min. code = R-0.26		unit										
Single	R-0.16	6,867				7,404						
Rerout & fit DG units in ex timber frame		3,860	4,388	8,248		6,796		608		114	12.1	-10.0
Double, 4-12-4	R-0.35	10,513	1,935	12,448		6,796		608		114	48.8	-7.3
Double Low-E, 4-12-4	R-0.52	13,600	1,935	15,535		6,662		742		139	62.1	-9.0
Double Low-E Argon, 4-12-4	R-0.62	14,189	1,935	16,124		6,371		1033		194	47.7	-7.1
Insulation, joists at 450 centres		$150m^2$	$150m^2$									
FLOOR TIMBER												
No insulation						5,461						
Sisalation 100mm sag	code R-1.3	279	996	1,275		4,741		720		135	9.4	8.6
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,980	3,314		4,688		773		145	22.8	-1.2
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		4,476		985		185	19.3	0.3
WALLS												
No insulation						7,404						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	146	5,533		6,840		564		106	52.2	-7.8
2. 2 94mm ultra wall pink batts	code *1.5	5,487	146	5,643		6,774		630		118	47.6	-7.1
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	146	6,508		6,695		709		133	48.8	-7.3
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	6,435	8,077		6,840		564		106	76.2	-10.3
	code * 1.5	1,752	6,435	8,187		6,774		630		118	69.1	-9.7
	code * 2.0	2,617	6,435	9,052		6,695		709		133	67.9	-9.6
20% replacement in weatherboards	code R-1.5	2,098	6,435	8,533		6,840		564		106	80.5	-10.7
	code * 1.5	2,208	6,435	8,643		6,774		630		118	73.0	-10.1
	code * 2.0	3,073	6,435	9,508		6,695		709		133	71.3	-9.9
30% replacement in weatherboards	code R-1.5	2,555	6,435	8,990		6,840		564		106	84.8	-11.0
	code * 1.5	2,665	6,435	9,100		6,774		630		118	76.8	-10.4
	code * 2.0	3,530	6,435	9,965		6,695		709		133	74.8	-10.2
CEILING												
1.050mm degraded insulation						7,404						
1.8 75mm ceiling pink batts	code min 1.9	893	225	1,118		6,697		707		133	8.4	10.2
3.2 135mm ultra ceiling pink batts	code * 1.5	1,371	225	1,596		6,565		839		158	10.1	7.6
4.0 170mm ceiling pink batts	code * 2.0	1,884	225	2,109		6,523		881		163	12.9	4.6

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 6 Theoretical Energy Efficiency Cost Benefit Analysis – CHRISTCHURCH

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	135	0	1.00	2,665	0.183	0	488	0		
Electric night store HWC		1,227	135	132	1.00	3,197	0.151	-533	361	127	1.0	96.1
Gas Instant 26L		1,332	360	463	0.90	2,261	0.086	404	376	112	4.1	23.9
Gas Storage		3,439	360	2,569	0.90	2,961	0.086	-296	477	11	236.6	-17.0
Solar		4.720	1,500	4,990	1.00	595	0.183	2,070	109	379	13.2	4.4
Heat pump HWC		4,657	500	3,928	1.00	980	0.183	1,684	180	309	12.7	4.8
Glazing types – min. code = R-0.26		Unit										
Single	R-0.16	6,938				8,863						
Rerout & fit DG units in ex timber frame		2,876	4,388	7,264		8,122		741		136	2.4	-8.0
Double, 4-12-4	R-0.35	8,681	1,600	10,281		8,122		741		136	24.6	-1.9
Double Low-E, 4-12-4	R-0.52	10,066	1,600	11,666		7,958		905		166	28.5	-3.2
Double Low-E Argon, 4-12-4	R-0.62	10,613	1,600	12,213		7,604		1259		231	22.9	-1.2
Insulation, joists at 450 centres		$150m^2$	$150m^2$									
FLOOR TIMBER												
No insulation						6,493						
Sisalation 100mm sag	code R-1.3	279	996	1,275		5,616		877		161	7.9	11.1
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,760	3,094		5,551		942		173	17.9	-1.1
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		5,292		1,201		220	16.2	-2.1
WALLS												
No insulation						8,863						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	195	5,582		8,175		688		126	44.3	-6.6
2. 2 94mm ultra wall pink batts	code *1.5	5,860	195	6,055		8,039		824		151	40.1	-5.9
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	195	6,557		7,999		864		158	41.4	-6.1
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	5,996	7,638		8,175		688		126	60.6	-8.8
	code * 1.5	1,752	5,996	7,748		8,039		824		151	51.3	-7.7
	code * 2.0	2,617	5,996	8,613		7,999		864		158	54.4	-8.1
20% replacement in weatherboards	code R-1.5	2,098	5,996	8,094		8,175		688		126	64.2	-9.2
	code * 1.5	2,208	5,996	8,205		8,039		824		151	54.4	-8.1
	code * 2.0	3,073	5,996	9,069		7,999		864		158	57.3	-8.4
30% replacement in weatherboards	code R-1.5	2,555	5,996	8,551		8,175		688		126	67.8	-9.6
	code * 1.5	2,665	5,996	8,661		8,039		824		151	57.4	-8.5
	code * 2.0	3,530	5,996	9,526		7,999		864		158	60.2	-8.8
CEILING												
1.050mm degraded insulation						8,863						
1.8 75mm ceiling pink batts	code min 2.5	1,082	225	1,382		7,893		970		178	7.8	11.4
3.2 135mm ultra ceiling pink batts	code * 1.5	1,533	225	1,833		7,812		1,051		193	9.5	8.4
4.0 170mm ceiling pink batts	code * 2.0	2,517	225	2,817		7,744		1,119		205	13.7	3.9

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 7 Theoretical Energy Efficiency Cost Benefit Analysis – DUNEDIN

