STUDY REPORT

SR 227 (2010)

Wall retrofits in housing – Market potential and cost-benefits

IC Page

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Preface

This is an analysis of the costs and benefits of retrofitting insulation into walls. The trade-off is between the cost of the retrofit and the energy saved in subsequent years. The circumstances under which it is economic to retrofit are identified.

Acknowledgments

This work was funded by the Building Research Levy.

Note

This report is intended for designers and homeowners thinking about the benefits and costs of retrofitting insulation into walls.

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BRANZ Study Report SR 227

IC Page

Abstract

The retrofitting of insulation to housing has received renewed interest over the last year due to the Government Heat Smart programme subsidising retrofits to ceilings, floors, the provision of efficient heating appliances, and other efficiency measures. The retrofit of walls is not included in this programme, mainly because of the quite high cost, and in many cases the cost-benefits are not favourable. This report analyses the benefits and costs of wall retrofit and identifies the situations where this retrofit is cost-effective.

Contents Page

Figures Page

Tables Page

1. INTRODUCTION

Retrofitting of energy efficient measures to existing housing has a number of options. The low cost measures such as draught-proofing, wrapping cylinders and pipes, and installing efficient lights are usually done first. After that ceiling and floor insulation is most cost-effective. The last remaining components for heat loss are the walls and glazing and the cost-effectiveness of insulating the former is the subject of this report.

Energy savings for a variety of houses retrofitted in their walls was calculated using the ALF 3.1 software. The costs of retrofit were examined and compared to the energy savings in a present value analysis. Various climate zones were considered and the winter heating savings only, not summer cooling, were used in the analysis.

2. SUMMARY

Retrofit of walls was found to be economic in a number of situations. Table 1 shows the results for a medium-sized home (i.e. 120 to 160 sqm) heated to 20°C morning and evening, for different climate zones. To be cost-effective the benefit:cost ratio needs to be over 1.0 and the net present value (NPV) positive. Retrofit is cost-effective outside Auckland for electric resistant heating in non-weatherboard houses. It is also worthwhile for weatherboard houses in Invercargill for most heating types.

Table 1. Cost-effectiveness summary for commercial retrofitting

Medium house, Remove linings, insulate, reline Heating 20 deg C Morn/ Even						
Weatherboard cladding			**Benefit : Cost ratio**			
	Elect resist	Nitestor	Solid fuel	Pellets	Gas	Heat pump
Auckland	0.4	0.3	0.3	0.4	0.3	0.4
Wellington	0.7	0.5	0.4	0.5	0.5	0.5
Christchurch	0.8	0.5	0.5	0.5	1.1	0.5
Invercargill	1.4	1.0	0.8	0.8	1.6	0.8
			Net present value$			
Auckland	-5002	-5632	-5655	-5215	-5668	-5380
Wellington	-2536	-4077	-4603	-4403	-4373	-4383
Christchurch	-1780	-3859	-3935	-3759	481	-3975
Invercargill	2904	78	-1814	-1695	5188	-1928
Other cladding (brick, fibre cement, etc)			**Benefit : Cost ratio**			
Auckland	0.6	0.5	0.5	0.5	0.5	0.5
Wellington	1.0	0.7	0.6	0.7	0.7	0.7
Christchurch	1.1	0.8	0.8	0.8	1.5	0.8
Invercargill	2.0	1.5	1.1	1.2	2.4	1.1
Disct rate= 5%, Period = 30 yrs, Insulatn cost= $84 per sqm.						

The retrofit benefits are greater in non-weatherboard clad houses, e.g. veneer brick, because they have slightly lower uninsulated thermal R values than timber weatherboard houses and their energy savings after retrofit are higher.

There are a large number of assumptions behind the analysis including energy prices and escalation rates, retrofit costs, heating regimes, and the financial factors of the discount rate and the analysis period. The base case parameters are in Table 2. These are discussed later, but the most critical parameter is the retrofit cost.

Table 2. Base case parameters

Base case parameters	
Heating regime	20 degree C, Morning and evening, whole house heating.
Retrofit cost	$84/sqm of wall area
Discount rate	5%
Analysis period	30 years
Energy price escalation	1.6% pa above CPI inflation.
Existing insulation	Ceiling R4.0, Timber floor R2.0

Table 3 shows what price the retrofit needs to be for break-even between the retrofit cost and ongoing energy cost savings.

The calculated retrofit cost is $84/sqm of wall area, (see section 4.1), assuming removal and replace of linings and trim, painting, and R2.8 fibreglass insulation. The actual price of the insulation is about $18/sqm installed, so if the wall linings or cladding were being replaced for reasons other than insulation retrofit then the extra $18/sqm is well worthwhile as it is cost-effective for all situations in Table 3.

Similarly if the retrofit was deferred until when the owners are decorating then the paint top coat and trim cost is already committed, (about $26 per sqm) so that the effective cost of retrofit is reduced by this to about $58/sqm, which covers many of the combinations outside Auckland in Table 3.

The financial benefits of retrofit also depend on the energy cost. When heat pumps are used the economics of retrofit wall insulation are less favourable than with electric resistant heating. This is because heat pump unit costs (appliance and energy) are lower than for other heating sources for most situations, so the cost savings from insulation are lower.

Weatherboard houses had over 50% share prior to 1960, but in the 1960s and 70s other cladding types became more common. Wall, ceiling and floor insulation was mandatory in new houses from 1979 so it is the pre-1979 stock that is of most interest for retrofit. It is estimated the uninsulated timber weatherboard clad houses are only about 38% of the pre-1979 stock, the remainder being brick, fibre cement, and stucco. Hence the bottom parts of Table 1 and Table 3 cover the majority of uninsulated houses.

Table 3. Retrofit cost for break-even

Medium house, Breakeven cost for retrofitting			
	Break even cost $/sqm of wall area		
Timber weatherboard		Electric resistant heating	
	18degC M/E	20degC M/E	20degC All day
Auckland	26	33	40
Wellington	49	58	81
Christchurch	56	66	91
Invercargill	97	113	162
		Heat pump heating	
Auckland	27	29	32
Wellington	39	40	50
Christchurch	43	44	55
Invercargill	62	65	85
Other claddings (brick, fibre cement, stucco, etc)			
		Electric resistant heating	
	18degC M/E	20degC M/E	20degC All day
Auckland	39	48	60
Wellington	71	84	119
Christchurch	81	95	135
Invercargill	140	165	240
		Heat pump heating	
Auckland	43	45	48
Wellington	57	58	74
Christchurch	63	64	82
Invercargill	90	93	125
Disct rate= 5%, Period = 30 yrs.			
Already have R4.0 ceiling and R2.0 floor.			

