TE106/19

Cost benefits of sustainable housing retrofits

Final

A report prepared for Beacon Pathway Limited
April 2009

Note: This work was commissioned as part of Beacon's quest to identify the value in renovation to improve house performance. The benefits are wide ranging (e.g. financial, health, comfort) and fall to many players (e.g. occupants, industry, councils, central government and the environment). The cost benefit analysis makes the financial benefits (to a range of players) explicit: this is an important, but not the sole, contribution to our knowledge base around why renovation for performance is a valuable activity for New Zealanders. Readers are encouraged to read other aspects of Beacon's research on the website for further evidence of the benefits: interviews with occupants of the Waitakere NOW Home and Papakowhai Renovation homes, submissions to central government agencies and local bodies, and the National Value Case.

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FOUNDATION FOR RESEARCH SCIENCE & TECHNOLOGY
Tūāpapa Rangahau Pūtaiao

About This Report

Title
Cost benefits of sustainable housing retrofits

Authors
Ian Page, BRANZ

Reviewer
John Burgess, BRANZ

Abstract
This report considers the cost benefits of a variety of sustainable retrofits for the existing housing stock. The retrofits interventions costed are mainly energy and water related, and values are calculated for the four main centres and 11 house/ multiunit typologies. Health and comfort benefits are considered and the costs include initial costs of the measures and their replacements. Future operating costs are discounted and the results are expressed as net present values and benefit cost ratios. Typologies and locations are scaled up to derive national benefits. A spreadsheet model is provided on which users can change parameters and try various packages of measures.

Reference
Author/s. April 2009. Cost benefits of sustainable housing retrofits. Report TE106/19 for Beacon Pathway Limited.

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1 Executive Summary

This report presents the results from the development of a cost benefit model. Using this model, a range of retrofit efficiency measures for New Zealand houses were assessed by cohort for their cost effectiveness. Most of the measures were found to have net benefits in all four centres, i.e. Auckland, Wellington, Christchurch and Invercargill. All the measures in the Basic and Standard packages were cost-effective. In the Enhanced package, wall insulation retrofit was cost-effective but the other measures were either not cost-effective (rainwater tanks, hot water heat pump), or were cost-effective only in the cooler parts of the country (curtains, secondary glazing).

The net benefits for different housing cohorts varied by house cohort and location, and these were scaled up for the total housing stock to give total benefits of about $22 billion in net present value (NPV) terms, assuming retrofit of the total stock over the next 15 years. The investment required is about $12 billion in present $ and the benefit cost ratio (BCR) is approximately 2.8.

Sensitivity of the results to the assumptions was examined for a number of parameters and showed no significant areas of concern.

The spreadsheet model was designed to enable Beacon to select different packages of measures and derive the initial cost total, energy and water volumes saved, and the NPV and BCRs per house, by location, for any selection of measures.

2 Introduction

Beacon Pathway's goal is to improve the sustainability of New Zealand houses and a major part of this is to upgrade the existing stock with a range of sustainability measures. An integral part of sustainability is the economic performance of the measures and the purpose of this project was to calculate net benefits for various retrofit measures in the different housing types, in four main centres and to scale these up for national benefits.

The measures included improvements to the thermal envelope, water efficiency and conservation, heating appliances, indoor moisture control, and lighting. The benefits considered were energy and water savings, and savings from cheaper fuel types. Reduced maintenance from moisture control was included. Improved comfort and health benefits due to increased indoor temperatures were also considered.

The results from a set of Papakowhai houses, monitored before and after retrofit, were incorporated in the modelling. A variety of other studies on water use and efficiency, health benefits, and thermal modelling, were used to estimate the savings from various measures[1].

[1] ***A set of Papakowhai houses were monitored both before and after retrofits, and are the subject of a series of reports, including Burgess (2009). Other Beacon Pathway reports consulted include Heine (2006), McChesney et al. (2008), Lawton et al. (2007) and Lawton et al. (2008).***

3 Method

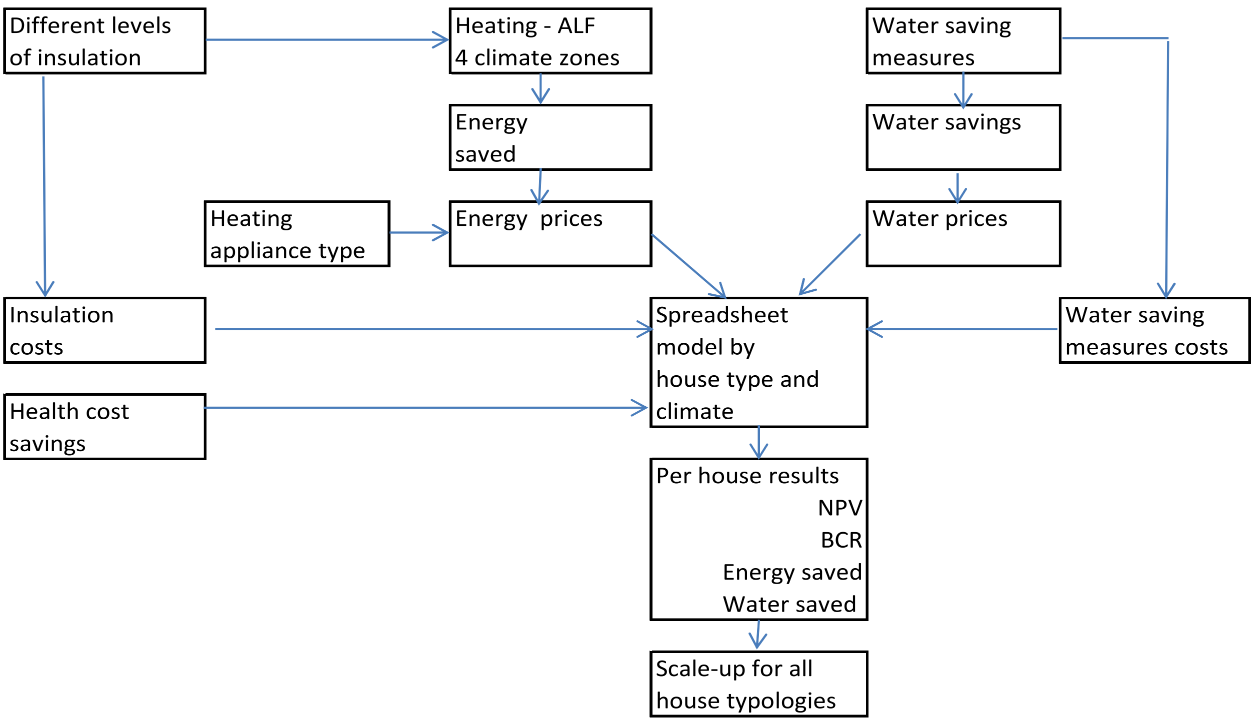
The present value method was used to assess the relative merits of various packages of efficiency measures. The model is shown in Figure 1. A fuller description of the present value method is in the appendix.

The model is a spreadsheet which enables users to vary:

- Heating regime (18°C and 16°C morning/ evening heating)
- Location (Auckland, Wellington, Christchurch and Invercargill).
- House typology (11 Beacon typologies available).
- Energy take-back percentage
- Financial parameters (discount rate, analysis period, energy price escalation rates).

The model gives the results for each house typology by city. This process was automated (using macros) to give national results (initial cost, energy and/or water saved, NPV and BCR) for each typology and city.

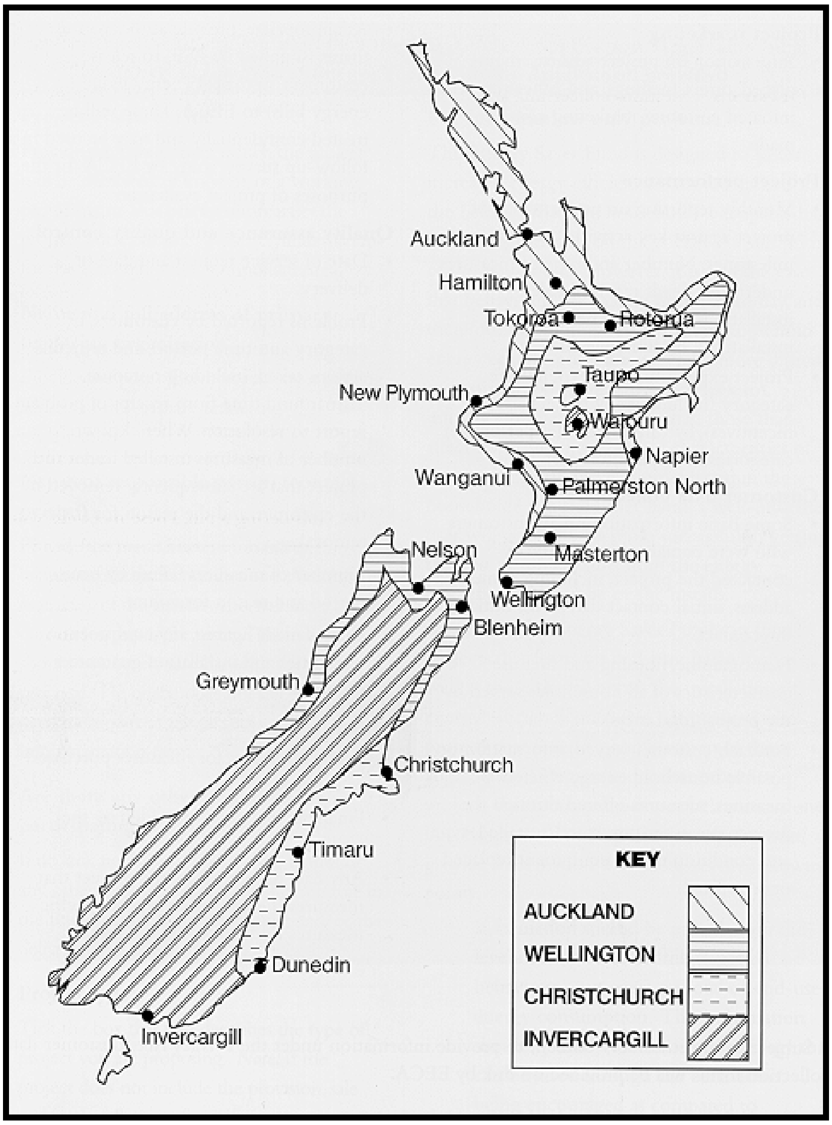
Figure 1: CBA model schematic



A considerable proportion of the project was in developing the spreadsheet model, which has been provided separately, and its use is described further in the Appendix.

It uses energy savings as modelled heating requirements using ALF, for the four main centres using an EECA map of New Zealand which identifies each city in one of four different degree day zones (see Figure 2).

