Beacon
TOGETHER, CREATING TOMORROW'S HOMES

Beacon Pathway Limited
PO Box 11 338 Auckland
FreePhone 0508 beacon
www.beaconpathway.co.nz
www.nowhome.co.nz

TE106

SUSTAINABILITY OPTIONS FOR RETROFITTING NEW ZEALAND HOUSES - ENERGY

A REPORT PREPARED FOR BEACON PATHWAY LIMITED

August 2006

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

FOUNDATION FOR RESEARCH SCIENCE & TECHNOLOGY
Tūāpapa Rangahau Pūtaiao

Creating homes and neighbourhoods
that work well into the future
and don't cost the Earth

SUSTAINABILITY OPTIONS FOR RETROFITTING HOUSES – ENERGY

AUTHORS

McChesney, I [1] and Amitrano, L[2]

Team leader signature ……………………………..

REVIEWERS

Page, I [2]

Saville-Smith, K[3]

1. Energy Consultant, Christchurch
2. BRANZ Ltd, Private Bag 50908, Porirua
3. CRESA, PO Box 3538, Wellington

Reviewer signature ……………………………..

ABSTRACT

This is a desk top study of all the existing research programmes that address the benefits of retrofitting house including: Housing, Insulation and Health (HIH) study – Wellington School of Medicine; Peak Load Reduction study – Orion; Energy and Public Housing Study 2003 – Otago University; Residential Energy Efficiency Retrofits – EECA; Heat Pump / Insulation Assessment – CEA; Private Dwelling Retrofit Study 1997-2000 – BRANZ/

Most programmes are aimed at low income households and include a "standard package" of measures - comprising ceiling insulation, basic underfloor foil and draught-proofing of doors. A combined efficiency/heating appliance package appears to provide better outcomes than a basic energy efficiency package alone, especially in colder parts of the country. Retrofitting needs be less of a standardised package across the country, with more attention given to geographic location, the characteristics of the house, and individual household circumstances.

REFERENCE

August 2006. Sustainability Options for Retrofitting New Zealand Houses - Energy

Report TE106/4 for Beacon Pathway Limited.

CONTENTS

TABLES

FIGURES

1. EXECUTIVE SUMMARY

Many New Zealand houses are cold and damp and hard to heat in winter. In order to tackle this ‘problem’, a number of research programmes have been undertaken in the past decade to study the impact of retrofitting houses in New Zealand. To better understand the results of these studies, the objective of this project was to carry out a desk top study of all the existing research programmes that address the benefits of retrofitting houses.

Six research programmes were reviewed:

- Housing, Insulation and Health (HIH) study – Wellington School of Medicine
- Peak Load Reduction study - Orion
- Energy and Public Housing Study 2003 – Otago University
- Residential Energy Efficiency Retrofits – EECA
- Heat Pump / Insulation Assessment - CEA
- Private Dwelling Retrofit Study 1997-2000 - BRANZ

The review included a detailed description, the key findings and the main conclusions of each programme, with the view to distilling key information that would support early and rapid adoption of retrofit housing at a national level. This project is one of a series of projects to provide Beacon Pathway Ltd (Beacon) with a way of engaging in the retrofit housing sector thereby improving the sustainability of existing homes.

The main conclusions of the project were:

In almost all instances, the selected programmes have aimed at low income households and included a “standard package” of measures - comprising ceiling insulation, basic underfloor foil and draught-proofing of doors. These measures generally achieved an average 0.5-1ºC temperature gain which was found to be insufficient to lift indoor temperatures into an acceptable zone of comfort (or health). As a result over time (1-2 years) it appears that much of the energy efficiency gains were taken back as “energy creep” to increase the temperature and comfort levels of what were essentially often under-heated homes.

Some energy efficiency retrofit programmes in New Zealand are now including a heating appliance upgrade as an integral part of the package. The combined efficiency/heating appliance package appears to provide a much better set of multiple outcomes (e.g. environmental outcomes and comfort gains) than a basic energy efficiency package alone, especially in colder parts of the country. These findings tend to reinforce a growing body of evidence both in New Zealand and overseas about the need to link together packages of integrated solutions for householders. These would be underpinned by good thermal insulation and efficiency upgrades but would not rely on these actions solely to achieve desired outcomes. Overall, it suggests that retrofitting needs be less of a standardised package across the country, with more attention given to geographic location, the characteristics of the house, and individual household circumstances.

As a result of these conclusions, the following recommendations were made:

R1. Quantify the temperature / energy savings trade off: further research is recommended to quantify ‘comfort creep’ effects, and ascertain the benefits to the energy system from insulation investment (from peak load reduction, energy demand reduction and environment mitigation). As it stands at present, if there are true long-term peak demand reductions available from insulation, they are currently going unrealised, and need to be quantified in the energy price assumptions used in cost-benefit analyses. [Key parties: EECA, Electricity Commission].

R2. Recognise that insulation on its own is not necessarily enough: a review and restructure of the scope of present retrofit programmes is recommended. Tailor insulation retrofit packages to particular market niches – recognising geography, etc. Move beyond the “one size fits all” approach. Integrated packages of heating and insulation should be available in order to provide a true focus on ‘outcomes’ – health, comfort, clean environment, etc. with a consistent funding approach. [Key Parties: EECA, MfE, EECN (Energy Efficiency Communities Network), Contact Energy. Beacon could play a key role in bringing parties together at a forum to facilitate new approaches]

R3. Investigate what could be done to better support retrofitting: tools that provide leverage for non-profit/private/commercial market players to better promote retrofitting and ‘best practice’ solutions are needed. Of priority would be the development of achievement standards and methods that enable householders to receive tailored, high quality advice and follow-up. [Key Parties: BRANZ, Beacon, EECN or EECA].