3. MARKET POTENTIAL

The four main methods for retrofitting thermal insulation into walls are:

- Remove and replace exterior cladding
- Remove and replace interior linings
- Inject insulation (polystyrene beads or insulating foam) through the linings or cladding
- Place an insulation sheet (e.g. polystyrene) over the existing linings and relining.

The first two of these may occur when the cladding and linings have deteriorated and require extensive repair and/or replacing. This work provides an opportunity to install insulation into the timber frame. Injection may be a viable solution, but requires a large number of injection points to ensure full wall cover and repair of the injection points.

Finally insulation sheet can be retrofitted without moving the existing linings, but requires work on the reveals at windows and trim work.

The potential market for these methods depends somewhat on the types of cladding and linings and their condition. The following examines these characteristics for houses built before 1978, when wall insulation first became mandatory.

3.1 Cladding and linings types and condition

The viability of fitting insulation from the outside of house depends on the type of cladding and its condition. For example, a brick veneer cladding in good condition would probably not be cost-effective to retrofit with insulation from the outside. Figure 1 shows the types of cladding by age of house from the *House Condition Survey* (HCS) (Clark et al 2005). Timber weatherboard claddings are common on early houses and the weatherboard is fairly easily to remove. Depending on the skill of the workers it may be possible to re-use the boards.

If the cladding needs replacing due to poor condition, then the insulation retrofit cost for purposes of calculating the cost-benefits is the cost of the insulation only and does not include the cladding cost. Figure 2 shows houses from the HCS with poor condition cladding that probably need replacing or major repairs. The 1930s decade has the worst condition homes and houses in this age group may be good candidates for replacement claddings and insulation retrofit.

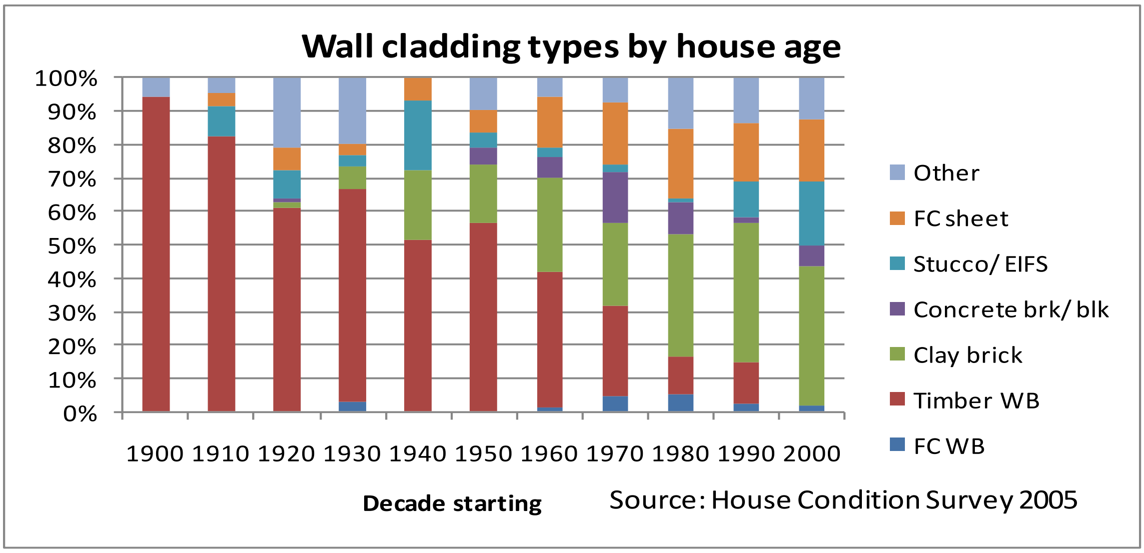

Figure 1. Wall cladding types by age of house

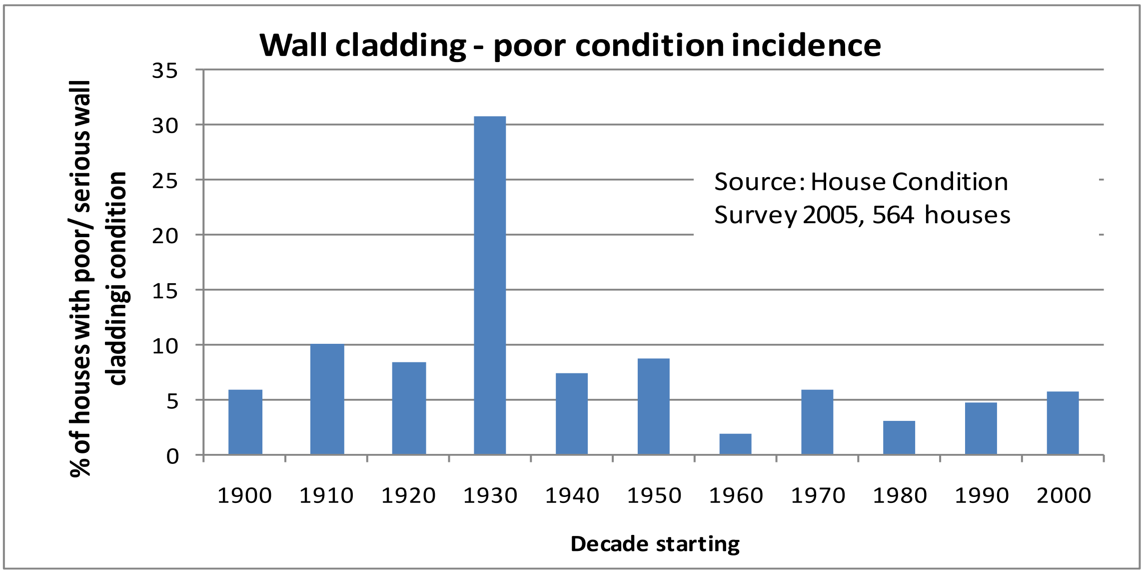

Figure 2. Wall cladding condition by age of house

An alternative to wall cladding retrofit is to remove the linings, replace the insulation, install new linings, and replace or install new trim to the internal wall. Most linings are plasterboard (see Figure 3). The lining condition is in Figure 4, and again the 1930s era houses are in the worst condition.