Figure 2: Map for Climate Zones to drive ALF based calculations of heating requirements



To scale up total energy use and costs, it was assumed all housing could be put into one of these four zones. Energy and water costs were included on a four regions basis: electricity (by 4 cities), gas (North/South Island), water (by 4 cities). Solid fuel and pellets were costed on a national basis. Health cost savings are nationally-based, drawing from the Wellington School of Medicine work[2] (See Appendix). The costs of interventions, e.g. insulation or heating renovations, were derived from a variety of sources, but included in the model as national figures.

[2] ***Chapman et al (2005)***

4 Results

4.1 Base case

The benefit cost ratios of common retrofit measures are shown in Figure 3 and Figure 4. The benefits are the energy and water discounted cost savings due to retrofit. The costs are the initial cost of the retrofit measures and the discounted costs of any replacements.

The base case parameters are:

- Heating regime 18°C, morning and evening, whole house.
- Take-back factor for space heating 30%.
- Fuel type is electricity.
- Heating appliance is electric resistance heaters.
- 5% discount rate
- 30 year analysis period
- Fuel price escalation is 3% pa above general inflation.

These parameters were chosen for the following reasons:

- The World Health Organisation (1987) recommends a minimum temperature of 18°C in living areas, and 16°C in bedrooms. Beacon's HSS High Standard of Sustainability® (HSS®) sets its indoor environment quality benchmarks to these standards. ALF modelling provides for whole house heating so 18°C whole house for part of the day was used as an approximation to the WHO recommendations.

- A discussion on takeback is included in 4.3.2, where 30% was considered a reasonable percentage for the stock on average. However, different households and house cohorts will vary.

- The HEEP year 10 report found electricity was the most common main fuel type for space heating (Table 23, HEEP), at 43%, followed by LPG (31%), gas (16%), and solid fuel 10%. So electricity was used as the default. However it is noted that houses with a solid fuel heater were 1.5°C warmer than electrically-heated houses in the HEEP study.

- In sustainability studies, a discount rate of 5% is commonly used, for example, cost benefit studies for changes to insulation levels in buildings used 5%[3]. New building structures, including insulation, need to last a minimum of 50 years, according to the NZ Building Code, and this could be used as the analysis period. However, retrofitted houses may fail before 50 years and there is considerable uncertainty about energy prices in the long term. Also, discounted costs don't change much after 30 years. So an analysis period of 30 years was considered reasonable.

[3] ***Page and Stoecklein (2006)***

- The escalation in fuel prices is discussed later in 8.8, and a 3% per annum increase, above the rate of general inflation, was considered to be reasonable.

The results shown in the charts are for 1940s-60s mass housing only, but similar BCRs (i.e. within 0.2 BCR) are found for all other house types before 1979. Post-1978 houses have mandatory insulation and the BCRs are lower for extra insulation. The 1940s-60s group was selected as it is the largest cohort of houses, whereas results for any cohort can be calculated with the model.

Retrofitting ceiling insulation where none previously existed is worthwhile in all locations, i.e. the BCR is over 1.0. Similarly, retrofitting floor insulation is worthwhile in all locations. If some ceiling insulation already exists then topping up is economic (i.e. the BCR needs to be over 1.0) in all centres except Auckland. Similarly, wall retrofit insulation is economic (BCR>1) in all centres bar Auckland. Note that the costs for wall insulation include relining and insulation, but painting and replacing the trim is omitted because it is assumed the retrofit is carried out at a time the owner has already decided to decorate the interior. Retrofit of double glazing and installing secondary glazing panels are not economic, except in Invercargill.

In Figure 4 draught proofing is economic, solar water heating is barely economic, and other measures are not economic in most cases. Solar hot water and rainwater tank economics depend on the assumptions regarding solar installation optimisation and shadow water pricing, see the appendix.

In Figure 3 and Figure 4 the value of increased comfort due to take-back is not included. If the value of increased temperatures is considered then the BCRs increase. This is done by assuming the value on the increased comfort is equal to the value of energy savings foregone. In that case the BCRs are increased by 0.3/(1-0.3) or 43%. Wall retrofits become economic in Auckland, and double and secondary glazing is economic in Wellington and Christchurch.

In general, all results depend on a wide variety of other assumptions on take-back, fuel types, discount rates, initial costs, etc. The sensitivity analysis is discussed later, but in the following discussion the base case assumptions above are used.

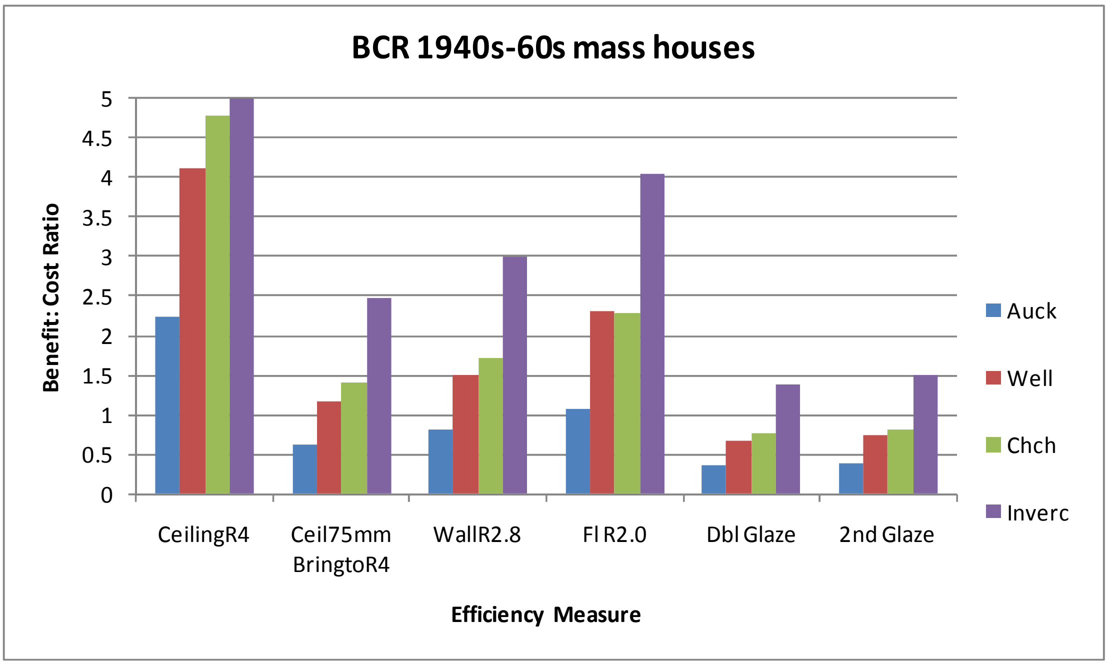


Figure 3: Benefit cost ratios for typical measures

In Figure 3 CeilingR4 is from nil ceiling insulation to R4 insulation, Ceil75mm is pre-existing insulation assumed to still be at 75mm thickness and well fitted, and insulation is added to bring it to R4. (In fact it may have settled, and have been poorly fitted in the first place, in which case the energy savings with added insulation will be larger than assumed). The wall has zero insulation and R2.8 is added, and the timber floor has zero insulation or foil, and R2.0 is added. In Figure 4 the heat transfer systems are simple duct and fan systems that take air from areas with a large amount of heating, i.e. living rooms with solid fuel heaters, and deliver it to otherwise unheated rooms. They are not the more complex DVS or HRV type systems.

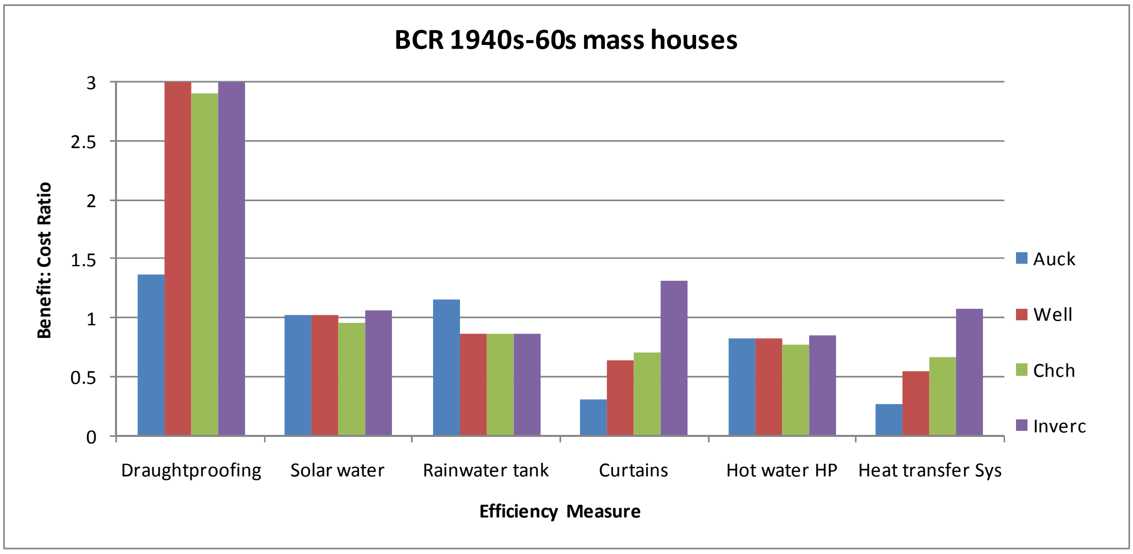


Figure 4: Benefit cost ratios for typical measures (continued).

The next sets of analyses are for three packages of measures suggested by Beacon. The first is the Basic package of low cost measures, with a total cost of about $1,700:

Table 1: Basic low cost measures

Measure	Cost
HWC thermostat adjustment/ replacement	$60
Dual flush cistern	$120
HWC wrap	$70
Pipe lagging	$20
Low flow shower head	$130
Flow restrictors on cold taps in the kitchen and bathroom	$60
Ground polythene	$520
Extractor fans for the kitchen and bathroom	$500
Clothes dryer vent and ducting	$70
Efficient light bulbs	$30
Kitchen waste bin	$120
TOTAL	$1,700

The results are in Figure 5 showing the net present value (NPV) for a typical house in the 1940s to 60s group. The NPV is similar for the other house typologies. All the measures add to the net benefit and the largest contributor is the low flow shower head, followed by the thermostat adjustment/ replacement.

The next package of measures is the Standard package, which includes the Basic package plus ceiling insulation, floor insulation and a wood burner, see Table 2.