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	108	0	1.00	2,665	0.214	0	570	0		
Electric night store HWC		1,225	108	130	1.00	3,197	0.173	-533	553	16	7.9	11.1
Gas Instant 26L		1,332	288	418	0.90	2,261	0.143	404	339	171	2.4	40.9
Gas Storage		3,439	288	2,524	0.90	2,961	0.143	-296	499	71	35.5	-4.9
Solar		4.720	1,500	5,017	1.00	798	0.214	1,867	171	399	12.6	4.9
Heat pump HWC		4,657	500	3,955	1.00	1031	0.214	1,633	221	349	11.3	6.2
Glazing types – min. code = R-0.26		Unit										
Single	R-0.16	6,938				10,335						
Rerout & fit DG units in ex timber frame		2,876	4,388	7,264		9,467		868		186	1.8	-5.7
Double, 4-12-4	R-0.35	8,681	1,520	10,201		9,467		868		186	17.6	1.3
Double Low-E, 4-12-4	R-0.52	10,066	1,520	11,586		9,276		1,059		227	20.5	-0.2
Double Low-E Argon, 4-12-4	R-0.62	10,613	1,520	12,133		8,862		1,473		315	16.5	1.9
Insulation, joists at 450 centres		$150m^2$	$150m^2$									
FLOOR TIMBER												
No insulation						7,563						
Sisalation 100mm sag	code R-1.3	279	996	1,275		6,536		1,027		220	5.8	16.4
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,760	3,094		6,461		1,102		236	13.1	4.4
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		6,158		1,405		301	11.9	5.6
WALLS												
No insulation						10,335						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.9	5,336	195	5,531		9,529		806		172	32.1	-4.1
2. 2 94mm ultra wall pink batts	code *1.5	5,811	195	6,006		9,371		964		206	29.1	-3.3
3.0 94mm ceiling ultra pink batts	code *2.0	6,313	195	6,508		9,324		1,011		216	30.1	-3.6
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	5,704	7,346		9,529		806		172	42.6	-6.3
	code * 1.5	1,752	5,704	7,456		9,371		964		206	36.2	-5.1
	code * 2.0	2,617	5,704	8,321		9,324		1,011		216	38.5	-5.6
20% replacement in weatherboards	code R-1.5	2,098	5,704	7,802		9,529		806		172	45.3	-6.8
	code * 1.5	2,208	5,704	7,912		9,371		964		206	38.4	-5.5
	code * 2.0	3,073	5,704	8,777		9,324		1,011		216	40.6	-6.0
30% replacement in weatherboards	code R-1.5	2,555	5,704	8,258		9,529		806		172	47.9	-7.2
	code * 1.5	2,665	5,704	8,368		9,371		964		206	40.6	-6.0
	code * 2.0	3,530	5,704	9,233		9,324		1,011		216	42.7	-6.3
CEILING												
1.050mm degraded insulation						10,335						
2.6 110mm ceiling pink batts	code min 2	1,082	300	1,382		9,200		1,135		243	5.7	16.8
3.6 155mm ultra ceiling pink batts	code * 1.5	1,533	300	1,833		9,105		1,230		263	7.0	13.1
5.0 190mm ceiling pink batts	code * 2.0	2,517	300	2,817		9,025		1,310		280	10.1	7.7

Material costs: for the night store heater the cylinder size needs to be larger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

3.2.2 Wellington Cost Benefit

Electric night store and instant gas heaters both have very favourable theoretical cost benefit analysis results, when an upgrade of a hot water cylinder is required in the Wellington region. The payback period is between 4-5 years.

For thermal efficiency, improvements installing insulation in the ceiling and underfloor insulation (foil) have the most significant benefit in terms of theoretical energy saved. It is interesting to note the higher value options are theoretically less cost effective, since you achieve greater savings per R-value at the lower end compared to the higher R-values.

With the work required to install insulation in the walls (by either taking off the internal lining or removing the external weatherboards) this analysis based on the modelling results shows wall insulation is not cost effective. The return rates are as low as -11.0% and paybacks are between 60 and 80 years. This is typical for all centres used for this analysis.

3.2.3 Christchurch Cost Benefit

A similar pattern to Wellington is seen with the Christchurch data. Theoretically night-store heaters are a much more favourable option, although it is likely to be dependent on the charging cost structure of the electricity company chosen by the homeowner.

Despite a theoretical low (negative) return rate for retrofitting double glazing, it is an option available in the Christchurch area that has been increasing in popularity over the last years. The financial benefits are not the only reasons for people to choose a more energy efficient retrofit option. Research into improvements in Indoor Environment Quality as well as monitoring of actual retrofit situations may give reasons why this is the case.

Solar hot water and heat pumps for hot water heating are theoretically just below 5% IRR at 4.4% and 4.8% respectively.

3.2.4 Dunedin Cost Benefit

The theoretical savings from hot water are similar to Christchurch although instant gas has a better IRR than night-store. The solar hot water and heat pumps IRR's hover between the 4-6% mark.

With the colder climate in Dunedin the theoretical payback for ceiling insulation is between 5-10 years with all three of the ceiling insulation options over the IRR 5% threshold. Retrofit trials for walls to look at ways to reduce costs for this retrofit option may be useful. All options for insulating underfloor insulation look acceptable with theoretical internal return rates from 4.4% to 16.4%. The low cost of foil and ease of installation provides a very good theoretical IRR for this option. However, this is assuming it will last 20 years, which requires that it be protected from wind, salts and animals.