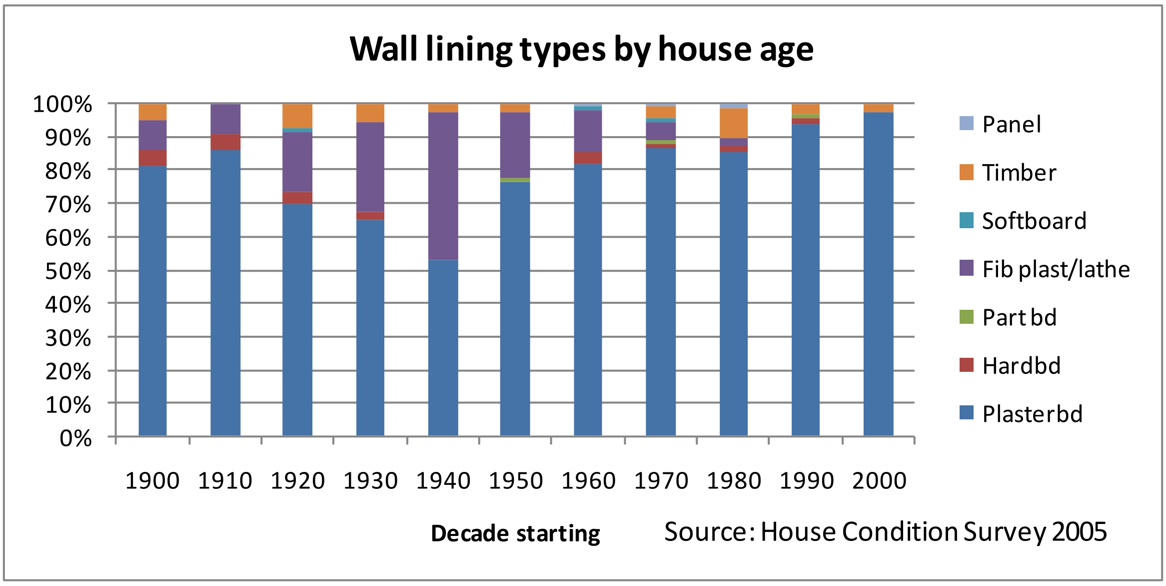

Figure 3. Wall lining types by age of house

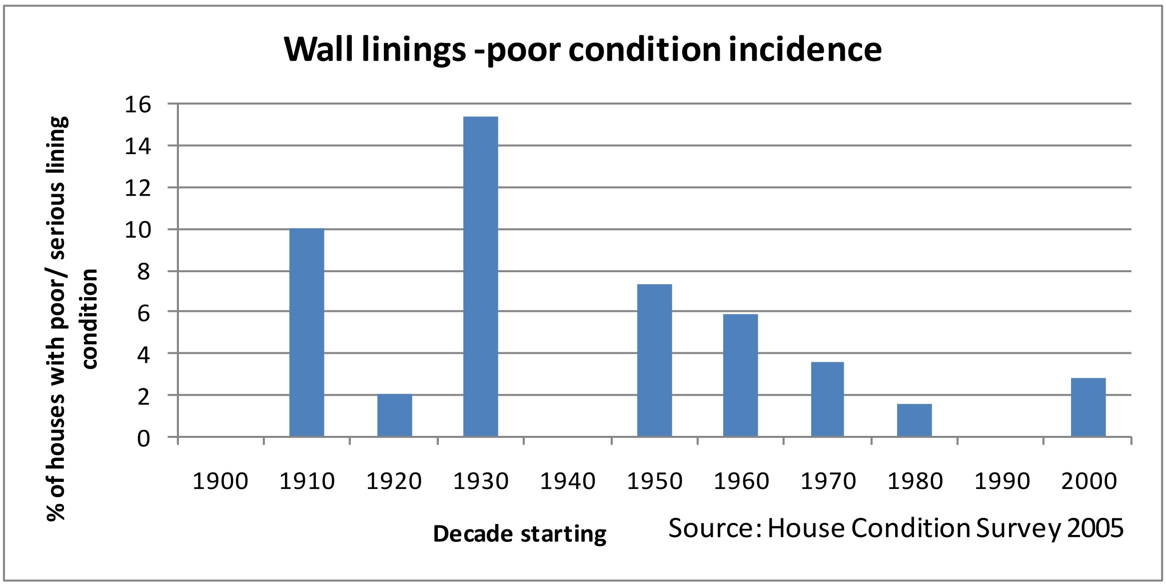

Figure 4. Wall lining condition by age of house

The age distribution of the dwelling stock is shown in Figure 5. The chart is based on Quotable Value data and it has been adjusted to the total numbers as at the 2006 Census. It includes empty homes such as holiday or for-sale homes. Numbers in the 1930s age group are not large, and in terms of retrofitting insulation the 1950s to 1970s offer the largest market. Between 4% and 8% of these houses, or about 35,000 houses, have poor claddings and/or linings, so a significant number will require work on their exterior walls, providing opportunities for insulation retrofit. The economics are favourable in these cases for all locations when the insulation is a marginal cost for the wall repairs that are already needed.

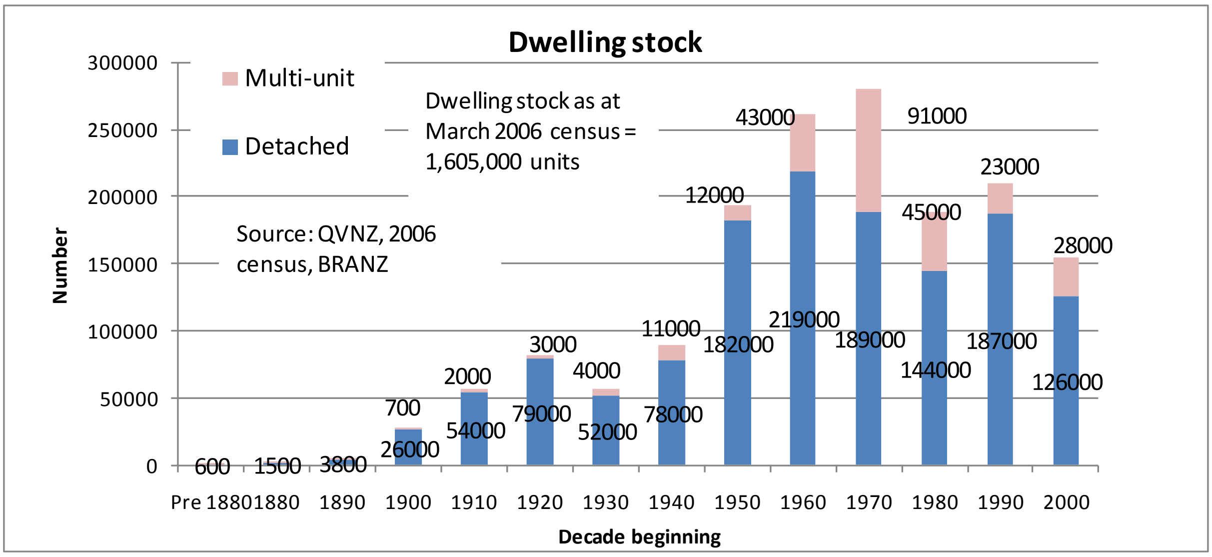

Figure 5. Dwelling stock distribution by age

Most of the analysis in this report considers the case where wall repair work is not needed from a condition viewpoint. What are the economics when cladding or lining removal and replacement costs need to be included in the decision?