Table 2: Standard package of measures

Measure	Cost
Basic package	*$1,700+*
Ceiling insulation	$2,100
Underfloor insulation	$2,100
Wood Burner	$2,500
TOTAL	$8,400

The NPV results for the Standard package are in Figure 6, and assume heating to 18 degrees, 30% take back and 3% pa electricity price escalation. The chart shows that the ceiling insulation and the wood burner add significantly to the net benefit. The burner contribution is high because the fuel energy cost savings (wood compared to electricity) is large and more than offsets the cost of the burner. The effect of takeback is expressed as an increase in comfort levels (indoor temperatures). This increased comfort has been valued at the value of the energy savings foregone with insulation retrofit. In effect this means the NPV analysis is the same as zero take-back and nil change in comfort.

Figure 5: NPV contributions by measure – Basic Package

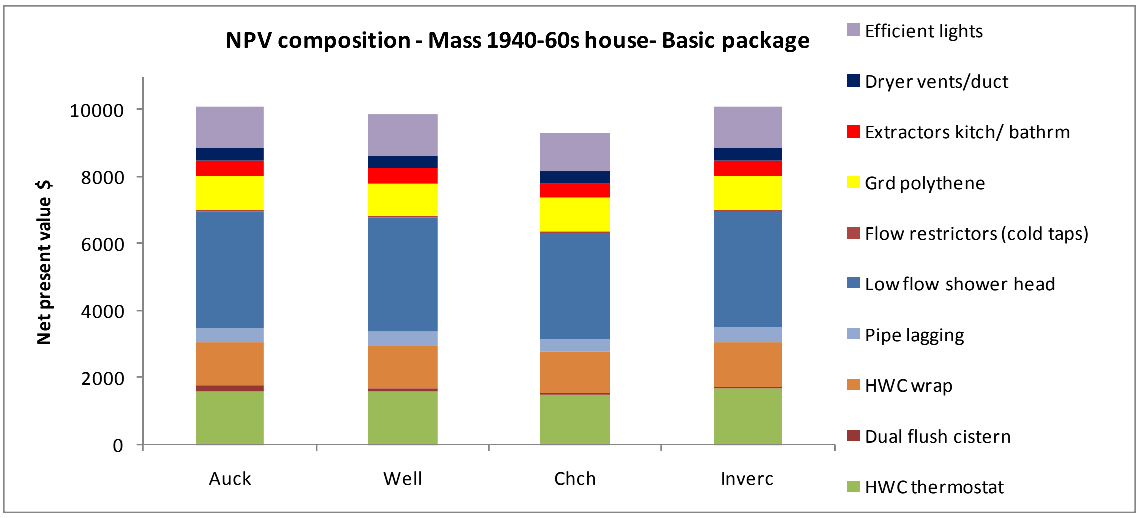
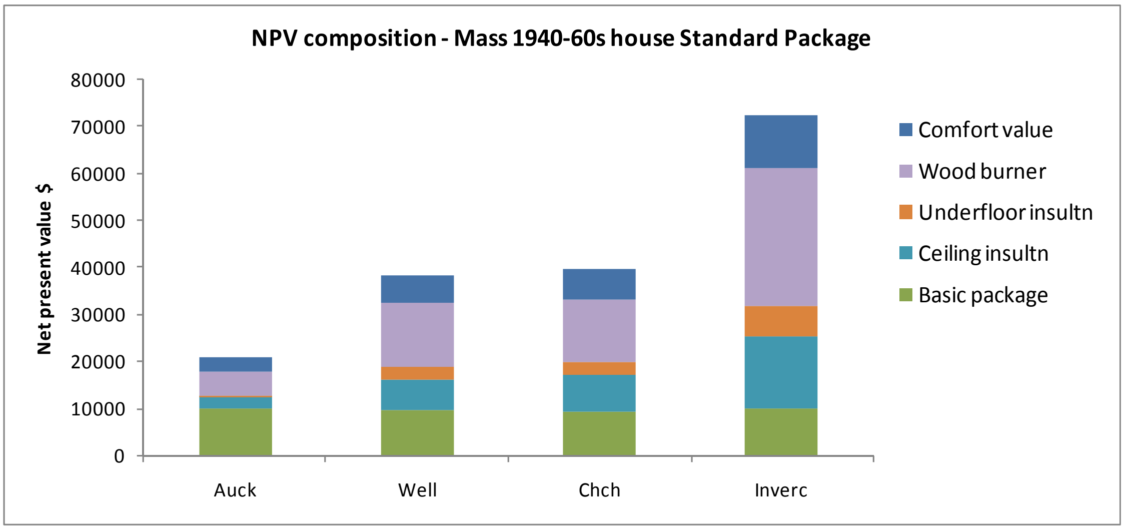


Figure 6: NPV contributions by measure – Standard Package



The third package is the Enhanced package of measures.

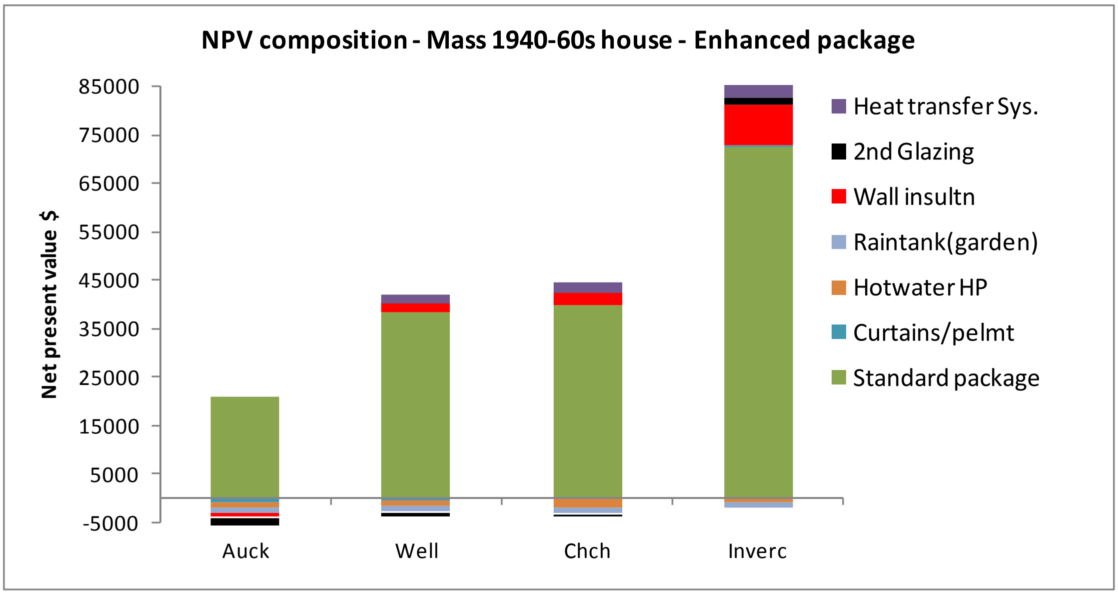
Table 3: Enhanced package of measures

Measure	Cost
Standard package	*$8,400+*
Curtains	$1,000
Pelmets	$120
Hot water heat pump	$5,000
Rainwater tank for garden use only	$1,000
Wall insulation	$4,100
Secondary glazing	$3,400
Heat transfer system	$1,000
TOTAL	$24,020

The Enhanced package results for a typical 1940s-60s house is shown in Figure 7 The new measures, additional to those in the Standard package, do not add much to the NPV and for most cases these additional measures actually subtract from the NPV. Wall insulation and heat transfer systems outside Auckland are positive and secondary glazing in Invercargill is also positive, otherwise the additional measures reduce the NPV carried through from the Standard package.

Health cost savings have not been included in any of the NPV charts, as it is assumed these health effects are minor at 18°C, compared to lower temperatures which are modelled later.

Figure 7: NPV contributions by measure – Enhanced Package



All the interventions are summarised in the two tables below. Table 4shows the benefit cost ratios, and Table 5shows the net present values. The majority of the measures are cost effective and those that are not are shaded red in the tables. Note; unlike the charts above the two tables below assume zero energy take-back. The reason for this is that the value of comfort has been identified separately in the earlier analysis (Figure 6), and take-back needs to be applied to each efficiency measure to avoid double counting. However in Table 4 and Table 5 there is zero take-back which means that if any take-back occurs in practice then we are allocating the comfort benefit directly to each efficiency measure.

The benefit cost ratio is calculated by the value of benefits (i.e. the discounted value of energy or water saved) divided by the cost of the efficiency measure (included the discounted cost of any replacements), see the appendix. The net present value is the benefits minus the costs. For the various heating appliances (heat pumps, solid fuel heater, and gas heater) the benefits include lower energy costs compared to normal rate electricity charges. The heat transfer systems are difficult to evaluate and it was arbitrarily assumed that there was 10% saving on space heating energy costs due to transfer systems. This is an approximation and more work is needed on the cost-benefits of these systems.

Table 4: Benefit cost ratios for all measures by city and house cohort

BENEFIT-COST RATIOS

18DegC heating. Period= 30yrs Disct rt=5%, Energy takeback=0%, Energy price escal=3%