Table 8 Theoretical Energy Efficiency Cost Benefit Analysis - ROTORUA

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	165	0	1.00	2,665	0.223	0	593	0		
Electric night store HWC		1,230	165	135	1.00	3,197	0.170	-533	543	50	2.7	37.1
Gas Instant 26L		1,332	440	513	0.90	2,261	0.070	404	263	330	1.6	64.4
Gas Storage		3,439	440	2,619	0.90	2,961	0.070	-296	312	281	9.3	8.7
Solar		4.720	1,500	4,960	1.00	432	0.223	2,233	96	497	10.0	7.8
Heat pump HWC		4,657	500	3,898	1.00	925	0.223	1,740	206	387	10.1	7.7
Glazing types – min. code = R-0.26		unit										
Single	R-0.16	6,584				8,239						
Rerout & fit DG units in ex timber frame	R-0.35	3,523	4,388	7,911		7,587		652		145	9.1	-8.1
Double, 4-12-4	R-0.35	9,566	1,600	11,166		7,587		652		145	31.6	-4.0
Double Low-E, 4-12-4	R-0.52	12,071	1,600	13,671		7,443		796		177	40.0	-5.9
Double Low-E Argon, 4-12-4	R-0.62	12,466	1,600	14,066		7,132		1,107		247	30.3	-3.7
Insulation, joists at 450 centres		$150m^2$	$150m^2$									
FLOOR TIMBER												
No insulation						6,156						
Sisalation 100mm sag	code R-1.3	279	996	1,275		5,385		771		172	7.4	12.1
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,980	3,314		5,329		827		184	18.0	1.0
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		5,102		1,054		235	15.2	2.8
WALLS												
No insulation						8,239						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	146	5,533		7,634		605		135	0.0	-6.1
2. 2 94mm ultra wall pink batts	code *1.5	5,487	146	5,643		7,563		676		151	37.5	-5.4
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	146	6,508		7,479		760		169	38.5	-5.6
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	5,996	7,638		7,634		605		135	0.0	-8.4
	code * 1.5	1,752	5,996	7,748		7,563		676		151	51.5	-7.7
	code * 2.0	2,617	5,996	8,613		7,479		760		169	50.9	-7.6
20% replacement in weatherboards	code R-1.5	2,098	5,996	8,094		7,634		605		135	0.0	-8.8
	code * 1.5	2,208	5,996	8,205		7,563		676		151	54.5	-8.1
	code * 2.0	3,073	5,996	9,069		7,479		760		169	53.6	-8.0
30% replacement in weatherboards	code R-1.5	2,555	5,996	8,551		7,634		605		135	0.0	-9.1
	code * 1.5	2,665	5,996	8,661		7,563		676		151	57.5	-8.5
	code * 2.0	3,530	5,996	9,526		7,479		760		169	56.3	-8.3
CEILING												
1.050mm degraded insulation						8,239						
1.8 75mm ceiling pink batts	code min 1.9	893	225	1,118		7,715		524		117	9.6	8.3
3.2 135mm ultra ceiling pink batts	code * 1.5	1,371	225	1,596		7,427		812		181	8.8	9.5
4.0 170mm ceiling pink batts	code * 2.0	1,884	225	2,109		7,453		786		175	12.0	5.4

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 9 Theoretical Energy Efficiency Cost Benefit Analysis – GISBORNE

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	150	0	1.00	2,665	0.291	0	775	0		
Electric night store HWC		1,223	150	128	1.00	3,197	0.136	-533	434	341	0.4	266.3
Gas Instant 26L		1,332	400	488	0.91	2,228	0.091	436	390	385	1.3	79.0
Gas Storage		3,439	400	2,594	0.91	2,928	0.091	-264	453	322	8.1	10.8
Solar		4.720	1,500	4,975	1.00	349	0.291	2,316	102	674	7.4	12.2
Heat pump HWC		4,657	500	3,913	1.00	881	0.291	1,784	256	519	7.5	11.8
Glazing types – min. code = R-0.26		Unit										
Single	R-0.16	6,655				3,975						
Rerout & fit DG units in ex timber frame	R-0.35	3,607	4,388	7,995		3,621		354		103	13.0	-10.5
Double, 4-12-4	R-0.35	9,803	1,512	11,315		3,621		354		103	45.3	-6.8
Double Low-E, 4-12-4	R-0.52	12,453	1,512	13,965		3,543		432		126	58.2	-8.5
Double Low-E Argon, 4-12-4	R-0.62	12,897	1,512	14,409		3,373		602		175	44.3	-6.6
Insulation, joists at 450 centres		150m^2	150m^2									
FLOOR TIMBER												
No insulation						2,843						
Sisalation 100mm sag	code R-1.3	279	996	1,275		2,423		420		122	10.4	7.2
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,980	3,314		2,393		450		131	25.3	-2.1
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		2,269		574		167	21.4	-0.6
WALLS												
No insulation						3,975						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	146	5,533		3,646		329		96	57.8	-8.5
2. 2 94mm ultra wall pink batts	code *1.5	5,497	146	5,643		3,608		367		107	52.9	-7.9
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	146	6,508		3,562		413		120	54.2	-8.1
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	6,289	7,931		3,646		329		96	82.9	-10.9
	code * 1.5	1,752	6,289	8,041		3,608		367		107	75.3	-10.3
	code * 2.0	2,617	6,289	8,906		3,562		413		120	74.1	-10.2
20% replacement in weatherboards	code R-1.5	2,098	6,289	8,387		3,646		329		96	87.6	-11.2
	code * 1.5	2,208	6,289	8,497		3,608		367		107	79.6	-10.6
	code * 2.0	3,073	6,289	9,362		3,562		413		120	77.9	-10.5
30% replacement in weatherboards	code R-1.5	2,555	6,289	8,843		3,646		329		96	92.4	-11.6
	code * 1.5	2,665	6,289	8,953		3,608		367		107	83.9	-11.0
	code * 2.0	3,530	6,289	9,818		3,562		413		120	81.7	-10.8
CEILING												
1.050mm degraded insulation						3,975						
1.8 75mm ceiling pink batts	code min 1.9	893	225	1,118		3,690		285		83	13.5	4.1
3.2 135mm ultra ceiling pink batts	code * 1.5	1,371	225	1,596		3,534		441		128	12.4	5.0
4.0 170mm ceiling pink batts	code * 2.0	1,884	225	2,109		3,494		481		140	15.1	2.9

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 10 Theoretical Energy Efficiency Cost Benefit Analysis – MASTERTON