4. COST-BENEFIT ANALYSIS OF RETROFIT

4.1 Retrofit costs

The retrofit costs were estimated using Rawlinson (2009), and the details are in Table 4 for the removal of linings and in Table 5 for the removal of claddings. Generally removal of the linings, insulating and replacing is cheaper than removing the wall claddings, insulating and re-cladding. If complete replacement of linings or claddings was occurring in any case, then the marginal cost is only $18/sqm of wall area, the cost of the insulation.

Table 4. Retrofit costs for interior access

Remove linings, insulate, replace. or fix polystyrene sheet to lining			
	$/sqm		
Option 1 Contract work	wall area		
Remove existing linings/ dispose.	2		
Standard plasterboard fix, stop	26		
Paint, seal 2 top coats	16		
Trim	18		
Insulation R2.8 Ultra	22		
	84		
Option 2 DIY, material cost only			
Standard plasterboard fix, stop	10		
Paint, seal 2 top coats	5		
Trim	9		
Insulation R2.8 Ultra	18		
	42		
Option 3 Glue fix polystyrene sheet over existing plasterboard			
100mm polystyrene	52		
Standard plasterboard fix, stop	26		
Paint, seal 2 top coats	16		
Trim	18		
Reveals/ sills at windows	20		
	132		
Source: Rawlinson 2009 NZ Construction Handbook			
Bullnose arch 60 x 10 mm rad pre-primed		11	$/m
Linear m trim per sqm wall		1.6	
Trim (skirting / window trim, no ceiling (sq flush)		18	$/sqm wall

For interior access removing and replacing linings is the cheaper option. The do-it-yourself (DIY) option is included for home-owners willing to do their own installation, and is significantly cheaper than commercial rates. Fixing polystyrene sheet and relining is quite expensive, and the floor area of the room is slightly reduced.

Table 5. Retrofit costs for exterior access

Remove weatherboards, insulate, replace	
	$/sqm
	wall area
Option 1 10% broken during removal, other 90% reinstated.	
Remove all boards	10
Replace 10%, include exterior trim	13
Reinstate 90%, include trim=	78
Insulation R2.8 Ultra	22
Paint	18
	141
Option 2 30% rotten (replaced anyway,	
5% broken during removal, other 65% reinstated.	
Remove all boards	7
Replace 5% incl exterior trim	7
Reinstate 65% incl trim	57
Insulation R2.8 Ultra	22
Paint (70% only)	13
	105
Replacement incl trim is $130/sqm	
Reinstatement assumed to be 67% of replacement.	

In comparison with the lining removal and replacing, the exterior option is expensive and would not normally be chosen.

4.2 Thermal modelling

Six single-storey houses were analysed in Alf 3.1 (Stoecklein et al 1999) for the energy saved for winter heating. The base case has draught-proofing, ceiling insulation to R4.0 and floor insulation to R2.0, and single glazing. These are the most cost-effective measures to be done first when houses are retrofitted (Page 2009). Then various amounts wall insulation were added, and the energy saving calculated. The results for adding R2.8 insulation are in Table 6, for weatherboard cladding. R2.8 is the highest R-value fibreglass product currently available. The savings in kW/sqm of floor area vary quite widely between the different sized houses in the same climate zone. Also brick clad houses have energy savings approximately 40% larger than the values shown in the table.

Table 6. Energy saving with wall retrofit

Energy savings with wall retrofit Weatherboard clad house.							
House ident.		1	2	3	4	5	6
Floor area sqm (1)		103	128	162	100	175	250
Floor plan shape		T	Rect	T	L	L	L
Window:Floor area		21%	23%	21%	23%	23%	23%
		kWh per sqm per year					
		18DegC Morn/Even					
Auckland		8.9	5.3	5.3	6.2	4.2	3.0
Wellington		16.5	9.9	9.7	11.6	7.8	5.8
Christchurch		20.3	12.2	11.9	14.2	9.6	7.1
Invercargill		32.4	19.4	19.1	22.6	15.3	11.5
		20DegC Morn/Even					
Auckland		11.3	6.8	6.6	7.9	5.3	4.0
Wellington		20.0	11.9	11.7	13.9	9.5	7.1
Christchurch		24.2	14.5	14.2	16.8	11.5	8.6
Invercargill		38.2	22.8	22.4	26.5	18.1	13.6
		20DegC All Day					
Auckland		14.4	8.3	8.8	9.1	6.6	5.0
Wellington		28.4	16.7	17.0	19.4	13.2	10.1
Christchurch		34.4	20.2	20.6	23.5	16.0	12.3
Invercargill		55.5	32.8	33.2	38.0	26.0	19.9
(1) Floor area is the conditioned floor area, i.e excludes garages.							
Assumes ceiling insulation R4.0 and floor insulation R2.0.							
Energy volumes from ALF3.1							

The conditioned area is for the whole house, excluding the garage. Morning and evening heating is 7am to 9am and 5pm to 11pm.

4.3 Net benefit summary

The cost-benefit analysis was done using the present value method and the details are in the appendix. The results averaged across the three smaller house types (i.e.103 sqm, 128 sqm and 162 sqm conditioned area) are in Table 7 for weatherboard houses, and Table 8 for other claddings.

The results for weatherboard are rather disappointing because they indicate that retrofit is not cost-effective outside the Invercargill climate zone except for quite high heating. The table has a number of assumptions including:

- installation cost $84/sqm of wall area
- energy prices escalate at 1.6% per annum above the rate of general CPI inflation
- the appliance cost is included in the unit energy price
- discount rate is 5% and analysis period is 30 years.

Table 7. Cost-benefit summary results –weatherboard cladding

Are wall retrofits cost effective Y/N? Weatherboard clad houses					
		Insulate	ALF Heating case		
	Analysis	relining cost	18°C M/E	20°C M/E	20°C All Day
	period	$/sqm			
	(Years)	National benefit case, commercial installation (r=5%, e= 1.6%pa.)			
Auckland	30	84	N	N	N
Wellington	30	84	N	N	Y, elect
Christchurch	30	84	N	N	Y elect,gas
Invercargill	30	84	Y elect,gas	Y elect,gas	Y
		DIY with short payback required (r=5%, e=1.6%pa).			
Auckland	10	42	N	N	N
Wellington	10	42	N	N	N
Christchurch	10	42	N	N	Y elect,gas
Invercargill	10	42	Y elect,gas	Y elect,gas	Y
		National benefit case, commercial installation (r=3%, e=1.6%pa)			
Auckland	30	84	N	N	N
Wellington	30	84	N	N	Y elect
Christchurch	30	84	N	Y elect,gas	Y elect,gas
Invercargill	30	84	Y elect,gas	Y elect,gas	Y
r= discount rate (real rate, excludes inflation).					
e= energy price escalation per annul, (real rate above general inflation)					
M/E = morning and evening heating, 7am to 9am, and 5pm to 11pm.					
All day is 7am to 11pm.					
N= Not economic for all fuels.			Y = economic for all fuels		
Y elect = economic for electrical resistant heaters only					
Y elect,gas = economic for electrical resistant heaters, gas heaters only					
Y excl HP = economic for all fuels except heat pumps.					