2. INTRODUCTION

2.1 Background

Despite New Zealand being in the mid-latitude zone with a temperate climate, our houses have a reputation as being cold, damp and hard to heat in winter. Some see this as reflecting a certain stoic resilience and thrift on the part of Kiwis – that cold spells and the vagaries of the New Zealand climate are things to be endured rather than being protected from. But there is a growing awareness that cold damp homes pose health risks, especially for particular groups in the community, mainly the very young, and elderly, and those with chronic health problems (Howden-Chapman et al, 2004). In addition, the types of heating used pose health concerns, in particular, air pollution caused by solid fuel heating, and the release of combustion products from unflued gas heaters.

To date, much of the focus of retrofit measures has been on improving the thermal insulation of houses, based on the rationale that thermal insulation will a) reduce heat loss and improve indoor temperatures, and b) reduce the amount of heating required. The primary benefits of home insulation are therefore: improved energy efficiency of home heating systems; reduced pollution from the energy sources; and the ability to better maintain comfortable indoor temperatures. Insulation can also provide a reverse benefit in hot weather by slowing the rate of heat from the outside to the inside, and thus maintaining houses in a comfortable (cooler) state.

Prior to 1978 there were no requirements nationally for thermal insulation to be included in new house construction. Thus, about 65% of the current housing stock (or about 0.9m dwellings) are estimated to have been built prior to any mandated requirement for insulation. Of these, a small percentage would have had insulation installed when they were constructed (regardless of there being no legal obligation), while many others have been retrofitted with some form of insulation, mainly in the ceiling. Since the mid 1990s an increasing number of energy efficiency retrofit programmes have been underway throughout the country, with Government assistance being available for low income homes. In 2001 Government set a target through the National Energy Efficiency and Conservation Strategy (NEECS) to address all pre 1978 homes with a *"suite of cost-effective energy efficiency measures"*. At that stage it was believed that about 0.6M homes had no or inadequate insulation, with some 0.15M low income households being the primary focus to achieve health and welfare improvements (EECA & MfE, 2001).

2.2 Terms of Reference

This project is one of a series of projects to provide Beacon Pathway Ltd (Beacon) with a way of engaging in the retrofit housing sector thereby improving the sustainability of existing homes. Beacon has five overarching objectives for its Retrofit Research Programme. These are:

1. Development of information to support early and rapid adoption of retrofit housing.
2. Defining an effective and achievable level retrofit for the New Zealand housing stock that Beacon can use in the short term (1 year) to improve the sustainability of houses.
3. Prioritise retrofit opportunities with respect to housing stock/home ownership market segments.
4. Leverage Beacon's existing work across the four research streams bringing a focus on retrofit.

5. Provide information and outline effective delivery mechanisms that will influence government policy by providing compelling quantitative case for retrofitting houses nationally with respect to the economic, health benefits and reduction in carbon emissions.

This project contributes primarily to objectives 1 and 2 and comprises four key stages:

- Stage 1 : Cost benefit analysis at house level
- Stage 2: The THEN House
- Stage 3: National cost-benefit analysis
- Stage 4: Establish pilot community project

Each stage consists of a number of steps. Stage 1 consists of three steps:

- Step 1. Carry out a desk top study of all the existing research programmes that address the benefits of retrofitting houses.
- Step 2. Identify a range of options and the feasibility of each option using the information from Step 1.
- Step 3. Test the range of options against a number of different scenarios dependent on the base case to develop a range of achievable retrofit options or packages

This report details the results of Stage 1, Step 1. The results of the other stages and steps is reported elsewhere.

2.3 Project Scope

This project was tasked with investigating all existing research programmes that address the benefits of retrofitting houses. To manage the scope of the project, the following criteria were applied in order to select programmes for review:

- The programmes had to be New Zealand based and undertaken in the past decade
- The programmes focussed on the benefits of ‘energy-based’ retrofits (in particular, the addition of insulation)
- The programmes focussed on understanding and providing a baseline for energy use in New Zealand homes.
- The programmes had a robust research methodology that investigated outcomes

Based on these criteria, eight programmes were selected for review:

- Housing, Insulation and Health (HIH) study – Wellington School of Medicine
- Peak Load Reduction study - Orion
- Energy and Public Housing Study 2003 – Otago University
- Residential Energy Efficiency Retrofits – EECA
- Heat Pump / Insulation Assessment - CEA
- Private Dwelling Retrofit Study 1997-2000 - BRANZ

Other short-term initiatives include: CFL lights campaigns (Christchurch and Auckland); and a refrigeration upgrade campaign. These had not been fully evaluated at the time this report was written and were therefore excluded from this study.

Each programme was reviewed by describing the nature of the trial or study and noting any particular issues around the sample selection, measurement, time period etc. Quantitative results for energy savings, temperature and humidity (where available) are analysed, and any other outcome findings examined. Comment is provided on the overall results and their applicability.

2.4 Structure of Report

Chapter 1 details the Executive Summary to the report.

Chapter 2 provides the background, terms of reference, and scope of the project.

Chapter 3 outlines the benefits of retrofitting houses.

Chapter 4 provides an overview of the selected research programmes that address the benefits of retrofitting houses.

Chapter 5 provides a discussion of the results of chapter four and makes relevant conclusions.

Chapter 6 provides the project's recommendations.

3. BENEFITS OF RETROFITTING HOUSES

The focus on insulation as an important energy retrofit strategy for cold homes and air pollution is primarily founded on the rationale that thermal insulation will:

a) reduce heat loss and improve indoor temperatures, and

b) reduce the amount of heating required (and reduce air pollution as a result).

The addition of insulation slows down the rate of heat loss from the house to the surrounding outside area. The ability of the insulating material to resist heat flow is measured as an R-value (Total Thermal Resistance). The higher the R value, the better the insulation. The primary benefits of home insulation are therefore: improved energy efficiency of home heating systems; reduced pollution from the energy sources; and the ability to better maintain comfortable indoor temperatures. Insulation can also provide a reverse benefit in hot weather by slowing the rate of heat from the outside to the inside, and thus maintaining houses in a comfortable (cooler) state.