Location		R4 ceiling none existing	Add R2.8 R1.5 existing	Wall R2.8 replace cladding	Wall R2.8 replace linings	Timber floor R2.0 polyst	Draught proofing	Doub glaze exist alum frame	Secondary glazing	Curtains	Wood burner	Heat pump	Heat transfer sys.
Villas	A	3.3	0.9	0.2	0.6	1.6	2.5	0.5	0.6	0.6	2.4	2.3	1.4
	W	6.2	1.7	0.4	1.1	3.5	8.2	1.0	1.1	1.2	5.3	4.9	3.0
	C	7.2	2.1	0.5	1.3	3.4	5.4	1.1	1.2	1.3	5.1	5.3	3.2
	I	12.6	3.7	0.9	2.3	6.1	9.5	2.0	2.2	2.4	9.4	9.9	5.6
20s Bungalows	A	3.3	0.9	0.2	0.6	1.6	2.4	0.5	0.6	0.5	2.4	2.2	1.4
	W	6.2	1.7	0.4	1.1	3.5	7.7	1.0	1.1	1.1	5.2	4.7	2.9
	C	7.2	2.1	0.5	1.3	3.4	5.0	1.1	1.2	1.2	5.0	5.2	3.1
	I	12.6	3.7	0.9	2.3	6.1	8.9	2.0	2.2	2.3	9.2	9.6	5.5
ArtDeco	A	3.2	0.9	0.2	0.6	1.5	2.2	0.5	0.5	0.5	2.3	2.1	1.3
	W	5.9	1.7	0.5	1.2	3.3	7.0	1.0	1.0	1.0	5.0	4.6	2.7
	C	6.8	2.0	0.5	1.4	3.3	4.6	1.1	1.2	1.1	4.8	5.0	2.9
	I	12.0	3.5	0.9	2.4	5.8	8.2	2.0	2.1	2.1	8.9	9.3	5.2
Mass40s-60s	A	3.2	0.9	0.3	0.7	1.5	2.0	0.5	0.5	0.4	2.2	2.0	1.3
	W	5.9	1.7	0.5	1.4	3.3	6.3	1.0	1.0	0.9	4.9	4.4	2.7
	C	6.8	2.0	0.6	1.6	3.3	4.2	1.1	1.2	1.0	4.7	4.8	2.9
	I	12.0	3.5	1.1	2.8	5.8	7.3	2.0	2.1	1.9	8.5	8.9	5.1
Multiunit60s-70s	A	3.2	0.9	0.4	1.1	1.5	1.5	0.4	0.5	0.5	1.6	1.4	1.0
	W	5.9	1.7	0.8	2.1	3.3	4.9	0.8	0.9	1.0	3.3	3.0	2.1
	C	6.8	2.0	0.9	2.4	3.3	3.2	1.0	1.0	1.1	3.4	3.3	2.3
	I	12.0	3.5	1.6	4.2	5.8	5.6	1.7	1.9	2.0	6.6	5.9	4.1
House 1970-78	A	3.2	0.9	0.3	0.7	1.5	na	0.5	0.5	0.5	2.4	2.2	1.4
	W	5.9	1.7	0.5	1.4	3.3	na	1.0	1.0	1.1	5.2	4.8	2.8
	C	6.8	2.0	0.6	1.6	3.3	na	1.1	1.2	1.2	5.0	5.3	3.0
	I	12.0	3.5	1.1	na	5.8	na	2.0	2.1	2.3	9.2	9.7	5.4
House 1979-80s	A	0.6	0.9	na	na	0.6	na	0.5	0.6	0.5	2.5	2.3	0.9
	W	1.0	1.7	na	na	1.2	na	0.9	1.1	1.2	5.2	4.7	1.8
	C	1.3	2.0	na	na	1.4	na	1.2	1.5	1.3	5.0	5.3	2.0
	I	2.2	3.5	na	na	2.4	na	2.1	2.6	2.4	8.9	9.7	3.6
House90-96	A	0.6	0.9	na	na	0.7	na	0.5	0.6	0.6	2.3	2.2	0.9
	W	1.0	1.7	na	na	1.2	na	0.9	1.1	1.2	5.0	4.7	1.8
	C	1.3	2.0	na	na	1.4	na	1.2	1.5	1.3	4.8	5.3	2.1
	I	2.2	3.5	na	na	2.4	na	2.1	2.6	2.4	9.1	9.9	3.7
Multiunits1980-96	A	0.6	0.9	na	na	0.5	na	0.4	0.5	0.6	1.5	1.4	0.7
	W	1.0	1.7	na	na	0.9	na	0.8	0.9	1.3	3.1	3.0	1.3
	C	1.3	2.0	na	na	1.0	na	1.0	1.0	1.4	3.2	3.4	1.5
	I	2.2	3.5	na	na	1.8	na	1.7	1.9	2.6	6.4	6.1	2.7
House Post96	A	na	na	na	na	0.7	na	0.5	0.6	0.6	2.1	2.1	0.6
	W	na	na	na	na	1.3	na	0.9	1.1	1.3	4.7	4.5	1.2
	C	na	na	na	na	1.5	na	1.2	1.5	1.5	4.4	5.1	1.4
	I	na	na	na	na	2.5	na	2.1	2.6	2.7	8.5	9.5	2.5
Multiunits Post96	A	na	na	na	na	0.5	na	0.4	0.5	0.7	1.4	1.5	0.5
	W	na	na	na	na	1.0	na	0.8	0.9	1.5	3.1	3.1	1.0
	C	na	na	na	na	1.1	na	1.0	1.0	1.7	3.2	3.5	1.1
	I	na	na	na	na	1.9	na	1.7	1.9	3.2	6.4	6.3	1.9

(red shading) = measures with BCR less than 1.0

Table 5: Net present values for all measures by location and house cohort

Net Present Value for individual measures
18DegC heating. Period= 30yrs Disct rt=5%, Energy takeback=0%, Energy price escal=3%

Location		R4 ceiling none existing	Add R2.8 R1.5 existing	Wall R2.8 replace cladding	Wall R2.8 replace linings	Timber floor R2.0 polyst	Draught proofing	Double glaze exist alum frame	Secondary glazing	Curtains	Wood burner	Heat pump	Heat transfer sys.
Villas	A	5998	-98	-20434	-4018	1592	510	-2185	-1833	-612	12706	15781	418
	W	13295	1178	-15236	1180	6292	2388	26	378	241	28349	36589	2581
	C	15779	1766	-13604	2812	6241	1460	641	993	411	28675	40988	3056
	I	29813	4335	-3774	12642	12963	2828	4800	5152	1948	59493	76736	6783
20s Bungalows	A	5623	-92	-19157	-3767	1493	457	-2049	-1719	-660	11798	14568	300
	W	12464	1105	-14284	1106	5899	2218	24	354	139	26477	34089	2327
	C	14793	1656	-12753	2637	5851	1348	601	931	300	26751	38213	2772
	I	27949	4064	-3538	11852	12153	2631	4500	4830	1740	55625	71741	6267
ArtDeco	A	5066	-154	-16112	-2888	1264	394	-2084	-1765	-717	11343	13961	158
	W	11365	948	-11626	1598	5320	2015	-175	144	19	25541	32840	2025
	C	13509	1455	-10217	3007	5276	1215	356	675	166	25789	36826	2435
	I	25621	3673	-1733	11491	11078	2395	3946	4265	1493	53692	69243	5652
Mass40s-60s	A	4542	-138	-12054	-1680	1133	319	-1868	-1582	-785	9980	12142	-11
	W	10189	850	-8031	2343	4770	1772	-157	129	-125	22732	29090	1662
	C	12111	1305	-6768	3606	4731	1054	319	605	7	22903	32664	2030
	I	22970	3293	839	11213	9932	2113	3538	3824	1196	47890	61751	4914
Multiunit60s-70s	A	2446	-74	-5413	173	610	118	-1023	-883	-370	4102	4937	-690
	W	5486	458	-1878	3708	2568	901	-286	-146	-14	10848	13944	211
	C	6521	703	-938	4648	2547	514	-81	59	57	11210	15868	409
	I	12369	1773	5445	11031	5348	1084	1305	1445	697	24814	31410	1962
House 1970-78	A	5590	-169	-14835	-2067	1394	na	-2299	-1947	-649	12706	15781	328
	W	12540	1046	-9884	2884	5871	na	-193	159	164	28349	36589	2387
	C	14906	1606	-8329	4439	5822	na	393	745	326	28675	40988	2840
	I	28271	4052	1032	13800	12224	na	4354	4706	1790	59493	76736	6389
House 1979-80s	A	-1165	-175	na	na	-388	na	-2537	-1530	-626	13605	16832	384
	W	89	1079	na	na	195	na	-541	465	212	29508	38061	2508
	C	666	1656	na	na	383	na	980	1987	379	29860	42597	2975
	I	3189	4179	na	na	1493	na	5994	7000	1889	61427	79233	6635
House90-96	A	-1200	-180	na	na	-383	na	-2614	-1577	-603	13615	16994	441
	W	91	1111	na	na	217	na	-558	479	260	30222	39089	2629
	C	686	1706	na	na	411	na	1010	2047	433	30600	43763	3110
	I	3286	4306	na	na	1555	na	6175	7212	1987	63361	81731	6881
Multiunits1980-96	A	-635	-95	na	na	-422	na	-1315	-1135	-279	5919	7363	-464
	W	48	588	na	na	-104	na	-368	-188	178	14593	18943	695
	C	363	903	na	na	-2	na	-104	76	270	15058	21417	950
	I	1740	2280	na	na	604	na	1678	1858	1093	32549	41400	2946
House Post96	A	na	na	na	na	-361	na	-2921	-1762	-512	15433	19420	667
	W	na	na	na	na	310	na	-623	536	452	33967	44088	3113
	C	na	na	na	na	527	na	1129	2288	645	34448	49312	3650
	I	na	na	na	na	1805	na	6902	8061	2383	71096	91720	7865
Multiunits Post96	A	na	na	na	na	-422	na	-1608	-1388	-188	7737	9790	-237
	W	na	na	na	na	-34	na	-450	-230	371	18339	23942	1179
	C	na	na	na	na	92	na	-127	93	482	18906	26967	1490
	I	na	na	na	na	832	na	2051	2271	1488	40285	51390	3930

(red shading) = measures with negative net present value

4.2 National benefits

The net benefits for each house type and city were calculated for the three retrofit packages and scaled up for all New Zealand. The retrofit arrangements at the starting point and the eventual uptake after 15 years are shown in Table 6. For example, in Wellington, the House Condition Survey (HCS) data shows approximately 60% of existing pre-1978 houses have zero or close to zero insulation and the other 40% have 75mm or more of insulation in the ceiling. Over a period of time we have assumed the upgrade in Wellington is that 30% of the stock will achieve the Basic package, 40% the Standard package, and 30% the Enhanced package. Similar estimates were made for the other centres, based on the HCS.

Table 6: Retrofit proportion assumptions by region for national benefits.

Retrofit assumptions for National benefits						
	Start at		**Upgrade to**			Total
	Ceiling nil	Ceiling 75mm insultn	Basic	Standard	Enhanced	
Auck	50%	50%	40%	40%	20%	100%
Well	60%	40%	30%	40%	30%	100%
Chch	40%	60%	15%	25%	60%	100%
Inverc	30%	70%	0%	20%	80%	100%

The scaled up results for all New Zealand are in Table 7 and assume the total stock has been upgraded to the levels set out in Table 6. It allows for the different savings and NPVs for each house cohort. The cost of upgrade is about $17.4 billion and the net benefits, in present day values assuming the upgrade occurred immediately, is $32 billion. In fact the retrofit will occur over a number of years so the NPV will be lower. If we assume an even rate of upgrade over the next 15 years then the NPV is reduced by about 31% to $22 billion. This allows for the initial costs of the measures, so the potential net benefits are large.