In Table 7 the trade-off is between the cost of the wall retrofit and the energy saved, discounted over the period to present value. There needs to be a positive net value and the table indicates that in Invercargill when the heating is electric resistant, electric night-store or gas heating, the retrofit is cost-effective. Also, in Christchurch with gas heating the retrofit is cost-effective. Elsewhere insulation is not cost-effective, regardless of the type of heating.

Expensive heating fuels, such as electrical resistant and LPG in the South Island, make it worthwhile to retrofit, otherwise it is not cost-effective for the chosen parameters (20°C morning and evening, $84/sqm retrofit cost, and 5% discount rate over 30 years). The next section looks at changes in the parameters.

Table 8 has a more favourable picture for other cladding types with wall insulation being cost effective in Wellington and Christchurch at 20°C electric heating morning and evening.

Table 8 Cost-benefit summary results –other claddings (brick, fibre cement, stucco)

Are wall retrofits cost effective Y/N?					
Non-weatherboard clad houses (i.e. Brick, fibre cement and stucco)					
	Analysis period (Years)	Insulate relining cost $/sqm	ALF Heating case 18^{o}C M/E	20^{o}C M/E	20^{o}C All Day
		National benefit case, commercial installation (r=5%, e= 1.6%pa.)			
Auckland	30	84	N	N	N
Wellington	30	84	N	Y, elect	Y, elect
Christchurch	30	84	N	Y, elect,gas	Y
Invercargill	30	84	Y	Y	Y
		DIY with short payback required (r=5%, e=1.6%pa).			
Auckland	10	42	N	N	N
Wellington	10	42	N	Y, elect	Y, elect
Christchurch	10	42	N	Y, elect, gas	Y
Invercargill	10	42	Y	Y	Y
		National benefit case, commercial installation (r=3%, e=1.6%pa)			
Auckland	30	84	N	N	N
Wellington	30	84	Y, elect	Y, elect	Y
Christchurch	30	84	Y, elect	Y, elect	Y
Invercargill	30	84	Y	Y	Y

r= discount rate (real rate, excludes inflation).
e= energy price escalation per annul, (real rate above general inflation)
M/E = morning and evening heating, 7am to 9am, and 5pm to 11pm.
All day is 7am to 11pm.
N= Not economic for all fuels. Y = economic for all fuels
Y elect = economic for electrical resistant heaters only
Y elect,gas = economic for electrical resistant heaters, gas heaters only
Y excl HP = economic for all fuels except heat pumps.

5. SENSITIVITY ANALYSIS

The various parameters were altered to assess the effect on NPV (see Figure 6 to Figure 9 for a weatherboard clad house).

The parameters were changed by +50%, +25% and -25%, -50% for the amount of energy saved, the period, the rate of energy price escalation, the discount rate, the insulation R-value and the retrofit cost. The charts show the effect of the change in the parameter, keeping all the other parameters at their base case value, with one exception. The exception is that the change in R-value is achieved by using insulation with a different cost to the base case.

The values of the changed parameters in the sensitivity analysis are in Table 9. For example, a 50% increase in the discount rate brings it to 7.5%. Another example – the volume of energy saved – is changed by -25% bringing it to 5.1kWh in Auckland (this could be due to poorly fitted insulation). The base case parameters are shown in the 0% change row.

Table 9. Changes in parameters in the sensitivity study

Sensitivity analysis - Parameters changed Weatherboard house							
Percent change	Discount rate %	Period (years)	Energy price escalation % pa	R value insulation	Retrofit cost $/ sqm wall	Energy saved kWh/ sqm/yr (1) Auckland	Christchurch
-50%	2.50%	15.0	0.80%	1.40	42	3.4	7.2
-25%	3.75%	22.5	1.20%	2.10	63.0	5.1	10.9
0	5.0%	30.0	1.60%	2.80	84.0	6.8	14.5
25%	6.25%	37.5	2.00%	3.50	105.0	8.5	18.1
50%	7.50%	45.0	2.40%	4.20	126.0	10.1	21.7
The base case is 0% change in the parameters							
(1) Energy savings are for the 128 sqm medium house. 20 degC Morn/Even heating.							

The most sensitive parameter (i.e. the lines in the charts with the steepest slope) is the retrofit cost, followed by the discount rate. In contrast, changes in the energy price escalation rate do not affect the NPV very much. Likewise changes in the insulation R-value do not affect NPV greatly, probably because for this parameter the insulation cost has also been changed simultaneously with the R-value. The R-value line demonstrates that the default case of R2.8 is optimum (NPV has the highest value) in Invercargill, and in the other regions it is optimum at -25%, i.e. at R2.1.