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	135	0	1.00	2,665	0.258	0	691	0		
Electric night store HWC		1,230	135	135	1.00	3,197	0.126	-533	404	287	0.5	
Gas Instant 26L		1,332	360	463	0.90	2,261	0.148	404	402	289	1.6	62.5
Gas Storage		3,439	360	2,569	0.90	2,961	0.148	-296	505	186	13.8	3.8
Solar		4.720	1,500	4,990	1.00	493	0.259	2,172	128	563	8.0	9.4
Heat pump HWC		4,657	500	3,928	1.00	931	0.259	1,734	241	450	8.7	9.6
Glazing types – min. code = R-0.26		unit										
Single	R-0.16	6,867				8,171						
Rerout & fit DG units in ex timber frame	R-0.35	3,860	4,388	8,248		7,503		668		173	8.0	-7.1
Double, 4-12-4	R-0.35	10,513	2,205	12,538		7,503		668		173	32.7	-4.3
Double Low-E, 4-12-4	R-0.52	13,600	2,205	15,625		7,356		815		211	41.4	-6.1
Double Low-E Argon, 4-12-4	R-0.62	14,189	2,205	16,214		7,038		1,133		294	31.8	-4.1
Insulation, joists at 450 centres		150m²	150m²									
FLOOR TIMBER												
No insulation						6,039						
Sisalation 100mm sag	code R-1.3	279	996	1,275		5,249		790		205	6.2	15.1
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,760	3,094		5,191		848		220	14.1	3.6
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		4,959		1,080		280	12.8	4.7
WALLS												
No insulation						8,171						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,387	146	5,533		7,551		620		161	34.4	-4.7
2. 2 94mm ultra wall pink batts	code *1.5	5,487	146	5,643		7,479		692		180	31.4	-4.0
3.0 94mm ceiling ultra pink batts	code *2.0	6,362	146	6,508		7,393		778		202	32.2	-4.2
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	6,728	8,369		7,551		620		161	52.0	-7.8
	code * 1.5	1,752	6,728	8,480		7,479		692		180	47.2	-7.1
	code * 2.0	2,617	6,728	9,344		7,393		778		202	46.3	-6.9
20% replacement in weatherboards	code R-1.5	2,098	6,728	8,826		7,551		620		161	54.9	-8.1
	code * 1.5	2,208	6,728	8,936		7,479		692		180	49.8	-7.5
	code * 2.0	3,073	6,728	9,801		7,393		778		202	48.6	-7.3
30% replacement in weatherboards	code R-1.5	2,555	6,728	9,282		7,551		620		161	57.7	-8.5
	code * 1.5	2,665	6,728	9,392		7,479		692		180	52.3	-7.8
	code * 2.0	3,530	6,728	10,257		7,393		778		202	50.8	-7.6
CEILING												
1.050mm degraded insulation						8,171						
1.8 75mm ceiling pink batts	code min 1.9	893	225	1,118		7,634		537		139	8.0	10.9
3.2 135mm ultra ceiling pink batts	code * 1.5	1,371	225	1,596		7,340		831		216	7.4	12.1
4.0 170mm ceiling pink batts	code * 2.0	1,884	225	2,109		7,264		907		235	9.0	9.3

Material costs: for the night store heater the cylinder size needs to be larger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

Table 11 Theoretical Energy Efficiency Cost Benefit Analysis – INVERCARGILL

Products		Material Cost ($)	Labour Cost ($)	Additional installed costs ($)	Fuel efficiency	Input (kWh/yr)	Fuel ($/kWh)	Savings (kWh)	Running Cost ($/yr)	Savings in running costs($/yr)	Simple payback (years)	IRR (%)
Water Heating Replacement		unit										
Electrical HWC		1,095	168	0	1.00	2,665	0.180	0	480	0		
Electric night store HWC		1,225	168	130	1.00	3,197	0.100	-533	319	161	0.8	124.1
Gas Instant 26L		1,332	448	518	0.90	2,261	0.281	404	698	-218	-2.4	-ve
Gas Storage		3,439	448	2,624	0.90	2,961	0.281	-296	895	-415	-6.3	-ve
Solar		4.720	1,500	4,957	1.00	798	0.180	1,867	144	336	14.7	3.1
Heat pump HWC		4,657	500	3,895	1.00	1,035	0.180	1,630	187	294	13.3	4.3
Glazing types – min. code = R-0.26		Unit										
Single	R-0.16	6,938				14,487						
Rerout & fit DG units in ex timber frame	R-0.35	2,876	4,388	7,264		13,295		1,192		215	1.5	-4.6
Double, 4-12-4	R-0.35	8,681	1,600	10,281		13,295		1,192		215	15.6	2.5
Double Low-E, 4-12-4	R-0.52	10,066	1,600	11,666		13,032		1,455		262	18.0	1.0
Double Low-E Argon, 4-12-4	R-0.62	10,613	1,600	12,213		12,464		2,023		365	14.5	-3.3
Insulation, joists at 450 centres		$150m^2$	$150m^2$									
FLOOR TIMBER												
No insulation						10,681						
Sisalation 100mm sag	code R-1.3	279	996	1,275		9,271		1,410		254	5.0	19.3
Sisalation & 4.5 fibre cement sheet	code *1.5	1,334	1,760	3,094		9,168		1,513		273	11.3	6.1
2 x expanded polystyrene foam warmfoot	code R-2.8	2,079	1,494	3,573		8,752		1,929		348	10.3	7.4
WALLS												
No insulation						14,487						
INTERIOR LININGS												
1.8 75mm wall batts	code R-1.5	5,386	195	5,531		13,381		1,106		199	27.8	-2.9
2. 2 94mm ultra wall pink batts	code *1.5	5,811	195	6,006		13,161		1,326		239	25.1	-2.1
3.0 94mm ceiling ultra pink batts	code *2.0	6,313	195	6,508		13,098		1,389		250	26.0	-2.4
WEATHERBOARDS												
10% replacement in weatherboards	code R-1.5	1,642	5,996	7,638		13,381		1,106		199	38.3	-5.5
	code * 1.5	1,752	5,996	7,748		13,161		1,326		239	32.4	-4.2
	code * 2.0	2,617	5,996	8,613		13,098		1,389		250	34.4	-4.7
20% replacement in weatherboards	code R-1.5	2,098	5,996	8,094		13,381		1,106		199	40.6	-6.0
	code * 1.5	2,208	5,996	8,205		13,161		1,326		239	34.3	-4.7
	code * 2.0	3,073	5,996	9,069		13,098		1,389		250	36.2	-5.1
30% replacement in weatherboards	code R-1.5	2,555	5,996	8,551		13,381		1,106		199	42.9	-6.4
	code * 1.5	2,665	5,996	8,661		13,161		1,326		239	36.2	-5.1
	code * 2.0	3,530	5,996	9,526		13,098		1,389		250	38.1	-5.5
CEILING												
1.050mm degraded insulation						14,487						
2.6 110mm ceiling pink batts	code min 1.9	1,082	300	1,382		13,160		1,327		239	5.8	16.5
3.6 155mm ultra ceiling pink batts	code * 1.5	1,533	300	1,833		12,929		1,558		281	6.5	14.3
5.0 190mm ceiling pink batts	code * 2.0	2,517	300	2,817		12,760		1,727		311	9.1	9.1

Material costs: for the night store heater the cylinder size needs to be latger (say 300L instead of the assumed 250L HWC) ***kWh/yr input:*** the LPG instant heat cylinder avoids standing losses of 700kWh/yr
Fuel efficiency: gas fired cylinders are less efficient than electric cylinders due to flue head losses ***IRR:*** the base case for calculating the IRR are: electric HWC, single glazing, no floor insulation and no or 50mm ceiling insulation.