Table 7: National benefits for total stock retrofit upgrade

National net benefits 18DegC heating. Period= 30yrs Disct rt=5%, Energy takeback=30%, Energy price escal=3%							
	Location	Stock Numbers	Total initial $ million	GWh/yr saved	NPV $ million	BCR	Water saved million cum/yr
Villas	A	24,361	252	85	365	2.4	1.3
	W	22,454	298	126	692	3.3	1.2
	C	20,099	422	162	679	2.6	1.2
	I	4,245	114	56	332	3.9	0.3
20s Bungalows	A	33,307	332	113	484	2.5	1.7
	W	23,274	297	126	683	3.3	1.2
	C	18,013	364	140	575	2.6	1.0
	I	4,364	112	55	321	3.9	0.3
ArtDeco	A	20,934	200	68	291	2.5	1.1
	W	18,046	220	92	502	3.3	1.0
	C	12,428	238	91	375	2.6	0.7
	I	3,777	92	44	262	3.8	0.2
Mass40s-60s	A	239,780	2115	755	3209	2.5	12.3
	W	137,341	1536	663	3551	3.3	7.3
	C	91,337	1596	628	2557	2.6	5.3
	I	25,022	557	272	1582	3.8	1.5
Multiunit60s-70s	A	56,925	387	128	467	2.2	2.4
	W	35,907	305	119	538	2.8	1.6
	C	18,172	230	88	298	2.3	0.8
	I	4,796	75	36	180	3.4	0.2
House 1970-78	A	92,622	919	317	1398	2.5	4.8
	W	36,963	466	201	1131	3.4	2.0
	C	28,892	568	226	977	2.7	1.7
	I	9,050	226	115	699	4.1	0.6
House 1979-80s	A	118,978	899	315	1541	2.7	6.1
	W	39,123	365	133	830	3.3	2.1
	C	30,211	419	151	699	2.7	1.7
	I	9,047	158	68	461	3.9	0.6
House90-96	A	68,919	480	188	814	2.7	3.5
	W	17,811	156	62	364	3.3	0.9
	C	20,578	275	105	462	2.7	1.2
	I	3,315	56	25	170	4.0	0.2
Multiunits1980-96	A	35,620	210	68	236	2.1	1.5
	W	26,214	191	63	281	2.5	1.1
	C	11,969	126	41	128	2.0	0.5
	I	3,197	41	15	80	2.9	0.2
House Post96	A	125,789	914	328	1424	2.6	6.5
	W	31,769	291	103	632	3.2	1.7
	C	34,162	476	164	732	2.5	2.0
	I	8,596	152	61	432	3.8	0.5
Multiunits Post96	A	19,687	122	37	129	2.1	0.8
	W	11,088	85	26	122	2.4	0.5
	C	5,412	60	18	59	2.0	0.2
	I	1,012	14	5	27	2.9	0.0
		1,604,611	17,414	6,683	31,769	2.8	83.6
Includes comfort benefit, excludes health benefits.							

4.3 Sensitivity analysis

The above analysis uses the base case parameters for the heating regime, takeback, discount rate, analysis period, energy price escalation, and ignores health benefits but includes a $ value for comfort. Variations in these parameters are now discussed.

4.3.1 Heating regime

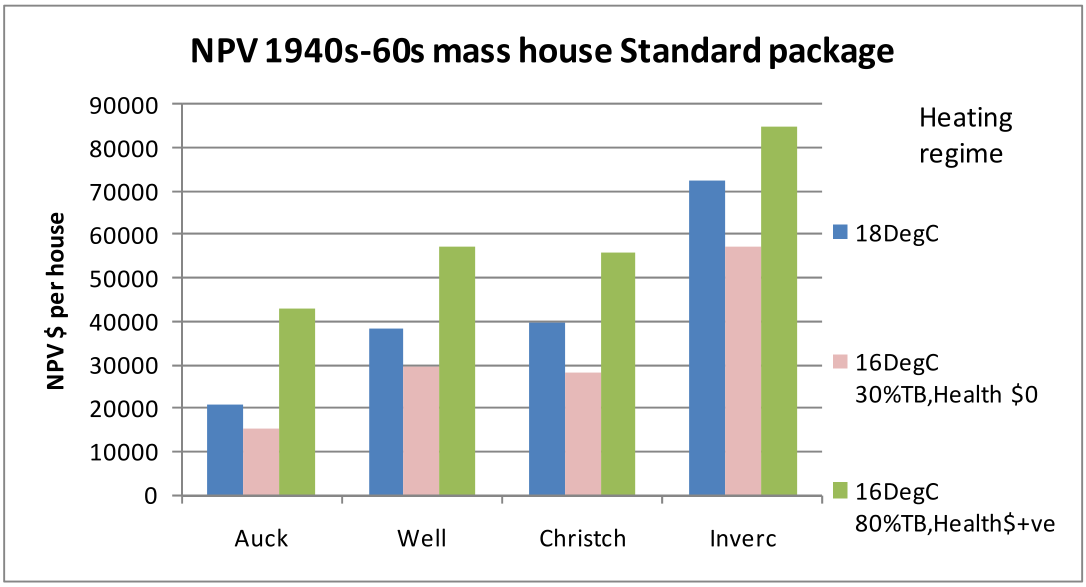
The default heating case of 18°C morning and evening, for the whole house, is higher than what actually occurs at present according to HEEP results[4]. Average winter indoor temperatures of about 16.8°C were recorded in HEEP for living rooms heated by electricity. These are in approximate agreement with the Papakowhai results of average living room temperatures after retrofit of about 17.4°C, (and 16.5°C for living room and bedrooms together).

The justification for using 18°C in our modelling is that the stock needs to be upgraded to allow these temperatures to be maintained economically, and for health reasons, and that the retrofit package needs to be chosen to achieve near optimal net benefits. This is also the benchmark set out in Beacon's HSS High Standard of Sustainability®.

The results for 16°C heating, compared to the base case of 18°C are shown in Figure 8. Three scenarios are:

- 18°C heating 30% takeback, as before.
- 16°C heating, 30% takeback, ignore health effects.
- 16°C heating, 80% takeback, allow for health effects.

Figure 8: Typical house NPV – Effect of heating regime and health cost savings



[4] *Isaac et al (2007)*

The chart indicates that with a lower heating regime and no allowance for health costs the NPV is lower than in the 18°C scenario. However, when health cost savings are included, the NPV rises above that for the 18°C scenario. There is large takeback and the temperature rises significantly with a large gain in health cost savings and an increase in comfort values. The assumption in the third scenario is that every house is initially at 16°C or below, and that temperatures rise in all houses with retrofit and every house has a health cost saving of $215 per year. This is possibly over-optimistic but indicates health cost savings are a significant part of the net benefit.

The ALF analysis in the appendix indicates the rise in temperature from 16°C with large takeback is between 1°C and 3°C, depending on the location, and the amount of existing and retrofit insulation. This is in approximate agreement with what was found in the Papakowhai houses (see the Appendix).

4.3.2 Takeback

Takeback expressed as a percentage is given by:

Takeback % = (Theoretical energy savings- Actual energy savings)*100
/Theoretical energy savings.

Where, theoretical savings are those expected due to the efficiency measure, with the same temperatures before and after retrofit. Actual energy savings may be less than expected because owners increase their "comfort" levels.

The Papakowhai results[5] indicate the Standard package homes have unchanged energy use and higher temperatures after retrofit implying near 100% takeback. For the "High" package Papakowhai homes there is a reduction in energy use for two cases out of three though in the third house the temperatures declined.

The HEEP year-10 report[6] reviewed the NZ experience of before and after retrofit temperature measurements. It found small temperature increases of 0.6 to 1.0°C after retrofit and small or zero energy savings, though these were mainly for low income groups. They conclude "We cannot expect to get large energy savings from insulation retrofit of houses in New Zealand."

[5] ***Burgess et al (2009)***
[6] ***Issacs et al (2006), p. 73***

Given that New Zealand houses generally have low comfort levels we believe it is quite likely that a significant proportion of the theoretical energy savings due to retrofit will be taken back in increased comfort. Accordingly, 30% for takeback is considered reasonable for the majority of the housing stock. This percentage directly affects the net energy savings shown in Table 7, but it does not affect the NPV, since we have assumed the takeback energy and improved comfort levels has a value to the owner equal to the value of the theoretical energy savings foregone by the owner. In other words, the lower cost efficiency of the insulation due to reduced energy savings from takeback is exactly off-set by the value of the increased comfort levels.

4.3.3 Retrofit takeup

An alternative and lower rate of uptake of the retrofits to those assumed in Table 6 is shown in Table 8. In this lower uptake scenario between 50% and 75% of the stock, depending on the region, has some level of retrofit (Basic, Standard or Enhanced), compared to the base case in Table 6 of 100% retrofit (after a number of years).

Table 8: Retrofit proportion assumptions - low scenario

Retrofit assumptions for National benefits - Low uptake						
	Start at		**Upgrade to**			Total
	Ceiling nil	Ceiling 75mm insultn	Basic	Standard	Enhanced	
Auck	50%	50%	30%	20%	0%	50%
Well	60%	40%	20%	30%	10%	60%
Chch	40%	60%	10%	15%	50%	75%
Inverc	30%	70%	10%	15%	50%	75%

The results are compared in Table 9 which shows that the lower takeup has about half the initial cost and energy savings of the 100% takeup case. The NPVs assume a 15 year retrofit rollout to the housing stock, and indicate the national NPV is about 60% of the 100% takeup case.

Table 9 Different retrofit takeup comparison

Savings with different retrofit takeups				
	Total initial	GWh/yr	NPV	BCRs
All house cohorts	$ million	saved	$ million	
Expected uptake (as per Table 4)	11,819	6,593	22,807	2.9
Low uptake (as per Table 6)	5,818	3,639	13,936	3.4
Assume retrofit occurs evenly over 15 years.				

The Low uptake scenario has a higher BCR than the Expected uptake scenario because the former does not include as much of the Enhanced packages as the Expected uptake. The Enhanced package includes measures which are not cost effective in most locations (hot water heat pumps, rainwater tanks, secondary glazing) so their reduced number in the Low uptake scenario improves its BCR.

4.3.4 Financial factors

The financial factors include the discount rate, analysis period and energy price escalation rates. A summary of the effect the changes in each of these parameters has on the NPV is shown for the 1940s-60s house in Figure 9 for Auckland, and Figure 10 for Invercargill. There is a similar pattern for both centres. The NPV changes the most when the analysis period is reduced and when the energy price escalation is increased. The horizontal axis shows the percentage change in the parameters. For example, if the analysis period changes from 30 years (base case) to 10 years that is a negative 66% change in the base analysis period. If the energy price escalation changes from 3% (base case) to 5% that is a 66% change in the base escalation rate.

None of the parameters investigated are particularly sensitive to the base assumptions. The possible exception is the energy price escalation rate, where the NPV rises sharply as the escalation rate exceeds the discount rate.