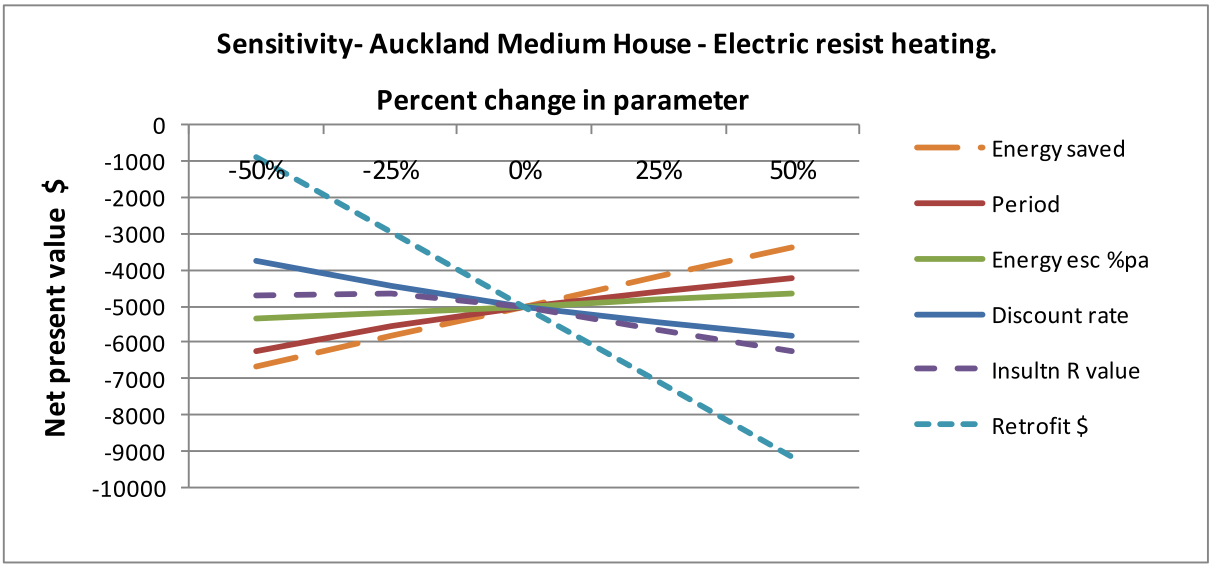

Figure 6. Sensitivity analysis – Auckland

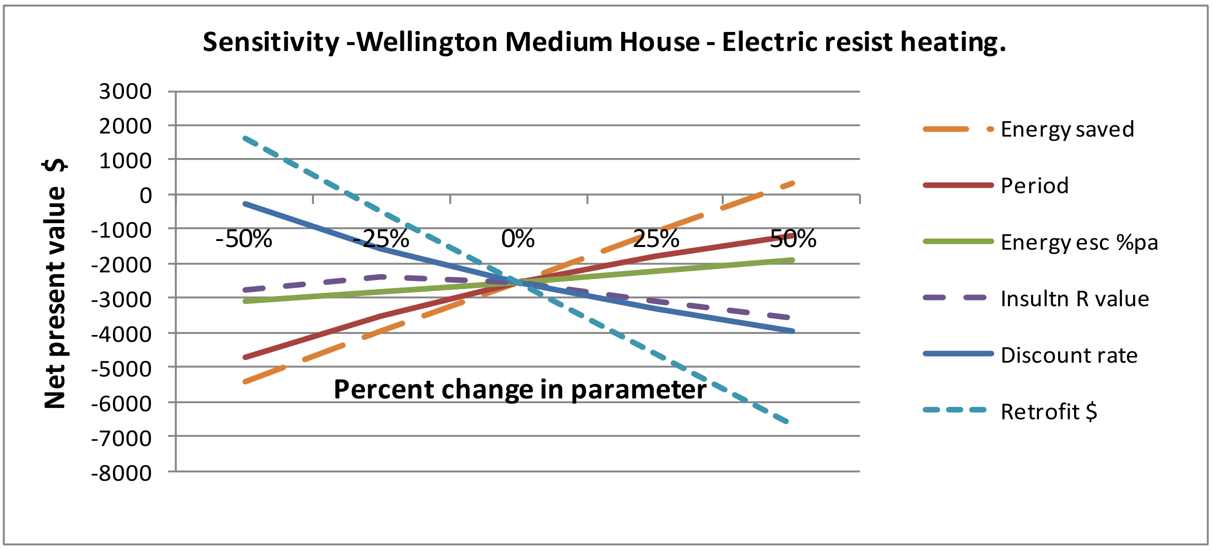

Figure 7. Sensitivity analysis – Wellington

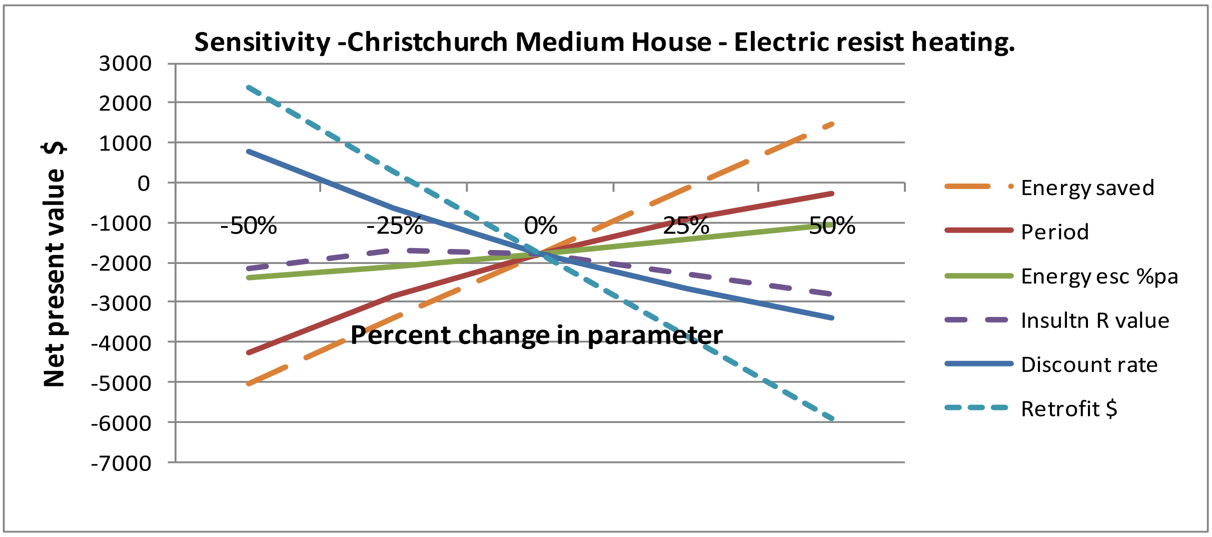

Figure 8. Sensitivity analysis – Christchurch

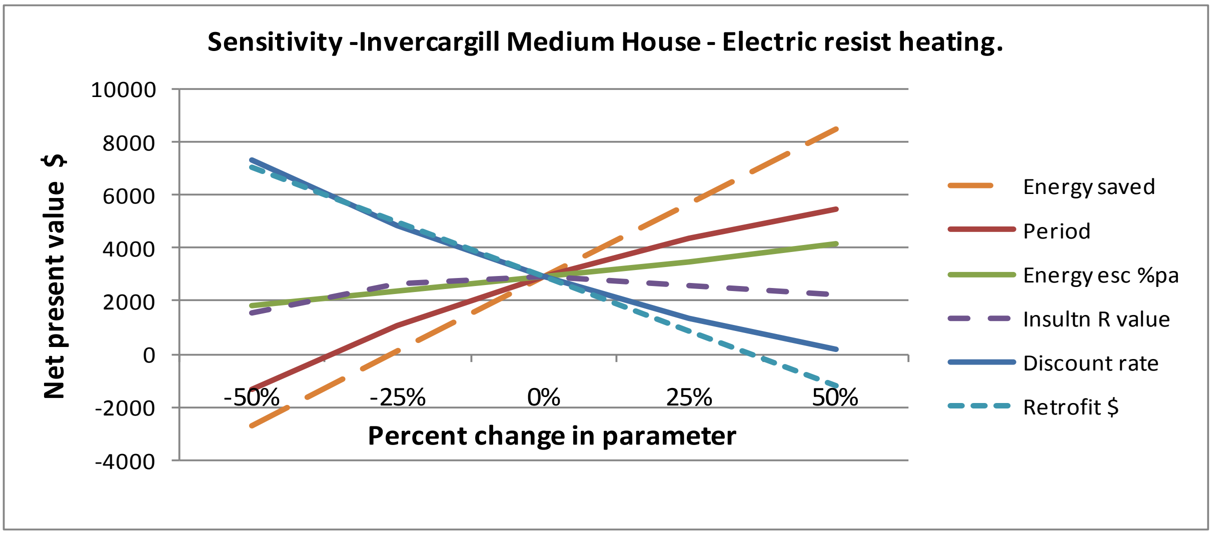

Figure 9. Sensitivity analysis – Invercargill

The charts show the amount of change required to obtain a positive NPV. For example, in Wellington the retrofit cost needs to reduce by more than 25% (from the base case $84/sqm), or the amount of energy saved has to be 50% higher than assessed by ALF.