3.2.5 Compact Fluorescent Lights (CFLs)

Potentially one of the simplest ways of saving money is by replacing standard incandescent lights with CFLs. If a high CFL is used with a lifetime of 10,000 hours then a basic calculation shows that at 18c/kWh a CFL lamp will save approximately $100 over the lifetime of the bulb, which is a significant saving.

Wider benefits of using CFLs throughout New Zealand are a reduced winter peak load on the electricity network, which delays the need for new transmission lines, reduces greenhouse gas emissions and waste to landfill given the fact they last 10 times longer than a standard light.

To achieve this level of savings, high quality CFLs must be used with a good power factor (above 0.9) and good harmonics.

Depending on the heating type used, it may be that the theoretical savings from the CFLs are reduced because the heat released by the incandescent bulbs (which makes them inefficient) will need to be replaced by another heating source. If this other source is an electric resistance heater, (which typically is low wattage), it is likely that some of the savings will be taken back in additional heating costs. This will not only reduce the savings for the homeowner but also reduce the peak load savings. However, if another source of fuel is used and particularly if it has high wattage (and by default higher internal temperatures), it is less likely that this take back will occur, as the room will be sufficiently warm.

3.2.6 Greenhouse Gas Emissions

The Kyoto Protocol is an international treaty that is aimed at lowering greenhouse gas emissions to 1990 levels. One of the leading contributors to these emissions on an international level is carbon emissions. By lowering our energy use through insulating our homes to a better level, the carbon emissions are also reduced. The results from lowering the carbon emissions (by location) through insulating all housing stock to standard Building Code level is shown in the tables below.

For the carbon emissions to be “collected” it has to be assumed all the savings of an insulation retrofit will be taken as energy savings and there will be no take back from increased temperatures. So, emissions savings are in direct competition to comfort improvement through temperature increase (and hence health benefits). Therefore it is not possible to claim the carbon savings as calculated below and comfort and health benefits together. Indeed this is also true for the energy savings.

In all regions theoretically more emissions are saved through insulating the floors with underfloor foil than the other insulation retrofits options (i.e. increasing the R-value of the ceiling or insulating the walls). This is based on the number of houses that require that improvement in each region. For the ceiling insulation, the percentage of houses was determined using the BRANZ House Condition Survey (Clark et al, 2006) based on the percentage of houses (compared to total number of houses in the region) that have 50mm or less insulation. The percentage of houses requiring underfloor insulation and wall insulation was estimated to be the number of houses built before 1979.

Table 12. Potential Greenhouse Gas Emissions

Auckland CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
21% of houses with 0-50mm ceiling insulation	3,321,511	905,867	100,319
60% of houses with no wall insulation	7,592,026	2,070,553	1,419,177
60% of houses with no floor insulation	9,926,061	2,707,108	327,021

Wellington CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
32% of houses with 0-50mm ceiling insulation	3,308,163	902,226	52,290
75% of houses with no wall insulation	6,185,260	1,686,889	606,805
74% of houses with no floor insulation	7,709,795	2,124,762	137,962

Christchurch CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
24% of houses with 0-50mm ceiling insulation	3,562,992	971,725	50,745
66% of houses with no wall insulation	6,949,670	1,895,365	563,840
62% of houses with no floor insulation	8,321,912	2,269,612	210,986

Dunedin CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
31% of houses with 0-50mm ceiling insulation	1,697,876	463,057	20,666
85% of houses with no wall insulation	3,305,997	901,636	226,874
83% of houses with no floor insulation	4,113,363	1,121,826	51,067

Rotorua CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
23% of houses with 0-50mm ceiling insulation	262,973	71,720	5,608
66% of houses with no wall insulation	871,266	237,618	79,683
65% of houses with no floor insulation	1,093,501	298,228	18,083

Gisborne CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
29% of houses with 0-50mm ceiling insulation	109,969	29,992	4,312
83% of houses with no wall insulation	363,330	99,090	61,105
81% of houses with no floor insulation	452,649	123,450	13,741

Masterton CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
35% of houses with 0-50mm ceiling insulation	518,892	141,516	10,798
82% of houses with no wall insulation	1,403,591	382,797	125,262
81% of houses with no floor insulation	1,766,636	481,810	28,512

Invercargill CO_2 Annual Emission Savings (kg) with insulation levels lifted to meet the Building Code	Annual CO_2 Emission Savings (kg)	Carbon Emissions Savings (kg)	Cost to Insulate ($000)
30% of houses with 0-50mm ceiling insulation	857,562	233,881	8,928
84% of houses with no wall insulation	2,001,280	545,804	100,085
82% of houses with no floor insulation	2,490,614	679,258	22,522

New Zealand CO_2 emission savings with insulation levels lifted to meet the Building Code	CO_2 emission savings (tonnes)	Carbon emission savings (tonnes)	National GWh/yr savings	Cost to Insulate ($million)	$/tonne CO_2 emission saved per year
25% of houses with 0-50mm ceiling insulation	25,826	7,044	256	480	19,000
67% of houses with no wall insulation	53,619	14,623	797	5,943	111,000
62% of houses with no floor insulation	63,707	17,375	785	1,265	20,000

From the figures provided, large potential savings in greenhouse gas emissions can be achieved, by insulating older houses if no take back occurs. Until a reasonable average temperature level in our homes is reached, evidence from the analysis of actual retrofit programmes clearly shows that low income people at least are more likely to choose comfort over savings, especially over time. Therefore it is likely any savings in greenhouse gas emissions will have to wait until New Zealand houses are warm and comfortable.

3.3 Waste

A significant amount of landfill waste (approximately 35% by weight) comes from the construction of residential buildings. Of this waste, the majority is from the construction of new houses. Hence, renovations (unless significant) do not have much of an impact on the total amount of construction waste.

When renovating, people should consider recycling or reusing any materials or products. Most cities will have metal (or just steel) recycling options for plumbing fixtures and fittings. It is also possible to recycle or on-sell timber frames and doors, bathroom and laundry fittings, floors and larger support beams. Auckland also has concrete crushing facilities although it may not be economic for domestic/residential jobs.