Thus the benefits of retrofitting houses can be broadly categorised as a private and/or public benefits, both energy and non energy related. For example:

- Financial (cost savings) benefits to the home occupier through reduced energy costs and potentially smaller and fewer heating appliances
- Private and public health benefits through reduced air pollution
- Improved comfort and health – benefits are both private and public
- Private environmental health benefits, primarily noise mitigation through the sound absorbing qualities of insulation materials
- Improved house value/resale value, and other private benefits.

The remainder of this chapter examines these benefits in more detail as a means of informing the evaluation of the selected research programmes.

3.1 Energy saving benefits

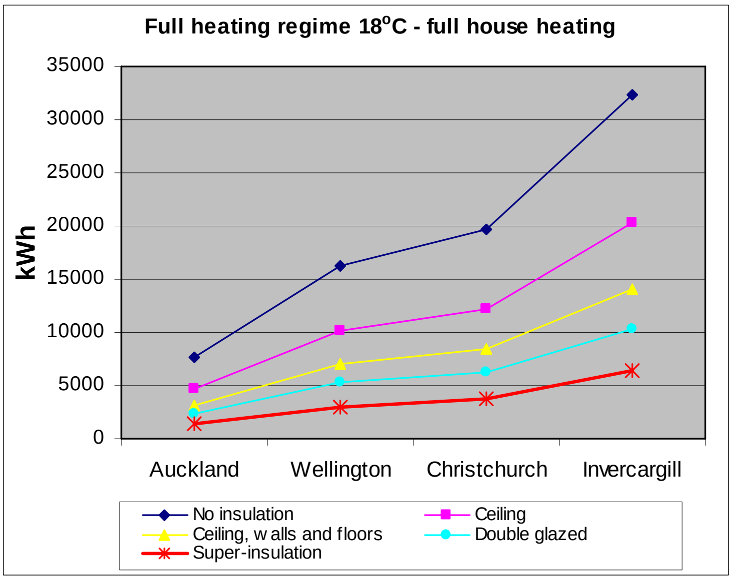
The energy saving benefits of insulation are highly context-related and thus depend on a range of variables. The main factors are:

- location (i.e. in relation to climate)
- the heating regime adopted
- type(s) of heaters used in the home
- the order in which insulation retrofitting occurs, and
- the levels of insulation retrofitted.

In order to explore the influence of these variables, BRANZ's ALF3[1] modelling tool was used. A typical house was modelled in 4 locations throughout the country, using 2

[1] The acronym ALF stands for *annual loss factor,* referring to the net energy losses from a building.

different heating regimes (full heating, and a lesser level – "kiwi" heating regime), with a range of insulation regimes ranging from uninsulated to superinsulated[2] (Figure 1).



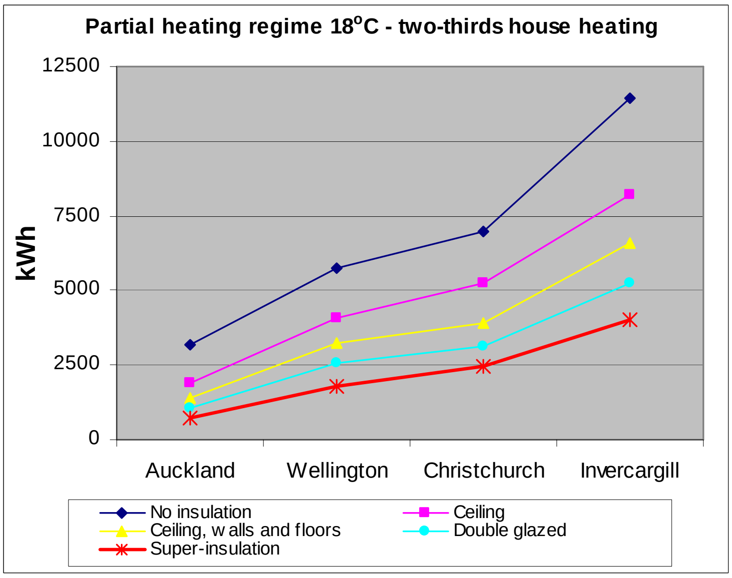


Figure 1. Theoretical annual heating requirements under two different heating regimes and a range of insulation levels (calculated using ALF3[3]).

Under a full heating regime[4] the addition of ceiling insulation to the uninsulated house in Christchurch in theory would save 7,500kWh per annum, while in Invercargill the savings

---

[2] Note that these examples are provided to be indicative, not definitive. The modelled house contained a number of assumptions based on the 'typical' (e.g. 130m^2, detached, single story etc). The 'super-insulated' case is based on relatively high levels of insulation applying to all of the building envelope elements, but is not optimised for the most cost-effective levels of insulation.

[3] The means of estimating energy use for the two-thirds heating example was quite unsophisticated and was simply a pro-rata from full house heating. For a more detailed discussion on ways of correcting ALF for unheated areas of the house see Isaacs et al (2005).

[4] Heating maintained for 24 hours per day, maintained at an average of 18ºC.

could be as high as 12,000kWh. On the face of it, this suggests paybacks on ceiling insulation investment could be as low as 1 year or less in some circumstances[5].

However full house heating is rarely achieved in practice. In the partial heating regime, much more akin to New Zealander's real heating behaviour, theoretical savings would be 1,700kWh for Christchurch and 3,200kWh Invercargill, representing paybacks of 5 years and 3 years for electrical resistance heating. If the heating was undertaken by an efficient wood burner, or a heat pump, where the effective per kWh energy cost was about 8c/kWh, the paybacks would increase to 7-13 years. If the wood was "free" through self collection, the payback would depend on the value of time and other costs individuals attached to their wood harvesting efforts. Theoretical energy paybacks under some of these assumptions are summarised in Table 1.