Retrofit costs are the most sensitive parameters and a further analysis of these is in Figure 10. This chart indicates the retrofit cost needs to fall to about $60/sqm of wall area in Wellington and Christchurch before there is a positive NPV. In Auckland the cost needs to be about $30/sqm for positive NPV.

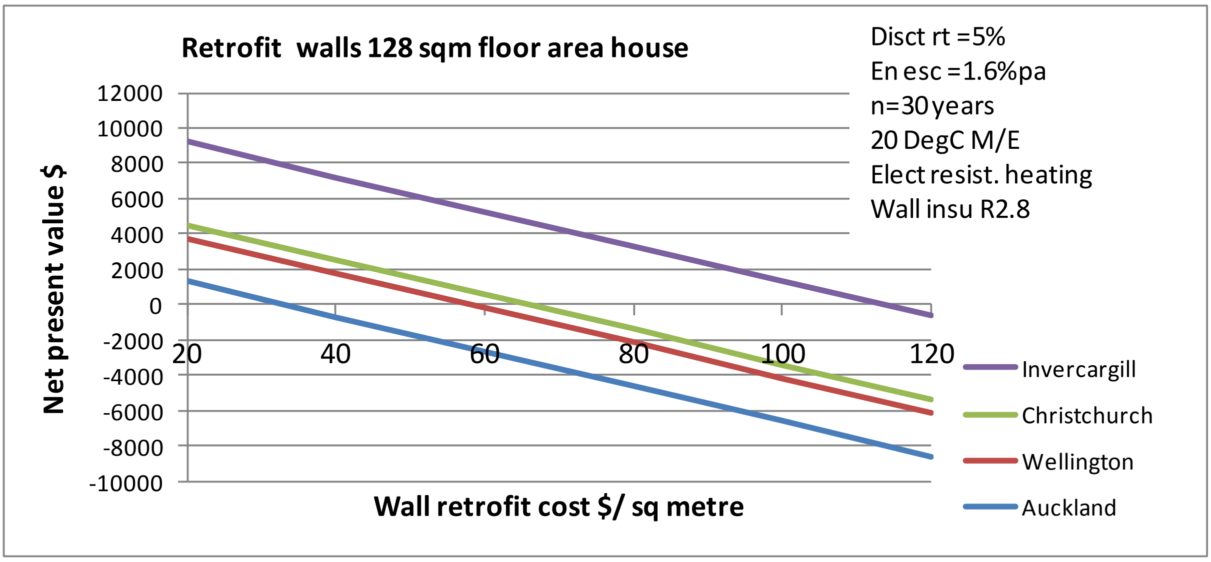

Figure 10. Wall retrofit cost and NPV

An alternative approach is to ask what the retrofit cost needs to be, with various insulation R-values, at the break-even point where the discounted value of the energy savings just covers the cost of the wall retrofit. Figure 11 shows these values for the medium-sized weatherboard house. It can be seen that above R2.8 insulation the curves are quite flat, indicating that products other than fibreglass (which may have a higher insulation rating and can fit in the 95 mm wall cavity) do not improve the energy savings significantly.

Figure 11 can be used for alternative insulation measures such as foams injected into the wall cavity. If the R-value of the insulation is known then the required retrofit cost for break-even can be calculated. For example, suppose the installers claim an R-value for their insulation of R2.8. Then in Wellington the installed price needs to be less than $60/sqm of wall area for the home-owner to be better off assuming various parameters (30-year period, 5% discount rate, 20°C heating etc).

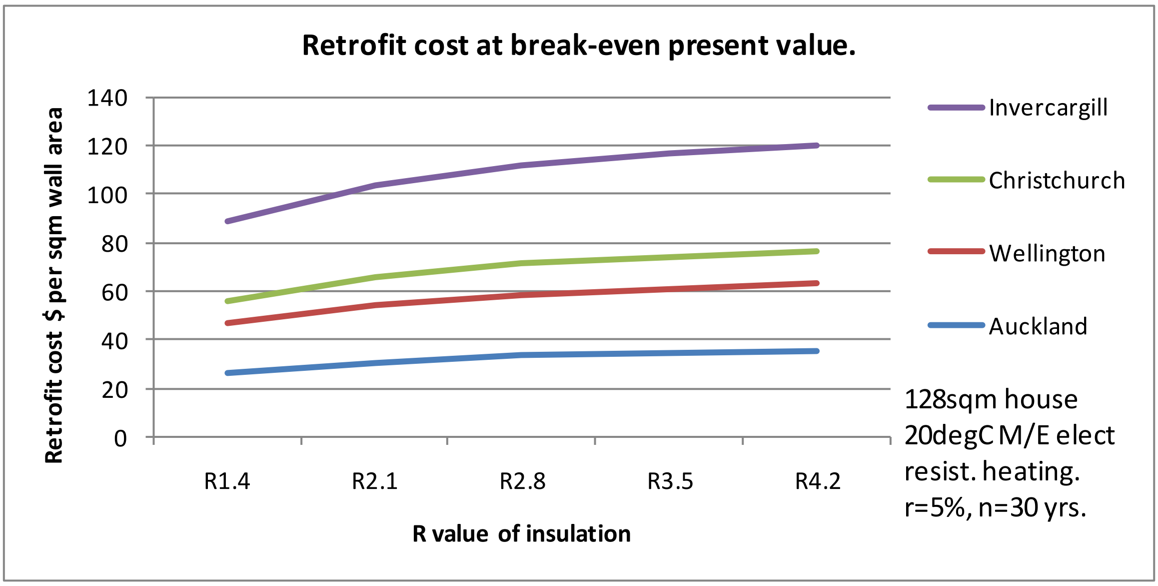

Figure 11. Required retrofit cost at break-even point by insulation R-value – default assumptions

Most home-owners would be looking for a shorter payback than 30 years and Figure 12 shows the required retrofit cost for a 15-year payback period for the weatherboard house. It indicates that the retrofit cost needs to be below $50/sqm in Christchurch, $40/sqm in Wellington, and $20/sqm for Auckland.