It should be noted that if a substantial programme of retrofitting occurs, as is needed to achieve Beacon's sustainability goals, then construction waste from retrofitting could become a significant part of the waste stream. As part of a sustainable retrofit therefore it is also important to look at minimising ongoing waste. Simple options available for this include:

Organic materials

- Worm farm (cost approximately $45 at local hardware store) that can be used on the garden etc. This is practical for most houses with a small open space.
- Compost bins (cost approximately $60 - $100) for people with a larger area and gardens.

Both of these simple options only require a small change in routine for a household collecting food scraps etc and putting them either in the worm farm or compost bin.

Inorganic materials

Recycling (either curbside or local recycling stations) are set up by local councils or businesses and are available in most larger population areas. They require a commitment from a household to sort their rubbish and recycle where possible.

4 Conclusions

At a national level the following options have a theoretical internal rate of return greater than 5% making them worthwhile implementing from a financial perspective:

- Rainwater tanks (2,000L) for Auckland only, assuming 100% retention
- Low flow shower heads for high pressure systems
- Dual flush toilets
- Low flow taps/flow restrictors
- Water efficient ("AAA") washing machines
- Water heating upgrade (if current water heating tank needs replacing)
  - Solar hot water heating
  - Heat pump hot water heating
  - Instant gas hot water heating
- Floor insulation
- Ceiling insulation

Energy efficiency bundle

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Appendix1 Climate characteristics

NIWA identifies nine distinct climate zones in New Zealand, which include: the northern zone, with a distinctly sub-tropical, maritime influenced climate; the inland South Island zone, which is more continental in character with much greater extremes of heat and cold; and the cool temperate southern New Zealand zone. Using this zonal distinction, Table 13 presents a number of climate parameters for a range of sites throughout the country. The table cells are colour-coded to provide an indicative range of more to less favourable conditions for human comfort and warmth, with the darker blue indicating less favourable conditions.

Table 13 Climate characteristics of a range of sites throughout New Zealand

Location	Climate Zone	Sunshine	Radiation	Temperature				Ground frost	Wind	Gale days	Relative Humidity M-J-J-A (%)	Wet days
		hours	May-June-July-Aug average	Mean °C	M-J-J-A average °C	Very Lowest °C	Diff btwn highest & lowest °C	days	mean speed km/h	mean speed > 63kph		>= 1.0 mm
KAITAIA	Northern NZ	2,070	8.3	15.7	13.0	0.9	29.3	1	15	2	88.2	134
WHANGAREI		1,973	8.3	15.5	12.3	-0.1	30.9	11	16	1	88.1	132
AUCKLAND		2,060	8.2	15.1	11.9	-2.5	33.0	10	17	2	87.5	137
TAURANGA		2,260	8.0	14.5	10.8	-5.3	39.0	42	16	5	84.0	111
HAMILTON	Central NI	2,009	7.4	13.7	9.9	-9.9	44.6	63	12	2	89.5	129
ROTORUA		2,117	7.6	12.8	8.8	-5.2	36.7	57	13	1	84.9	117
TAUPO		1,965	na	11.9	7.9	-6.3	39.3	69	13	2	86.9	116
GISBORNE	Eastern NI	2,180	7.8	14.3	10.4	-5.3	43.4	33	15	2	79.9	110
NAPIER		2,188	7.6	14.5	10.3	-3.9	39.7	29	14	3	79.3	91
MASTERTON,		1,915	6.7	12.7	8.6	-6.9	42.1	60	11	1	80.7	130
NEW PLYMOUTH	South-West NI	2,182	7.5	13.7	10.5	-2.4	32.7	15	20	5	84.1	138
WANGANUI		2,043	7.5	14.0	10.5	-2.3	34.6	7	18	5	84.4	115
PALMERSTON NORTH		1,733	6.6	13.3	9.6	-6.0	39.0	38	17	3	86.9	121
WELLINGTON		2,065	6.3	12.8	9.8	-1.9	33.0	10	22	22	86.1	123
NELSON	Northern SI	2,405	7.1	12.6	8.2	-6.6	42.9	88	12	2	82.7	94
BLENHEIM		2,409	7.2	12.9	8.6	-8.8	44.8	60	13	4	82.1	76
WESTPORT	Western SI	1,838	6.3	12.6	9.5	-3.5	33.9	26	11	2	85.2	169
HOKITIKA		1,860	5.8	11.7	8.4	-3.4	33.4	54	11	2	86.6	171
KAIKOURA	Eastern SI	2,090	6.9	12.4	9.0	-0.6	32.1	27	15	28	70.6	86
CHRISTCHURCH		2,100	5.9	12.1	7.7	-7.1	48.7	70	15	3	86.6	85
TIMARU		1,826	6.7	11.2	6.8	-6.8	44.0	84	12	6	84.0	81
LAKE TEKAPO	Inland SI	2,180	na	8.8	3.4	-15.6	48.9	149	7	1	82.4	78
QUEENSTOWN		1,921	6.3	10.7	5.5	-8.4	42.5	107	12	2	82.5	100
ALEXANDRA		2,025	5.7	10.8	4.6	-11.7	48.9	148	6	3	88.3	66
DUNEDIN	Southern NZ	,1585	4.9	11.0	7.6	-8.0	43.7	58	15	8	79.1	124
INVERCARGILL		1,614	4.9	9.9	6.3	-9.0	41.2	94	18	18	88.1	158

More favourable … Less favourable

Appendix 2 Insulation Status of the Housing Stock

Total housing stock

The latest estimates from Statistics New Zealand indicate 1.55 million households existed in New Zealand at the end of 2005, although not necessarily all were occupied[3]. An estimate from Quotable Value suggested a total of 1.36 million in 2004 (Table 14). In this review a total of 1.4 million occupied houses in 2005 has been used.

Based on Table 14, 75% of houses are in the North Island and 25% in the South Island. About 0.55 million are in the warmest climate zone of the country (northern New Zealand).

In 1991, 74% of homes were owner occupied. By 2005 this had dropped to less than 68% (i.e. approximately 0.95 million owner occupier households, and some 0.45 million rented or rent-free).