Table 1. Theoretical energy savings paybacks on ceiling insulation retrofit (carried out as the first retrofit measure)

Heating Regime	Type of heating	Energy cost (c/kWh)	Auckland	Christchurch	Invercargill
			Simple payback (yrs)		
Full Heating	Electricity - resistance	19 c/kWh	3	1.2	0.8
	Electricity – heat pump	8 c/kWh	7	3	2
	Gas – bottled LPG	18 c/kWh	3	1.4	.9
	Gas – reticulated (natural)	11 c/kWh	5	N/A	N/A
	Wood burner	5 c/kWh**	11	5	3
	Wood burner (full cost)	18 c/kWh	3	1.4	.9
Partial Heating	Electricity - resistance	19 c/kWh	7	5	3
	Electricity – heat pump	8 c/kWh	17	13	7
	Gas – bottled LPG	18 c/kWh	8	6	3
	Gas – reticulated (natural)	11 c/kWh	12	N/A	N/A
	Wood burner	5 c/kWh**	28	20	11
	Wood burner (full cost)	18 c/kWh	8	6	3

For energy costs, see Appendix 2.

*Assumes a mix of commercial and self collected wood.

** Assumes commercially bought wood used. The price provided is an average as it varies significantly dependant on region and wood type.

The order of insulation installation is important in terms of marginal cost effectiveness[6]. Each successive insulation retrofit reduces overall heating energy use (all other things being equal) which means that the initial retrofit actions will tend to have the highest marginal energy savings and cost effectiveness. For example, in the case above for partial heating with electric resistance heating in Auckland, if wall and underfloor insulation were installed first, the total amount of energy use would be reduced so when the ceiling insulation was installed the simple payback would be 11 years (c.f. 7 years if installed first). This can have the effect of rendering some types of insulation retrofits "uneconomic" unless they can be considered as part of an integrated package.

---

5 Based on $13.50/m^2 for R3.2 ceiling insulation (installed) and 19c/kWh for electrical heating.

6 Cost effectiveness of the marginal energy savings (c/kWh) achieved with each successive insulation retrofit measure.

Diminishing return effects are also characteristic of the effectiveness of improving each measure. Doubling the thickness of insulation, for example, does not lead to a doubling in insulation performance.

A further factor, important in understanding the role played by insulation, is the influence of secondary forms of heat output in the house. Secondary heat sources include:

- heat standing losses from hot water systems
- heated towel rails
- standby losses from appliances
- heat dissipated refrigerator/freezer coils
- secondary heating effects from hot water use and from cooking
- heat from lights, and
- heat from humans.

They make up an important part of the overall heating 'budget' of a house. Insulation can raise house temperatures with zero primary heating input, simply as a result of increasing the heat retention from secondary sources, and improving the efficiency of natural energy capture (e.g. solar gains).

3.2 Non-energy saving benefits

The non-energy saving benefits of insulation depend to a large degree upon the behaviour of the householder, and the extent to which they trade off energy savings against temperature increases and improved comfort. When insulation is installed, householders can choose to maintain their existing level of warmth and comfort, reduce energy use and take the benefits as energy savings. Alternatively, they could choose to maintain their use of energy and take the benefits as increased warmth and comfort in the home. Or, they could choose some intermediate point which provides both comfort gains and energy savings.

Quantifying the 'average' trade-off is not simple. In reality the trade-off depends on variables including geographic location, house characteristics, extent of insulation, and householder heating behaviour. For example, a partially heated house in Auckland with an average temperature of 16.5ºC receiving a basic insulation retrofit of ceiling and floors might expect theoretical energy savings of 1,000-1,300kWh/year. If the occupants chose to be warmer by 1ºC – achieving an average house temperature of 17.5ºC - then the extra temperature gain would likely reduce the energy savings by about half. In Invercargill, if a house was heated all day to an average temperature of 15ºC and received the same insulation retrofit package, theoretical energy savings might be about 5,000kWh/year. In order to achieve an average 1ºC temperature lift, some 2000-2,500kWh of savings would need to be traded off. So, depending on circumstances, if householders chose to heat their house 1ºC more as a result of insulation, it could typically involve trading off 500-2,500kWh of potential energy savings[7]. One aspect of the

[7] The analysis was based on ALF calculations and extrapolations. House sizes were 110-130m2. Note also that the energy calculation is based on effective heating energy and does not account for inefficiencies in appliance use. Energy savings would be higher if an appliance energy efficiency factor of less than 100% was assumed (e.g. a gas heater at 75% efficiency).

review of empirical studies in Chapter 7 is to compare any actual findings in relation to the temperature-energy savings trade-off with the theoretical results outlined here.

The implications of this trade-off flow through to the level of public benefits achieved. If warmth and comfort are chosen over energy savings, then potential environmental health benefits from energy savings (e.g. reductions in air pollution or carbon dioxide emissions) will not be realised because this benefit stream is in proportion to the actual reduction in energy use achieved. However, other public health benefits might be achieved, such as reduced incidence of respiratory illness and reductions in cold-related morbidity and mortality rates, as well as private benefits of warmth and comfort. Therefore, understanding the trade-offs involved and avoiding potential double counting of benefits needs to be carefully considered. This introduces the strong influence of householder behaviour as a major determinant of the level, and form of benefit provided by insulation.

Other potential non-energy benefits relate to possible added value to the house, and improving occupant retention (both owner-occupiers and tenants can be more inclined to stay in the house and avoid the cost of shifting if it is warm, dry and healthy). Most of these benefits have been observed through studying attitudinal and behavioural responses, and thus learnt about empirically, rather than through first principles.

4. DESCRIPTION OF RESEARCH PROGRAMMES

This chapter reviews the findings from research programmes undertaken in New Zealand over the last decade which have attempted to address the benefits from home insulation. The programmes reviewed were:

- Housing, Insulation and Health (HIH) study – Wellington School of Medicine
- Peak Load Reduction study - Orion
- Energy and Public Housing Study 2003 – Otago University
- Residential Energy Efficiency Retrofits – EECA
- Heat Pump / Insulation Assessment - CEA
- Private Dwelling Retrofit Study 1997-2000 - BRANZ

These studies have different starting points, different geographical locations, different levels of insulation being compared, and different measurement parameters etc. An important part of this analysis therefore is to discern the points in common, the results that can be generalised (to the wider population), and the results that perhaps have limited applicability.