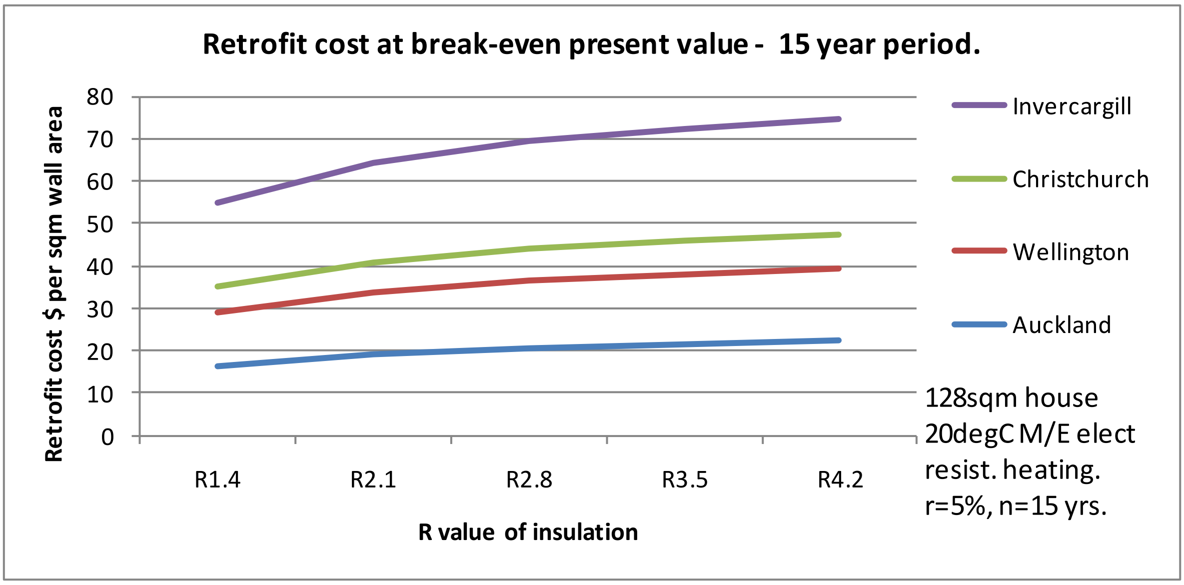

Figure 12. Required retrofit cost at break-even point by R-value – 15-year analysis period

6. DISCUSSION

Table 1 indicates that very few locations and fuel types provide cost-effective wall retrofits for the weatherboard house. The results for other cladding types are better and electric resistant heated houses in Wellington and cooler locations are worth retrofitting. These results are based on the default parameters of $84/sqm and 20°C morning and evening heating.

The retrofit cost was based on commercial rates as calculated in Table 4 and allows for new trim, stopping and repainting. It can be argued that the replacement trim, lining and finish are likely to be to a higher standard than existed prior to retrofit, and hence not all the cost should be included in the financial analysis. Wall retrofit mainly occurs on pre-1979 houses rather than younger houses when wall insulation became mandatory. If the cost of the painting and trim is subtracted in Table 4, i.e. it is assumed that work was done for aesthetic reasons, the retrofit cost reduces to $50/sqm. From Table 3 it can be seen that Wellington and Christchurch become cost-effective for retrofit with most combinations of heating temperatures, heating appliance and cladding type.

The energy prices used in the default case include the cost of the heating appliance spread over the life of the appliance and the volume of energy used. The details are in the appendix. The assumption is that the decision to purchase the appliance and retrofit the wall is made at the same time. If the heating appliance is already in place before deciding to retrofit the wall, then in financial terms the appliance cost is "sunk". This means that the retrofit analysis considers only the fuel cost, without the appliance cost. The result is that the energy cost is lower than the default case and the economics of insulation are worsened.

7. REFERENCES

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8. APPENDIX

This appendix contains the following:

- Present value method
- Fuel and appliance costs.

8.1 Present value method

The present value method is used to bring all costs to present day values so that consistent comparison can be made between different retrofit options having different energy consumption levels.

Present value PV = $M + C_1/(1+r) + C_2/(1 + r)^2 + C_3/(1+r)^3 + \ldots + C_n/(1+r)^n$
Where:
M is the cost of the retrofit at year t=0.
$C_1, C_2, C_3, \ldots + C_N$ are space heating energy or water supply costs in year 1, 2, 3 … n.
r = discount rate.
n = period of analysis, years.

Net present values are calculated for the various measures with the base case being nil wall insulation (but ceiling and floor insulation). The fuel cost includes the appliance cost amortised over its replacement period and the details are in Table 10. Fuel costs are assumed to escalate above the rate of general inflation, so the energy costs change from year-to-year.

8.2 Fuel and appliance costs

Table 10. Energy and heating appliance costs

Energy cost modelling						
	Electric resist. (1)	Electric nitestor	Solid fuel (coal, wood)	Pellets burner	Gas (flued) Nat or LPG	Elect Heat pump
	Fuel costs c/kWh at year 0.			(2)		
Auckland	19	13	10	9	10	7
Wellington	19	13	10	9	10	7
Christchurch	18	11	10	9	22	6
Invercargill	20	14	10	9	22	7
	Appliance cost $ (include installation) (4)					
Auckland	275	1100	2750	4400	2200	3300
Wellington	495	1100	2750	4400	2860	4400
Christchurch	495	1100	2750	4400	2860	4400
Invercargill	660	1650	3300	5500	3850	5500
	Years (5)					
Appliance replacement	15	20	30	30	20	15
	Energy cost + appliance costs c/kWh					
Auckland	20.2	16.9	19.2	23.6	17.3	17.9
Wellington	20.0	14.9	14.2	15.7	14.4	13.6
Christchurch	18.7	13.0	13.7	15.0	25.9	12.4
Invercargill	20.5	15.5	12.7	13.5	25.2	11.6
(1) Electric resistant panels						
(2) Pellet burners with automatic feed.						
(3) Gas heating is natural gas in the North Island, and LPG in the South Island.						
(4) Appliance costs allow for bigger heaters, or more of them in the cooler regions.						
(5) BRANZ estimate of appliance replacement period.						
(6) Energy + appliance costs allows for a sinking fund for the appliances over their lives. Assumes 5%						
discount rate , and cents/ kWh are calculated for the appropriate energy consumption after retrofit:						
		kWh/ yr				
	Auckland	2894	)			
	Wellington	6315	assumes ceiling, wall and floor insulation			
	Christchurch	7123	) and single glazing - Medium hse 20 DegC M/E.			
	Invercargill	11758	)			

Repayments on the sum borrowed for a heating appliance are added to the energy cost in the above table. Outside of Auckland the cheapest appliance is the heat pump, followed by the solid fuel burner. In Auckland the cheapest heating is from the solid fuel heater.