Table 14. Number of pre 1980 houses (as proxy to those built prior to insulation requirements)

Region	Pre-1980	Total	% pre-1980
Northland	28,558	49,898	57%
Auckland	237,883	401,800	59%
Waikato	84,140	139,814	60%
Bay of Plenty	47,497	90,639	52%
Gisborne	11,276	13,964	81%
Hawkes Bay	35,954	48,588	74%
Taranaki	26,200	34,681	76%
Manawatu-Wanganui	58,581	78,001	75%
Wellington	116,365	157,079	74%
NORTH ISLAND	646,454	1,014,464	64%
Tasman/Nelson/Marlborough	26,872	46,726	58%
West Coast	7,911	10,110	78%
Canterbury	129,389	194,818	66%
Otago	45,805	64,257	71%
Southland	27,737	33,723	82%
SOUTH ISLAND	237,776	349,765	68%
NEW ZEALAND TOTAL	884,230	1,364,229	65%

Source: From Quotable Value NZ (information provided by EECA)

Approximately 0.9 million houses were built prior to 1978 when insulation became mandatory on new houses. The breakdown in Table 14 shows the range in pre-1980 houses according to areas of the country. Those areas experiencing more rapid population growth over the last two

3 http://www.stats.govt.nz/NR/rdonlyres/7D17BB1B-2BFF-40E3-91DC-C358D1DCE882/0/EstimatedHouseholdsandPrivateDwellingsbyTenure.xls

decades tend to have higher proportions of new houses (e.g. Auckland, Bay of Plenty, and sub-regional areas such as Queenstown); conversely, areas without much population change tend to have much higher proportions of pre-1978 houses (e.g. Southland, and sub-regional areas including Dunedin and Timaru).

Insulation information

No single study exists which provides an accurate picture of the insulation status of houses in New Zealand. A number of studies each provide a partial picture, and these have been used to provide a composite picture of the current insulation status of houses.

Warm Homes Survey 2004/05 (Ministry for the Environment)

In 2004/05 the Ministry for the Environment commissioned a large telephone survey of household heating practices (Wilton, 2005). The survey covered about 150 households in each of the 29 urban areas throughout the country that have been assessed as having domestic air pollution problems. Included in the questionnaire were questions on levels of insulation in the home. The survey results for a number of the urban areas are presented in Table 15.

Table 15 Percentage of houses with insulation – Warm Homes Survey (Wilton, 2005)

Location	Ceiling	Floor	Walls	Double glazing	Cylinder wrap	None
	% of households*					
Auckland	62	18	48	8	21	25
Hamilton	82	22	60	10	19	13
Rotorua	78	20	51	12	20	12
Napier	72	22	47	3	22	16
Gisborne	74	15	46	6	22	15
Te Kuiti	76	18	51	3	20	20
Masterton	80	21	58	4	20	18
Upper Hutt	86	21	60	7	21	8
Nelson	79	27	60	10	25	12
Blenheim	87	21	64	15	23	6
Westport	81	15	55	6	23	12
Timaru	83	18	47	9	21	12
Dunedin	70	23	33	10	18	21
Alexandra	88	28	67	14	28	5
Invercargill	81	13	44	10	18	12

* Households indicating “don’t know” were eliminated with all percentages in the table above adjusted upwards by the percentage of “don’t knows”.

This appears to be a valuable data source, but there are some important qualifiers about the veracity of the information. One difficulty is that there may be some sampling bias due to the small sample in each urban area[4]. A second, and perhaps more significant issue, is the lack of knowledge of the respondents. For example, when the Christchurch sub-sample was subjected to cross-checking it was found that the inaccuracy of responses from tenants within the sample was over 50% (Fyfe and McChesney, 2006). There are likely to be levels of error in the other sub-samples as well (e.g. the levels of ceiling insulation reported above for Auckland appear to be lower than expected (see the House Condition Survey below).

Hence it is concluded that the survey has most value as an indicative comparative guide, showing for instance:

- Generally less insulation in houses in warmer areas e.g. Auckland/Gisborne/Napier compared with most South Island areas
- Higher levels of ceiling and wall insulation (and low percentage of houses with no insulation) where there are higher proportions of new (post-1978) houses e.g. Blenheim, Alexandra (note also Table 14 for areas with high proportions of new houses).
- Some places stand out for a combination of reasons e.g. Dunedin, with relatively low levels of insulation despite the cold climate. The main reasons appear to be the relatively low level of new house building in the last two decades and thus a high proportion of pre-1980 houses (>80%), and high level of rental properties (university flats).

House Condition Survey 2005

BRANZ's House Condition Survey 2005 provides detailed, and measured insulation parameters for a sample of 400 houses in Auckland, Wellington and Christchurch as part of a much wider assessment of overall house condition (Clark et al, 2005). The important qualifier of this survey is that the survey is confined to owner-occupier homes—rental properties were not part of the sample of houses surveyed[5]. Also it is a small survey sample with only three centres included, and aggregated results are not weighted according to overall population distribution.

The series of three tables below sets out insulation details by coverage of ceiling insulation in pre-1980s houses (Table 16), thickness of ceiling insulation for all insulated homes (Table 17), and extent of other forms of insulation recorded (Table 18). In comparison with the Warm Homes Survey, the findings are reasonably similar except that the House Condition Survey indicated lower levels of wall insulation overall.

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[4] ***For example, in the Christchurch sub-sample 43% were rental properties, compared with about 31% in the Christchurch population as a whole.***

[5] ***The importance, as related to insulation, is that the incentives on rental property owners to invest in insulation are generally not strong; hence insulation levels in owner-occupied homes are likely to be higher overall.***

Table 16 Ceiling insulation coverage in pre-1980 houses (owner-occupier) (% of households)

	100% cover	50-100%	Sub-total 50% or more	<50%	None	Sub-total 50% or less
Auckland	70	10	80	6	14	20
Wellington	52	33	85	3	12	15
Christchurch	91	4	94	3	3	6

Table 17 Ceiling insulation thickness – all houses with insulation (owner-occupier)

Thickness	% of houses	Approx R value
50mm or less	28	R1.0
75mm	45	R1.5-1.8
100mm	24	R2.0-2.2
150mm and over	3	R3.6

Table 18 Wall, floor and window insulation – House Condition Survey 2005

	% with insulation*	% without	Comment
Walls	44	56	30% of the sample comprised post-1978 houses, so the implied overall percentage of pre-1978 houses with wall insulation is 20%
Floors	30	70	Percentages only apply to houses where the sub-floor was accessible (i.e. excludes houses with concrete slab on ground)
Double glazing			Large percentage increases since the 1999 survey for Christchurch – the evidence is that most is occurring in new-builds, and only a small amount as retrofits
Auckland	<1	99	
Wellington	3	97	
Christchurch	13	87	

* Also includes partial insulation (e.g. over 50%)

Conclusions

The various surveys present some coherency and consistency, although there are still some data gaps or inconsistencies. Nevertheless, the following conclusions about the current numbers of houses still lacking insulation measures seem reasonably robust. Throughout the country, it is estimated that:

- Some 200,000 houses either have no ceiling insulation at all or insulation is installed in less than half of the available ceiling space
- About 300,000 houses (mainly pre-1978 but includes some post-1978) have a very inadequate thickness of ceiling insulation (R1.2 or less)
- Some 700,000 houses have no, or very little, wall insulation
- Some 500,000 houses have no underfloor insulation (in situations where insulation is able to be fitted).