Each study has been reviewed by describing the nature of the trial or study and noting any particular issues around the sample selection, measurement, time period etc. Quantitative results for energy savings, temperature and humidity (where available) are analysed, and any other outcome findings examined. Comment is then provided on the overall results and their applicability.

4.1 Housing, Insulation and Health study - Wellington School of Medicine

4.1.1 Description

A total of 1,352 households from 7 communities (Otara, Eastern Bay of Plenty, Nuhaka/Mahia, South Taranaki, Porirua, Hokitika and Christchurch) were involved in this trial which was designed to determine the benefits of insulation (particularly health) for at risk households, and to determine whether insulation offered a means of reducing health inequalities. During winter 2001 baseline measurements were taken in all houses (and households). Half of the houses were randomly assigned to the intervention group which was then insulated over the summer. During the 2002 winter follow-up measurements were taken from the two groups (control and intervention). Following winter 2002, insulation measures were installed in the control group and the field work finished. As well, more intensive monitoring of temperature and relative humidity was undertaken on 140 houses.

The study is internationally regarded for the depth and quality of the research. In terms of its general applicability however, it is necessary to note the following qualifications concerning the study sample:

- The households were selected on the basis that there was one member having pre-existing chronic respiratory symptoms.
- The geographic locations chosen for the study, as well as the sampling criteria, meant there was a very high proportion of Maori and Pacific peoples – 74% compared with 21% for the general population.

- Coal was used in a few households but there were some extraordinary patterns of use recorded, so much so that coal was excluded from consideration of the overall energy savings made.

The insulation interventions provided basic measures – ceiling insulation to R2.5, underfloor insulation with foil (approx R1.1), a groundsheet where soil conditions were damp, and some draught-proofing – but did not include wall insulation or double glazing. No heating appliance upgrades were involved. However, as is typical in insulation retrofit programmes, not all houses were installed with all measures[8]. The overall installation rate in the intervention sample (based on 658 houses) was: ceiling insulation 94%, underfloor insulation 79%, and draught-proofing 71% (Howden-Chapman et al, 2005).

4.1.2 Findings

Temperature and humidity: Temperature and humidity recordings come from the sub-sample of 140 houses that were more intensively monitored. The results are for bedrooms only, based on monitoring over the 3 peak winter months (June, July, August[9]) (Table 2). An overall net increase in temperature of 0.5ºC and reduction in humidity of 2.3% was recorded.

Table 2. Recorded temperature and humidity for control and intervention groups.

Year	No insulation (control)	Insulation group (intervention)	Net Difference
Temperature (bedroom):			
2001	13.1ºC	13.5ºC	
2002	13.3ºC	14.2ºC*	**+0.5ºC**
Humidity (bedroom):			
2001	68.4%	68.6%	
2002	66.9%	64.8%*	**-2.3%**

* These measurements were taken post-insulation.

Exposure times: Because the absolute change in temperatures and humidity were very small as a result of the retrofitting, exposure times below particular temperatures and above particular levels of humidity were examined as a further explanatory factor (Cunningham et al, 2005). The average net time (accounting for control group changes) below 10ºC for the intervention group fell by 0.76h/day to 1.2h/day. The average net time above 75% relative humidity fell by 2.29h/day (or 49%) for the intervention group. While 10ºC and 75% RH were chosen as reference points for analysis, they don't necessarily represent thresholds. Rather, the findings indicated a significant reduction in exposure across a broad range of lower-than-desirable temperatures, and higher-than-desirable humidities.

Energy use: Energy consumption comparisons were made on the basis of measured consumption of commercial fuels (e.g. electricity and gas sales records were used), along with self-recorded estimates of purchases of other fuels (LPG gas bottles, wood and coal)

---

8 There are many reasons for this including lack of access to ceiling or underfloor areas, poor condition of windows (or windows having been recently upgraded) etc.

9 Note that the weighted average ambient three-month temperature in the areas surveyed is 9.3ºC.

and the use of non-commercial energy such as self-collected wood. Measurements were obtained from 526 households, confined to the June-July-August period (Chapman et al, 2005).

The results (Table 3) suggest first year energy savings (on the total energy bill) of 858 kWh/household or 19%[10] [11]. Given that this was just for the peak 3 winter months, the effect of insulation would be expected to be felt throughout the balance of the heating season as well. Chapman et al (2005) suggest a multiplier of 1.67 and this would increase savings to about 1,430kWh. One further justifiable correction that would further increase the energy savings would be to account for the proportion of intervention houses not receiving particular insulation measures (as noted earlier).

Table 3. Energy savings by heating type (from Chapman et al, 2005)

Type of household heating	Baseline consumption per household (kWh, 2001)	No of households with full heating data	Weighted baseline consumption kWh	Energy savings 2002 c/w 2001 (%)			Net savings* kWh	Weighted net savings kWh
				Control group	Intervention group	Net difference		
Electricity	2,450	479	2,231	3.1	7.2	4.1	100	91
Mains gas	2,470	31	146	3.4	16.5	13.1	324	19
Bottled gas	1,623	125	386	6.6	68.4	61.8	1,003	238
Wood	5,680	155	1,674	8.3	38.7	30.4	1,727	509
Coal	4,377	38	[316]	-253.5**	-160.1	93.4	4,088	
Average weighted all households (excl. coal)			**4,752**			**19.3%**		**858**

* These are savings per household using that form of heating except the bottom figure which is an all household weighted average (excluding coal)

**A negative saving means that between 2001 and 2002, consumption of this form of energy increased.

One issue with the energy data reported is that by far the largest apparent savings come from the 'self reported' sources – LPG and wood. Indeed these two fuel sources accounted for over 85% of the weighted energy savings determined and were so much larger than those for the measured energy sources, it is difficult to know whether they are real or subject to considerable error through the process of estimation by householders. One of the factors that needs to be considered is the degree of participant 'conditioning' that can occur through the kinds of processes that such projects entail. It has been observed in other projects that sometimes participants are apt to attribute instant benefits to insulation (quite out of proportion to physical realities), and this can also carry through to influence the perception of benefits and energy savings.