Figure 9: Sensitivity of the NPV to financial parameters Auckland

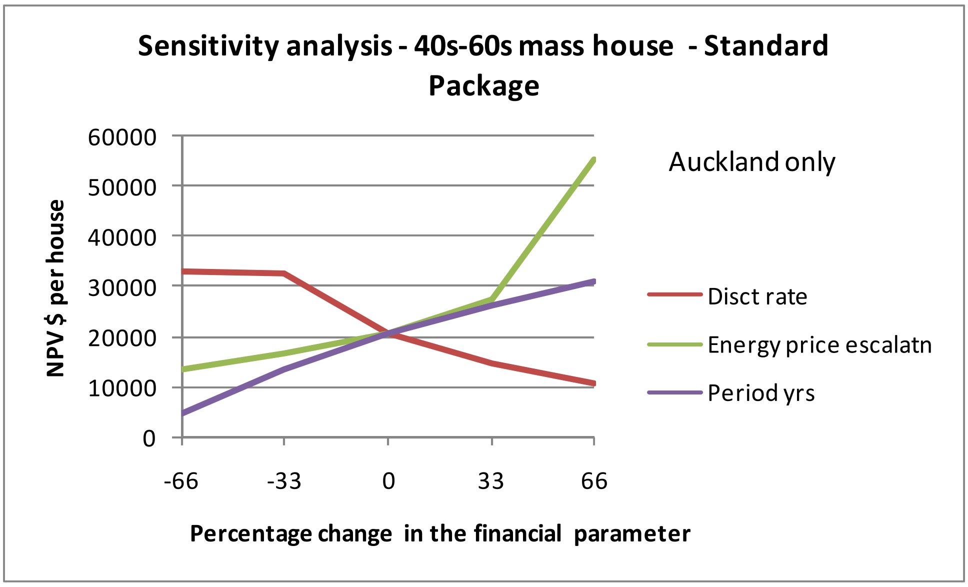
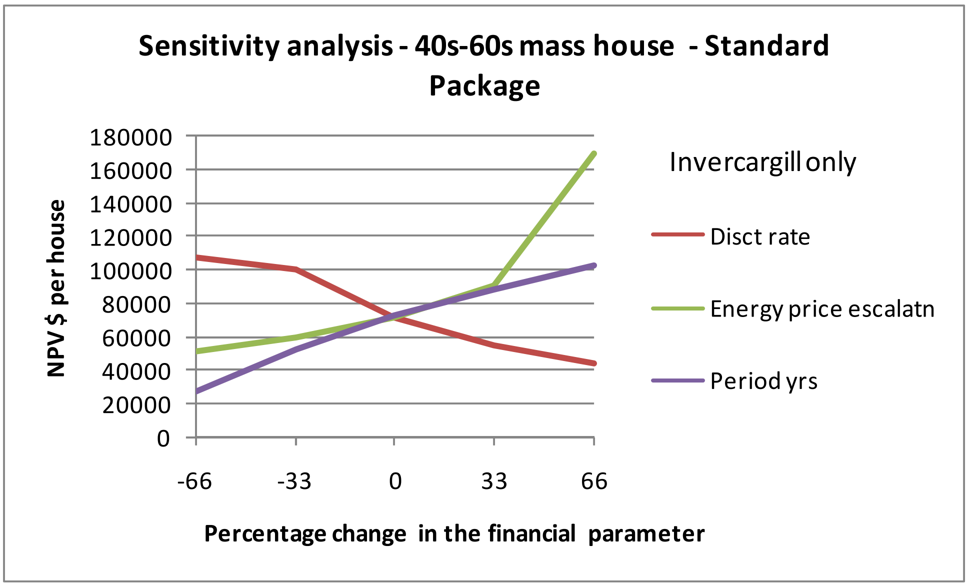


Figure 10: Sensitivity of the NPV to financial parameters Invercargill



5 Discussion

Multi-unit dwellings were included in the modelling for the sake of completeness of the analysis. However the energy modelling for these is approximate only and is based on kWh/m^2 numbers for stand-alone housing, with some approximate adjustments to allow for their different thermal performance. Multi-units need to have their own thermal modelling, to obtain more accurate energy use numbers.

The base case modelling was for 18°C morning and evening, which is a little higher than current heating levels of between 16.8°C to 17.4°C in the Papakowhai and HEEP houses. The HEEP work found that energy savings due to retrofit are likely to be small with most potential savings taken back as increased comfort. In a BRANZ survey[7] of new house owners a common complaint was the required indoor temperatures were not easily achieved. This suggests occupants want higher temperatures, and that 18°C is a reasonable performance level to set for the benefit cost analysis. This also reflects Beacon's HSS High Standard of Sustainability® benchmarks for indoor environment quality.

The main finding from the Papakowhai houses, applicable in this project, is that the energy savings are not large unless quite extensive retrofit measures are installed. For the Standard package of measures there were modest temperature rises in the houses and energy use was mostly unchanged, implying quite large takeback. Because the Papakowhai houses were of a similar age group, it is difficult to extend this to all cohorts. Also the packages used were to test a variety of interventions so optimal interventions were not necessarily achieved in the Papakowhai houses. Retrofit does need to be tailored for individual houses as even houses of the same cohort will vary in the feasibility and value of the various retrofit measures.

In deriving national benefits, this project has assumed that the Basic, Standard or Enhanced package is suitable for all houses, regardless of age. This is a simplification, done for estimating national totals, and it is suggested the main use of the spreadsheet tool is to calculate costs and net benefits of tailor made packages for individual houses.

All items in the Basic and Standard retrofit packages are cost effective in terms of the national benefit. Many of the measures are also cost effective from the owner's viewpoint, though this depends on the required payback period (i.e. the analysis period). The owner's payback was not explored in this project but is readily done using the spreadsheet tool.

[7] ***Page (2007)***

In the Enhanced package the hot water heat pump and the rainwater tanks are not cost effective. Secondary glazing is only effective in the South Island. There are some items in Table 10 not in any of the packages but with BCRs over 1, i.e. solar panels, wetbacks, and draughtproofing, which could be considered, particularly the latter for the Basic package.

The spreadsheet currently uses the same cost structure in all locations for the initial costs of the various measures. These will be adjusted for regional differences in later versions of the spreadsheet. In scaling up for national totals it was suggested that allowance be made for the findings of previous work, that particular measures are easier done or more likely for particular house cohort characteristics. This modification is quite complex to incorporate for calculating national totals and was not done, i.e. it was assumed if a particular measure was selected it was readily "installable" to all cohorts for the same unit cost ($\$/m^2$). As an alternative, spreadsheet users can select particular cohorts, by location, which will enable then to tailor make the package of measures suited to house style and location. Note however, the modelling does allow for different floor, ceiling, window and wall areas between cohorts, and the resulting variations in costs and benefits. Also regional energy and water costs are used in the spreadsheet. In its current form, users can alter any of the cost data in the data sheets, but they need to keep a separate copy of the original spreadsheet if they wish to revert to the original numbers.

In the sensitivity analysis the parameter with the largest influence was energy price escalation. A change from 3% to 5% per annum price escalation increased the base case NPV by 140% indicating high sensitivity to this parameter. The base case of 3% pa is based on past trends over the last 17 years; see Figure 14 in the appendix. In the last 7 years the rate has been higher, nearer 5% pa. This reflects the depletion of the Maui field, and the shift to higher marginal costs of new generation set mainly by wind power. Continuing escalation of about 3% pa is considered to be likely in the long term, rather than 5% pa.

Introduction of an efficient heater, such as a heat pump at the same time as insulation retrofit provides good benefits because of the multiplier effect of cheaper fuel and lower energy needs. If the heat pump or other low cost heating appliance, e.g. a solid fuel burner, is already installed before retrofit then these are sunk costs and the benefit of retrofit is much reduced because the fuel cost is reduced. For example, the BCRs in Figure 3 reduce to about a third of values shown, for a prior installed heat pump, and all measures apart from prior nil ceiling- R4 retrofit become uneconomic in all regions.

6 Conclusions

The Basic and Standard packages proposed by Beacon contain measures that are all cost effective in all centres. In the Enhanced package only the wall insulation retrofit is cost effective (outside Auckland). Some of the other Enhanced measures are cost effective in Invercargill only, i.e. secondary glazing, curtains and the heat transfer systems. This ignores the comfort benefits as it is assumed these have already occurred with the cheaper and more cost effective measures of ceiling and floor retrofit in the Standard package.

The spreadsheet enables users to look at tailor made packages for specific house types, with data on the initial cost, energy saved, NPV and BCR for each measure and for the total package. Users can enter their own cost data in the Data sheet, if desired.

Future extensions of the spreadsheet model will apply to a wider range of locations, and other sustainability measures may be added.

The cost savings from retrofit are potentially very large and the BCRs are favourable for achieving these cost savings under most scenarios.

7 References

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8 Appendices

The following appendices cover:

- Description of how to use the spreadsheet model.
- Types of efficiency measures, their costs, replacement cycles, BCRs, and data sources.
- Papakowhai houses space conditioning costs and temperature changes.
- Present value method details
- Calculation of temperature changes with energy take-back
- Space heater economics
- Water supply and waste water unit prices
- Energy price escalation
- Health cost savings

8.1 Use of the spreadsheet model

The spreadsheet runs in Microsoft Excel. The user selects the financial parameters required. It is suggested the default values be used, namely Discount rate = 5%, Energy price escalation = 3% pa, Analysis period 30 years, and Energy takeback factor = 30%.

The House Type, city centre and Heating Regime are chosen from the drop down boxes.

The user then selects the types of efficiency measures by entering "Y" in the D column.

The results for all measures for the house appear at the bottom of the A to F columns, line 73. The results for individual measures can also be read by row.

Users may wish to have results for each combination of typology and locations, for a chosen package of measures. Instead of using the dropdown boxes to change typology and location sequentially (a total of 11 x4 combinations) users can use the macro "Cycle1". This provides total results for the chosen package of measures from line 131.

Users should only change values within the heavy boxes. A clean copy of the spreadsheet should be retained in case other cells are inadvertently altered.

8.2 Retrofit initial costs, durability and typical BCRs

Table 10 shows the costs of the retrofit measures. The same costs were used in all locations although the spreadsheet model could be readily adapted to have different costs by region. The durability in years is required in order to assess the present value of replacement costs of the measures. The benefit cost ratios (BCRs) assume 18 degree C heating and have zero takeback. Since comfort is included in the benefits and is valued at the value of the energy saving foregone the BCRs do not change with takeback percentage. The cost data is mainly from Rawlinsons (2008).