Appendix 3 Residential energy use

This appendix sets out a breakdown of total residential energy use, and a further analysis of the space heating component. This is the aspect of energy use most influenced by thermal efficiency retrofits.

Total Energy

A breakdown of total residential energy use is presented in Table 19. Unfortunately, at present there does not appear to be a robust, definitive breakdown available from existing sources. So the analysis presented here is a composite based mainly on national-level data from the Energy Data File with some adjustments to the total wood energy used based on HEEP[6], and breakdowns into energy end-use categories also based largely on HEEP.

Based on the heating season characteristics reported by Isaacs et al (2005) and Wilton (2005), Figure 1 has been derived to show the monthly pattern of residential energy use.

Table 19 Estimated energy use in residential buildings 2004 (PJ)

	Coal	Oil	Gas	Geo-thermal	Solar	Wood	Electricity	TOTAL	% of total
Space heating/cooling	0.7	2.2	3.4	0.3		7.7	10	24.3	36%
Hot water	0.2		2.8		0.2	0.8	14.3	18.3	27%
Cooking			0.5			0.1	4.1	4.6	7%
Lighting							5.9	5.9	9%
Appliances/electronics							13.4	13.4	20%
TOTAL	0.9	2.2	6.7	0.3	0.2	8.7	47.7	66.6	100%

Sources: Synthesised estimates derived primarily from the Energy Data File, January 2005, Ministry of Economic Development; HEEP Year 9 Report, BRANZ; also EECA End-use database (see: http://www.eeca.govt.nz/enduse/endusesearchresults.aspx?type=E).

[6] The HEEP Year 9 Report (Isaacs et al, 2005) provides a detailed analysis of the energy used by solid fuel heating appliances in houses covered by the HEEP study. They found average energy use per appliance to be as follows: 1,000kWh for open fires, 1,600kWh for pot belly stoves, and 4,600kWh for enclosed burners. Based on these findings the authors noted that national level estimates of wood use (from the Energy Data File) may be only about one third of the actual level of energy use.

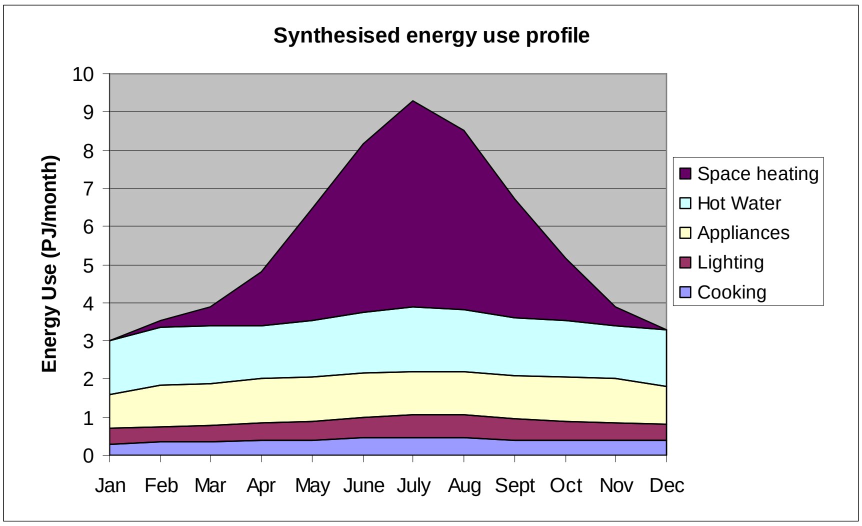

Figure 1 Estimated energy use profile by month (Source: composite based on this study)

Space heating

This analysis suggests that about 24PJ of energy is used annually nationwide for space heating. This is the equivalent of about 4,700kWh/house-year (gross) – when appliance efficiency is accounted for the effective heating is likely to be nearer an average of 3,800kWh/house/year (net). As indicated in Figure 1 the pattern of energy use is highly seasonal with the peak energy use occurring during July.

The overall average cost of energy supplied for space heating is estimated to be about 10c/kWh, and the overall average cost per effective unit of heating about 12c/kWh. This number is based on a weighted average of all fuel types and heater efficiencies, i.e. the costs of delivered energy and appliance efficiency for specific types of heating appliance (Table 20). The table indicates a range of heating options in a cost band of 7-10c/kWh, but these typically require a significant capital investment in the heating appliance (e.g. wood burner, pellet burner, heat pump). Heater running costs using low capital cost appliances is typically 20c/kWh or greater.

It is important to remember that "self-collected" wood plays an important role in the heating energy budget of many homes (Wilton, 2005).

Table 20 Energy costs of heating 2005

Heating Source	Appliance type	Delivered cost (c/kWh)	Efficiency of use (%)	Cost per effective unit of heating (c/kWh)
Electricity	Resistance – instantaneous	18-21	100	18-21
	Resistance – storage	10	100	10
	Heat pump	18-21	220-300	7-9
Wood – commercial	Open fire	4-8	10-15	27-54
	Enclosed burner	4-8	55-75	5-10
Wood – self collected	Open fire and/or enclosed burner	?	As above	?
Coal	Open fire	5	10-15	37-55
	Multi-fuel burner	5	55-75	7-10
Wood pellets	Enclosed pellet burner	6-8	75-92	7-9
LPG Gas	Unflued portable heater	18	80-90	20-22
	In-place flued heater	18	60-85	14-21
Natural gas	In place flued heater	9-12	60-85	12-17
	Central heating	9	90	10
Diesel	Convection/ central heater	8	65-80	9-13

Source: Based on Strategic Energy and EnergyConsult (2005)