It is not clear why savings in LPG and wood should be so much higher than electricity and mains gas although they are the less convenient fuels to use so there could be some preferences being shown by householders.

Benefit-cost analysis: Results of a benefit-cost analysis carried out on the measurable variables is shown in Table 4 (Chapman et al, 2005). The analysis is a discounted, present value calculation in which the measured health benefits have been quantified together with the energy savings (reported above). Overall, at a discount rate of 5% the

10 Coal use was excluded from the savings analysis as noted earlier.

11 Note that a proportion of the energy use recorded will be for non-space heating purposes (esp electricity and possibly some gas and wood). Overall is it estimated that the savings recorded represent about 25% of heating energy use for the period, and potentially about 30% of heating energy for the full heating season.

measured benefits came to $3,110/household, representing a benefit-cost ratio of 1.7 (the cost of the retrofitting averaged $1,800/household). At a higher discount rate of 7% the b-c ratio was 1.4. About two-thirds of the benefits derived from non-energy, health related benefits, in particular reduced hospital admissions and reduced days off work. Self reported benefits related to reduced GP visits were not included in the final analysis but would have increased the b-c ratio by a further 0.3-0.4. Note that the b-c analysis did not include the reported savings of wood and coal, but did include LPG savings.

Table 4. Present value analysis of benefits (Source: Chapman et al (2005))

Discount rate	Reduced GP visits (self-report)	Reduced hospital admissions	Reduced days off school	Reduced days off work	Energy savings*	Total benefits (excl. GP visit svgs)
	PV benefits per household ($)					
5% discount rate	[715]	1,100	150	790	1,060	3,110
7% discount rate	[580]	890	120	640	860	2,510

* Included electricity, mains gas and LPG but excluded wood for which there was considered to be no objective price information. Coal was also excluded.

[ ] indicates that this particular benefit, because it is based on self-report, is not included in the total.

Given the vary large reported decrease in LPG usage, it is not clear whether some of the health benefits noted above might have been related to a reduction in combustion products vented inside houses from unflued gas heaters (albeit that only one quarter of monitored households were using LPG). The issue of the health effects of unflued gas heaters is being addressed in a follow-up research trial with results due in 2007[12].

4.1.3 Conclusions

Health benefits: The extent of health benefits observed will be non-generalisable beyond the group of people where pre-existing health conditions exist. Survey selection, which was based on at least one member having a pre-existing respiratory condition, suggests an elevated level of health costs being incurred within these households. That said, asthma alone affects one in four children and one in six adults in New Zealand, and as well there is an increasing aged population who may be at risk to cold, damp homes. Potentially there is a large pool of households where these health benefits will be relevant, but the caution is that the extent of health benefits calculated will not necessarily apply across the board.

Energy, temperature characteristics and the temp-kWh trade-off: The reported findings on average temperature rises and reduction in energy use appear to conform reasonably with what might have been expected (from energy modelling). However, the robustness of information related to the major components of the energy savings is not clear. Neither is it clear how temperature-energy savings outcomes have played out beyond the 3 month monitoring period in the first year after retrofitting.

Prior to the measures being installed, about 40% of householders said that they would take the savings in cash, by having cheaper fuel bills, while one-third of people said that they expected to use the insulation to make their house warmer i.e. keep their fuel bill the same. The results are interesting from the point of view of people's intentions and the trade-off between savings and temperature. The B-C analysis suggests the non-energy

---

12 Housing, Heating and Health, He Kainga Oranga, Wellington School of Medicine & Health Sciences, University of Otago, see: http://www.wnmeds.ac.nz/academic/dph/research/housing/heating.html

benefits significantly outweigh the benefits of energy savings, and that the balance between saving energy and accepting more heat is a choice the householder can make. A cursory analysis suggests that if all the energy savings from the intervention group had instead been used to raise house temperatures, the average temperature gain is likely to have been over 1ºC (in addition to the gain actually recorded). It might be that some of those householders who chose to make energy savings would have been better off improving comfort and gaining the health benefits[13].

4.2 Peak load reduction – Orion study

4.2.1 Description

Following from the HIH study (of which Orion was a principal sponsor), Orion undertook further research using the sample of Christchurch homes used in the HIH study (Orion, 2004). One hundred and sixteen households participated in a two year study in which electricity demand during peak periods was measured during winter 2002 and winter 2003. Approximately half of the households had insulation installed in the ceiling and underfloor prior to the start of the study, and the remaining households had insulation installed halfway through the study.

In addition to the peak period analysis, total electricity use over the winter period was recorded.

There are several important issues to note with the methodology:

- The sample size was small, and not randomly selected (e.g. there had been some level of 'conditioning' through being involved in the HIS study)
- From May until mid-July 2003 New Zealand experienced very low hydro lake levels and there was a national 10% electricity conservation campaign being run throughout this period. The heating behaviour of households may have been quite variable as a result, and in particular the possibility that some fuel switching to solid fuels and/or gas occurred in order to reduce electricity demand.
- The 2003 winter was slightly warmer than 2002 (average temperature of 7.6ºC compared with 7.2ºC) – this may have reduced heating and peak load demand across the network, although the trial/control group methodology would be expected to largely negate this influence.
- The averaging of electricity consumption over the entire peak period for the season does not allow any analysis on whether there has been any change in the maximum peak recorded – which is perhaps more relevant to indicate the ability to help relieve network capacity constraints.

4.2.2 Findings

Peak loads: Between winter 2002 and winter 2003, households in the control group decreased average peak period demand from 1.97kW to 1.82kW (i.e. 0.15kW), while households in the trial group decreased demand from 2.15kW to 1.60kW (i.e. 0.55kW). The average net effect was a 0.4kW (18%) reduction in peak period demand.