Table 10: Retrofit measures costs and durability

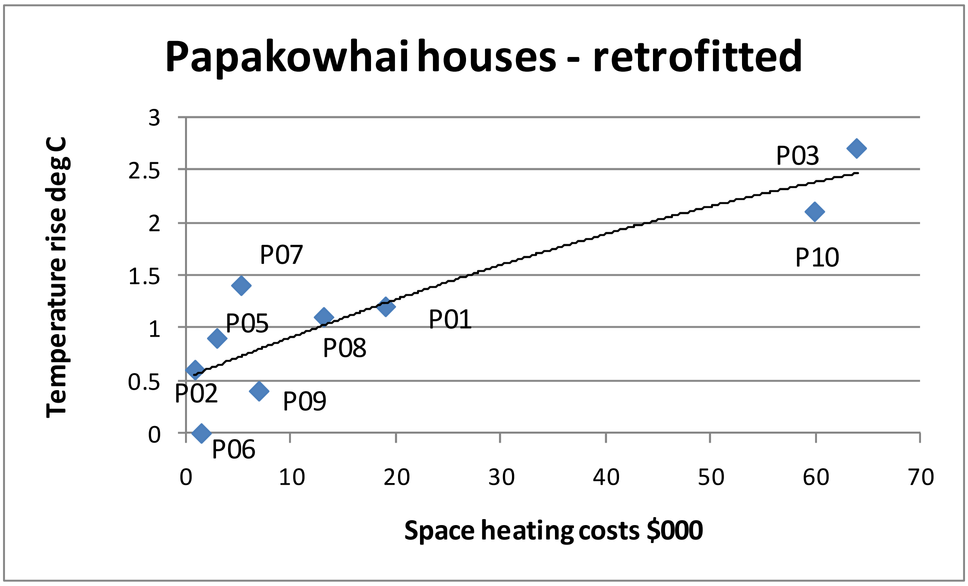
Energy and water saving measures					
Measure	Initial	Replace		Benefit-cost ratio (1), (2)	
Water	cost $ (1)	Years	Comment	Auckland	Invercargill
Solar water panels	7000	30	Include HWC. Some plumbing.	1.0	1.1
HW heat pump	5000	20	Assume COP=2.8	0.8	0.8
Wetback	1000	40	$1,000 is marginal cost of plumbing to HWC.	5.5	5.7
Instantaneous gas	1750	20	One only. Save on standing losses as per TE106C	3.1	1.0
HWC tempering value	300	20	Cost per Homesmart Renovations Plan Builder.	na	na
HWC Themostat	60	15	Save 10degC temp.	19.2	19.8
Dual flush cistern	120	15	$ per Homesmart Renovations Plan Builder.	1.9	1.4
Rainwater tank (toilet, laundry only)	3000	40	$3,000 incl plumbing. 5,000 litre tank for toilet, laundry use.	1.1	0.9
Rainwater tank (garden only)	1000	20	1000 litre tank, outdoor use only.	0.2	0.2
HWC wraps	70	50	One cylinder only. From EECA NBM	19.4	20.0
Pipe lagging	20	50	From EECA NBM	22.6	23.3
Low flow shower	130	15	One shower only. 3 showers/day. 4litr/min saving, 5 mins ea.	17.9	18.5
Flow restricter cold tap (bathroom)	30	20	1 tap only	1.9	1.4
Flow restricter cold tap (kitchen)	30	20	1 tap only	1.9	1.4
Insulation					
Ceiling nil, Add R4	2080	50+	$16 per sqm.	3.2	12.0
Ceiling 50mm, bring to R4	1560	50+	$12 per sqm	1.3	4.9
Ceiling 75mm or 100mm, bring to R4	1300	50+	$10 per sqm	0.9	3.5
Skillion relined (15% of area)	1365	50+	$70/sqm, 15% of ceiling area/ house on average	0.7	2.8
Wall add R2.8 replace Weatherbd/ Fibre cmt	16744	50+	Allow changing stud height in houses. R2.8 insul $165/sqm	0.3	1.1
Wall add R2.8 replace 50% Weatherbd	9555	50+	Allow changing stud height in houses. R2.8 insul $105/sqm	0.5	1.8
Wall add R2.8 replace linings	4095	50+	Allow for changing stud height . $80/sqm. R2.8 insul	1.1	4.3
Floor Timber Add Polystyrene	2080	50+	Press fit polystyrene R2.0 or FG Cosyfloor R2.0 $16/sqm.	1.5	5.8
Floor Concrete add polystyrene perimeter	967	50+	$20/ lin m. Rect hse 2x by 1x. Peri=6sqrt(A/2)	0.64	2.4
Draughtproofing (doors/ windows)	225	15	Assume 3 doors @ $15 each door, +6 windows @$30/window.	2.0	7.3
Windows					
Whole window replacement Double glazing	11440	40	Windows are about 22 to 25% of floor area. Assume $380/sqm.	0.2	0.6
Replace glazing only, DG in alum	3718	30	Assume $130/sqm incl DG, glazing inserts, remove existing glass.	0.5	2.0
Replace glazing only, DG in rework timber	5577	30	Allow 1.5 factor for timber windows.	0.3	1.3
Secondary glazing panels	3432	20	Glazing in alum frame fitted behind existing glazing.	0.5	2.1
Curtains	1000	20	Assume major windows only, not service rooms.	0.4	1.9
Pelmets	120	20	Assume 6 windows required 12m x $10/m	na	na
Heating appliance (3)					
Electric resistance wall panels	450	15	Consumer June 2007 $150 ea + some power circuits. 2Auck, 3Well,Chch, 4Inverc		
Electric Night store	1000	20	Prices from MfE Warm Homes Tech Report 2005	3.6	8.3
Solid fuel (timber/ coal)	2500	30	Free standing, include flue. Consumer July06	2.1	8.1
Solid fuel (pellets)	4000	30	Free standing, include flue. Consumer March07	1.3	4.4
Gas flued	3500	20	Consumer June 2008 $1700, plus $900 install, 4-5 kW	0.9	0.1
Heat pump (s)	2900	20	Consumer June 2006 $1800, plus $900 install, 4-5 kW	1.4	7.9
Heat transfer system	1000	20	Assume system savings are 5% of use with Ceiling and floor retrofit	0.3	1.0
Other (4)					
Ground polythene	520	40	Assume conc slab for post 1978	2.9	2.9
Extractor fan for kitchen	250	15	Consumer Nov 2005. $250 ea incl duct.	1.9	1.9
Extractor fan for bathroom	250	15	Consumer Nov 2005. $250 ea incl duct.	1.3	1.3
Clothes dryer vent	70	15	Clothes dryer vent and ducting	4.5	4.5
Clothes line	150	15		0.0	0.0
Efficient light bulbs	30	8		25.4	26.2
Kitchen waste (worm farms v insinkerator)	120				

(1) Cost and BCR analysis are for the 1940s-60s mass houses. Other cohorts have similar values.
(2) BCR assumes electricity heating, 0% takeback, 5% disct rate, 30 yr period, 3%pa energy price escalt
(3) Heating appliance BCR are based on fuel cost compared to electric resistant heating
(4) " Other" benefits arise from reduced mould levels due to moisture control.

8.3 Papakowhai house costs for space heating measures

Figure 11 shows the costs of the space heating measures retrofitted into the 9 Papakowhai houses. The temperature change is the average change in living room and bedrooms, at night before retrofit, and after 2 winters. The second winter was selected to measure changes because it is believed a delay of at least a year after retrofit was needed for take-back to fully occur.

Figure 11: Papakowhai temperature changes v retrofit cost



8.4 Present value discounting

The present value method was used for discounting costs back to the present. The cost benefit technique used in this study is used to convert all costs to the present value. This is based on the idea that one dollar expenditure in the future, costs less than the same expenditure now. Whereas in the second case $1 is needed now, in the first case a lesser amount can be set aside now to earn interest so that it amounts to $1 in 5 years' time. The amount to set aside now is that which, when compounded at the appropriate interest rate (or discount rate), will exactly equal $1 in 5 years' time. The compound factor is given by:

$(1 + r)^5 = 1.611$ for r=10%.

Hence, the amount to be set aside now is only $1/1.611 = 62 cents. Or, in other words, an expenditure of $1 in 5 years' time is only worth 62 cents in today's values.

The relevant present value formula is:

$$PV = M_i + C_1 / (1+ r) + C_2 /(1+r)^2 + C_3 /(1+r)^3 + \ldots\ldots + C_N /(1+r)^N + \Sigma M_t/(1+r)^t$$ Equation 1.

Where:

PV = present value of the current expenditure plus the future cost streams, out N years ahead.

M_i = Initial cost of the efficiency measure e.g. insulation, or double glazing, or rain water tanks, etc. Also includes the space heating appliance initial cost.

C_1 , C_2 , C_3 C_N = Space heating energy costs, or water supply/ waste costs in year 1, 2, 3...... N. For this study the energy costs are allowed to escalate at a rate of 1%per year above the rate of general inflation.

M_t= Replacement cost of the efficiency measure (occurs at time t years ahead and is discounted back to the present. Some measures, e.g. light bulbs are replaced more than once over the analysis period of N years) Also includes the replacement cost of the heating appliance.

r = discount rate.

N = period of analysis.

The benefit cost ratio is the PV of energy and water cost savings (compared to the base case of nil or low efficiency measures) divided by the cost of the efficiency measure costs (including discounted replacement costs, if any).

When the real discount rate is used (i.e. the nominal rate less expected inflation) the effect of inflation on future energy costs can be ignored, so that only energy price increases above the general inflation rate are considered.

The discount rate is an important factor affecting the relative advantage of low-energy use, high-cost insulation, against high-energy use, low-cost insulation. A high discount rate heavily reduces the present value of energy costs and penalised high amounts of insulation. Conversely a low discount rate means that energy costs are not so heavily discounted thereby favouring more insulation.

Net present value is calculated as the difference in present value between a base case (e.g. no efficiency measures) and the PV with sustainability measures. The spreadsheet works in terms of energy and water savings so the NPV is given by:

$$NPV = \sum_{t=1}^{N} Savings \; x \; unit \; price \frac{1}{(1+r)^{t}} \text{ - Initial cost of efficiency measure.}$$

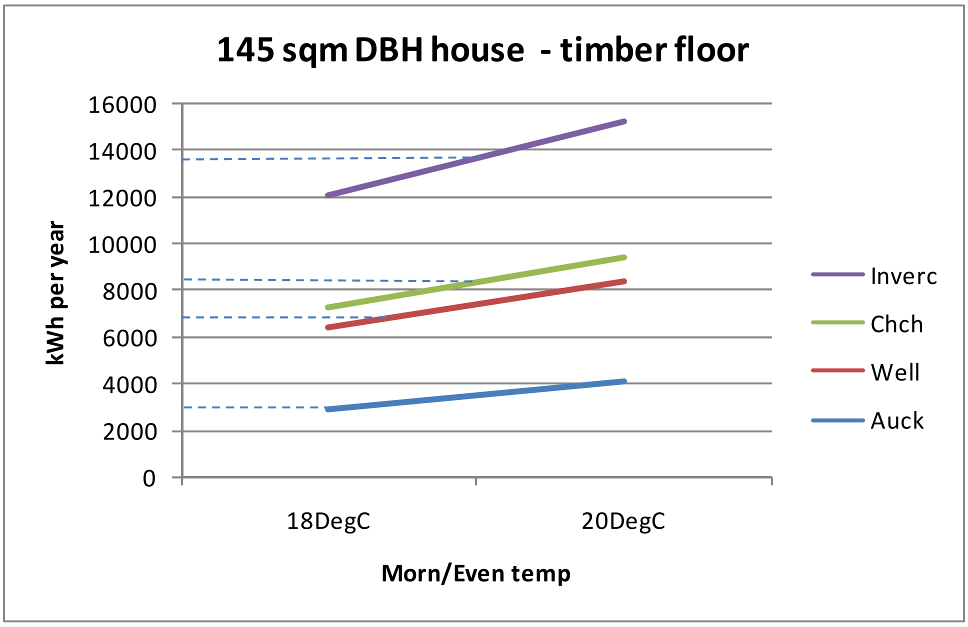
Where:

N is the period of analysis, years t= 1, 2, ... N.
r is the discount rate.
Savings are the energy or water savings.
Unit price is the price of energy or water.