Prior to insulation being installed, the peak period demand in some houses reached 6.5kW, but after insulation no house recorded more than 4.75kW.

---

[13] This argument depends on the energy savings estimates being reasonably accurate – which has been questioned in this review.

Electricity demand: During winter 2002 and winter 2003, households in the control group averaged 34kWh/day and 32kWh/day respectively (-4% difference). Households in the trial group averaged 33kWh/day and 28kWh/day respectively (-17% difference). The overall net reduction in the trial group was 13% (about 4.5kWh/day).

4.2.3 Conclusions

The findings of this monitoring suggest a substantial decline in peak period demand from insulated houses, while the findings on wintertime electricity use are generally consistent with other findings on energy savings reported here.

However, Orion themselves recommend that caution is exercised in interpreting these results more widely. They point to the small sample size; there is also the unknown effect of the national campaign to conserve electricity which occurred during the first half of 2003. It is likely that the trial group, who had insulation installed over the summer of 2002/03, would have had a heightened awareness of energy saving as a result, and hence may have had a greater propensity to reduce electricity usage in the subsequent few months. Moreover, there is little evidence to show that this study has been taken seriously by the electricity industry, or that the initial results have been seen to be worthy of further study.

The core uncertainty is whether the peak reductions and electricity savings recorded in year 1 have been sustained during subsequent winters. As observed in other studies reported here, there may be a tendency for 'comfort creep' – for householders to take back increasing levels of comfort (at the expense of energy savings) in subsequent years.

4.3 Energy and Public Housing Study 2003 - Otago University

4.3.1 Description

As part of HNZC's nation-wide energy efficiency upgrade of its pre-1977 housing stock, the Energy Management Group at Otago University undertook a study of 111 HNZC houses located primarily in Dunedin (a few houses were in Gore and Invercargill). Sixty one houses were upgraded with a basic package of insulation measures (ceilings and underfloor), while 50 houses were not upgraded and served as a control group. Thus it was a 'before' and 'after' insulation retrofit study.

Measurements were taken of bedroom and living room temperatures, energy use, while a range of qualitative assessments with the householders were also carried out (reported in Shen and Lloyd (2004)).

4.3.2 Findings

Temperatures: Temperatures were monitored over July-August, with differences between the insulation and control groups for living rooms and bedrooms averaging +0.5ºC and +0.7ºC respectively (

Table 5). Within the insulation group there was also a 6-9% reduction in the percentage of houses recording very low temperatures in living rooms and bedrooms (<12ºC). Nevertheless, compared with threshold temperatures for health and comfort, significant numbers of houses were still falling far short of desired temperatures.

Table 5. Southern NZ public housing study 2003 – recorded temperature differences

	No insulation	Ceiling and underfloor insulation	Difference
Mean living room temperature (July-August)	12.7ºC	13.2ºC	+0.5ºC
Mean bedroom temperature (July-August)	10.1ºC	10.8ºC	+0.7ºC
% of houses with temperatures <12ºC*:			
Living areas	52%	46%	-6%
Bedrooms	81%	72%	-9%

* recorded on one day in July when the ambient temperature averaged 6.4ºC. Over the full monitoring period the external temperature averaged 6.7ºC.

Perceptions of comfort: Prior to the retrofits, 56% of households found indoor temperatures were not comfortable, and 59% of households had a mould or damp problem. After the insulation measures were installed, 25% of occupants considered their house to be much warmer, 17% warmer, 18% a little bit warmer, and 40% found little difference.

Energy Use: Monitoring of electricity use for 50 upgraded houses in Dunedin from July 2003-April 2004 suggested a 13% reduction in electricity use after the insulation upgrade measures were installed. However, there are several possible problems with this information. It is not clear that the electricity reduction was baselined back to the control group for comparison; the upgrades were not finished until nearly mid-winter so the monitoring period covered only part of a full winter; the plot of comparative electricity use provided suggests that savings continued through the summer period Oct-Feb, a time that very little heating would likely to be on so the reduction in electricity use is most unlikely to be from insulation, and much of the information on gas and solid fuel use is not covered. This shows the importance of timing and careful monitoring for studies of these types, and the difficulty in drawing robust conclusions if all factors are not covered.

4.3.3 Conclusions

The findings on temperatures in the this study are broadly similar to the findings of the Housing, Insulation and Health study - namely, that at relatively low levels of household heating, a basic retrofit of ceiling and underfloor insulation lifts average indoor temperatures by typically about 0.5ºC.

There was a general lift in the occupants' perception of comfort, although almost 60% rated the comfort change as either no different from previously, or only a little bit warmer.

A reduction in electricity was recorded after the insulation was installed but there are a number of issues with the energy data set, and it is concluded that the energy savings cited are not sufficiently robust for evaluation purposes.

One of the most important aspects of this study is the geographical context it provides. Dunedin, in the middle of winter, is a cold, damp place. In addition, Dunedin's hilly aspect means that many houses will suffer from a degree of winter shading, limiting even further the potential for natural heating (Shannon et al, 2003). Both the quantitative and qualitative measurements indicated that the basic insulation retrofit package alone did not make much difference to either the comfort or energy saving outcomes for a lot of homes. If tangible differences in outcomes are to be achieved, then much more will be needed from a retrofit package in these environments. It might be that higher levels of insulation are required (e.g. better floor and ceiling insulation and perhaps walls and double glazing), although an integrated package that includes a better heater (such as a pellet burner, or heat pump in smaller homes) is likely to be the most cost-effective overall.

4.4 Residential energy efficiency retrofits - EECA

4.4.1 Description

The programme of retrofits supported by EECA (EnergyWise Home Grants) was described in the previous section. EECA was a major funder of the HIH study, supporting it largely to determine the benefits that might accrue through the insulation retrofit programmes. The subsequent study findings showing temperature, health and energy benefits have been used to underpin the EWHG programme since that time. EECA concluded that the findings of the HIH study provide a good proxy for the outcomes and benefits of the EWHG programme[14]. Thus, apart from audits of individual projects, EECA does not carry out any ongoing outcome-based evaluations.