8.5 Takeback effect on temperatures.

Figure 12 shows an ALF analysis of a typical house retrofitted with insulation to current NZBC requirements. The house was analysed in ALF assuming 16°C heating regime and nil insulation, and the required heating energy is shown as the dotted lines. Hence the chart shows the expected temperature rise when the house is retrofitted and the same amount of energy is used as for the nil insulation, 16°C heating regime case. The temperature rises are between 2°C and 3°C.

Figure 12: ALF modelling of typical house with take-back.



8.6 Economics of space heating appliances

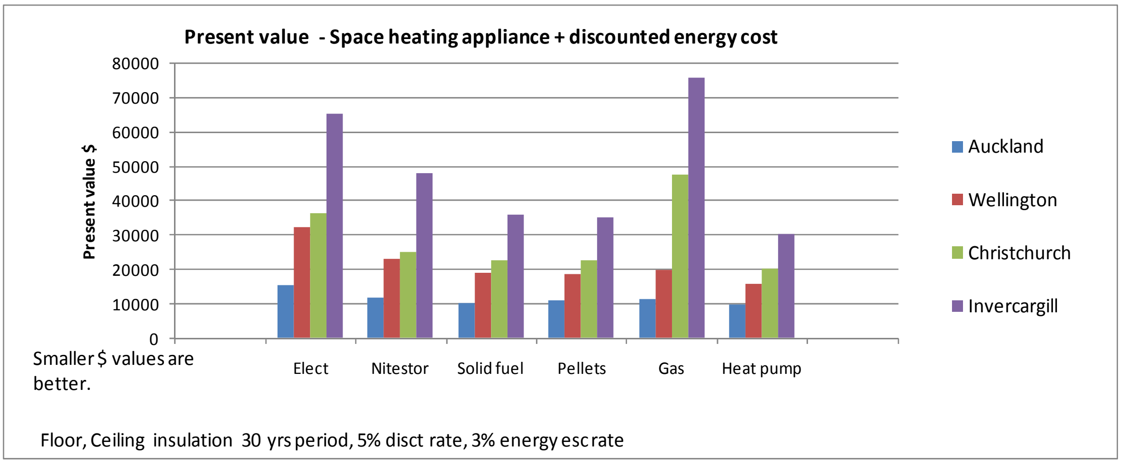
The economics of space conditioning depend greatly on the energy prices assumed, and also the type of heating appliance. The base assumptions in this report are electric resistant heating, which has unit prices around 19 c/kWh. However the unit price for other forms of heating are significantly lower, see Table 11. For heat pumps the prices are lower by a factor of 2.8, which is the assumed coefficient of performance for heat pumps. Solid fuel, wood pellet, and gas (in the North Island) are also quite low in unit price. Offsetting these lower prices is the higher heating appliance cost for the alternative fuels.

A present value analysis was done for the cost of heating and appliances over a 30 year period, and the results are in Figure 13. The present value is the cost of the heating appliance plus the discounted energy cost over 30 years. The energy used varies between 3,000 kWh in Auckland to about 14,000kWh in Invercargill.

Table 11: Energy prices $/kWh

	Elect	Nitestor	Solid fuel	Pellets	Gas	Heat pump
Auckland	19.3	13.3	10	9	10	6.9
Wellington	19.3	13.3	10	9	10	6.9
Christchurch	18.0	11.5	10	9	22	6.4
Invercargill	19.9	14.2	10	9	22	7.1
See www.meridianenergy.co.nz for regional pricing plans						

Figure 13: Space heater economics



The chart is for a typical 1940s-60s house and a similar result is obtained with other typologies, i.e. heat pumps are the most cost effective appliance in all locations, followed by solid fuel and wood pellets appliances.

8.7 Water prices

The shadow water prices used in the analysis are in Table 12. The unit prices for Auckland are from Metrowater[8] and the other prices are BRANZ estimates.

Table 12: Water unit prices

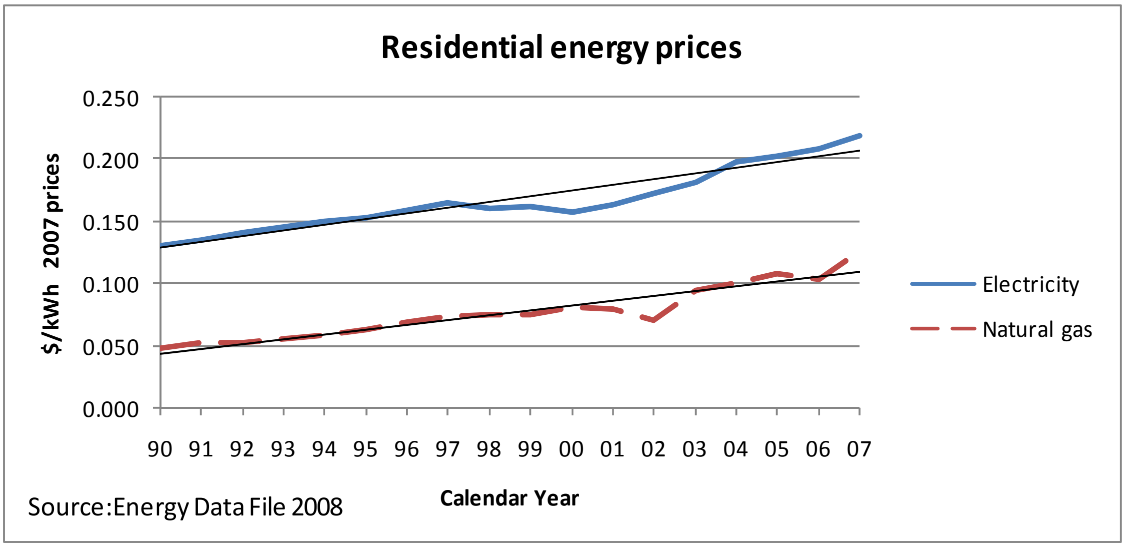
Actual/ shadow water charges $/litre		excl GST
	Supply only	Supply+waste
Auckland	0.0013	0.0035
Wellington	0.0009	0.0030
Christchurch	0.0009	0.0030
Invercargill	0.0009	0.0030

8.8 Energy price escalation

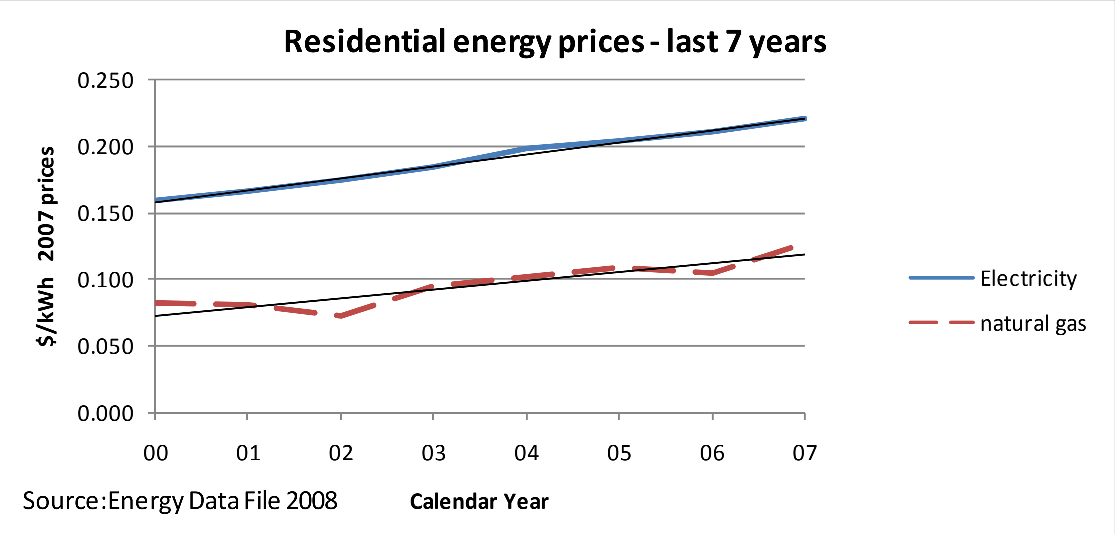
The Energy Data File published annually by the Ministry of Economic Development monitors movements in energy prices. The latest data, for the 2007 calendar year are shown in Figure 14.

Since 1990 real electricity prices have risen at about 3.1% pa and natural gas at 5.8% pa. Real prices are those prices adjusted for general inflation using the CPI. Energy price escalation has been even larger in the last 7 years, 4.8% pa and 6.5% pa respectively. These are significant rises caused by a transition away from the cheap Maui gas field, which also provided for electricity generation.

Figure 14: Residential energy price trends



[8] Price source: http://www.metrowater.co.nz/my-bill/Pricing/Pages/Residential.aspx. Accessed November 2008.



The most recent price projections from the ministry are in the October 2003 publication NZ Energy Outlook to 2025, which has domestic electricity escalation at about 1% pa above general inflation and natural gas at about 1.6%pa between 2005 and 2025. These rates are well below recent trends and suggest that MED have under-estimated future price movements. It was decided to use recent trends in the forecasts, and the modelling allows for 3% pa real electricity price escalation, as the base case.

8.9 Health cost savings

The Housing, Insulation and Health Study (Chapman et al, 2005) identified savings of $179.40 per household in reduced health costs, including reduced GP visits, hospital admissions, days off school and work. At the Consensus conference on the CBA for the Home Energy Rating Scheme (HERS December 2008) it was agreed that this value of savings should be used in current cost benefit studies, scaled up for inflation using the CPI, and that it should apply to the whole pre-1978 stock that is upgraded. This was based on discussions with two of the authors of the HIH report who were at the HERS conference.

The movement in the CPI between mid 2001 and December 2008 is 20.2%. Hence health costs savings to be used in the model is 1.202 x $179 = $215 per house.

8.10 Climate zones used as basis of energy requirements

Figure 15: Map for Climate Zones to drive ALF based calculations of heating requirements