4.4.2 Findings

At various times, qualitative assessments of EECA-supported community projects have been carried out. While these assessments generally lack objective, outcome-focused measurement and analysis, they do provide a valuable complementary perspective by focusing on the perceptions and perceived benefits gained by household participants. An example of one such assessment is summarised in Box 1, a recent community retrofit pilot project carried out in Rotorua (ref. Beattie (2005). Other qualitative assessments of projects carried out shortly after completion of the retrofit work tend to show very similar findings.

4.4.3 Conclusions

The benefits of EECA's programme are assumed through proxy to the HIH study. Given the low income and health focus of the programme, this is probably a reasonable assumption to make. Occasional, qualitative evaluations are undertaken on projects, and these tend to reinforce a very strong sense of individual benefit derived from householders.

4.5 Heat pump/insulation assessment – CEA

4.5.1 Description

Within their Clean Heat programme, Environment Canterbury undertakes a 'satisfaction' assessment some weeks after the retrofits occur. The results tend to indicate a high level of satisfaction, but they relate as much to satisfaction with the retrofit installation process rather than heating outcomes[15]. Beyond this qualitative assessment, no quantitative analysis of outcomes is undertaken by ECan (except, of course, outcomes related to improvements in air quality).

The only quantitative assessment of Clean Heat retrofitted homes undertaken to date has been two assessments carried out by CEA on a small sample of full assistance households that received a retrofit package involving heat-pumps and insulation (Walker,

---

[14] Personal communication Robert Tromop, EECA.

[15] Retrofits are carried out throughout the year, so for retrofits carried out in the summer households would be unlikely to have had the opportunity to assess performance during a prolonged cold period.

2004; Fyfe, 2005))[16]. The prior heating arrangement in these homes was predominantly an open fire supplemented with spot electric heating (fan, bar radiant heaters) and portable LPG heating. The survey assessed energy and electricity consumption before and after the installation of the retrofit measures, as well as a series of qualitative questions addressing issues of warmth and comfort of the household. The survey was undertaken initially in 2004 with a sample of 23 households and repeated in 2005 (with the same sample of households), but by this stage for various reasons (persons no longer living in the home, unavailable to take part, etc) the sample was reduced to 14 households.

[16] Note that the survey also included a handful of HNZC houses retrofitted in the same way.

Box 1: Rotorua Healthy Homes Pilot Project 2005

The Rotorua Healthy Homes pilot project retrofitted insulation into 111 houses in the Rotorua District from June-September 2005. The project received basic funding support from EECA, supplemented by funding from health authorities and charitable trusts within the Rotorua/southern Bay of Plenty area. The project was managed by Energy Options Charitable Company Ltd. Household participation conformed with standard EECA criteria with eligibility being those with a pre-existing chronic respiratory condition, Community Services Card and living in a pre-1977 house. The standard retrofit package comprising ceiling, underfloor, draught-proofing and HW cylinder insulation was installed, with the average cost per house being just under $2,100.

A case study involving 10 of the households was carried out post-retrofit. It concentrated on qualitative responses and was undertaken not long after the insulation measures were installed.

- Several of the households reported significant improvements in family health, in particular reductions in respiratory symptoms and reduced doctor/hospital visits.
- The subjective assessment of house temperature showed a very large shift from predominantly a "very cold" or "quite cold" ranking towards rankings of "quite warm" and "very warm". *"There's a marked difference* (in temperature*)"* seemed a typical response.
- The subjective assessment of dampness also showed a large shift, with typically a 2 point change is assessment rating (on a 5 point scale).
- All participants reported a change toward less heating and energy use. Most reported using heaters less, reductions in the power bill and using less firewood and gas. Most also indicated they had responded positively to the energy efficiency messages/education that was part of the project.

These subjective findings are characteristic of most insulation retrofit projects, especially when there has been a significant process involving admission to the project (via qualifying criteria), education /information resourcing, and follow-up. Objectively, one could point to a number of issues around the householder's perceptions and the follow-up evaluation including timing (some of the retrofits were not finished until towards the end of winter and the evaluation was carried out when the weather was warming up), the accuracy of the self reporting, and the lack of longer term evaluation (which is common to virtually all projects regardless of the form of evaluation). Nonetheless, there is no reason to believe that the benefits obtained are anything less than those reported through the other evaluations reviewed here. The subjective evaluations also clearly show that, within the sections of the community targeted for such programmes, there is an overwhelming sense of gratitude and a very positive view of the benefits, as encapsulated by the comments from participants below:

"I would like to see all houses in New Zealand fully insulated! However, as a low income earner, with 2 children who are asthmatics, I am so grateful about such a scheme, which assists people like myself. The changes to the health of my children are noticeable and the money I save on power has made my life less stressful. Please have more schemes running!"

"I'd like to thank you – I didn't know what a warm home was until I got this insulation put in. That was the best thing that could have happened for me and my whanau."

"It was brilliant, so good we had it done."

The studies have three main qualifications:

- The sample sizes are very small, and hence unable to be 'representative' of the wider population
- Because this is an assessment of the whole package involving retrofit of insulation and replacement of an open fire by a heat pump, it is impossible to separate out the effect of insulation alone

- Quantities of non-metered energy sources (LPG; coal and wood for the open fire) were estimated by householders rather than being accurately measured.

4.5.2 Findings

Perceptions of comfort*:* The surveys showed that householders rated the combination of heat pump/insulation retrofits very highly in terms of satisfaction and additional comfort/warmth, and this rating has been maintained across the 2 years (see further discussion and comparison in Chapter 8). A number of householders also reported the ability to heat greater areas of their house than previously, and some were using the heat pump for cooling on extreme heat days in the summer.

Temperature settings: No temperature measurements were taken in homes, but the survey asked for the heat pump temperature settings maintained by the household. Temperature settings for 2004 were either the same or higher than for 2003. The median high-temperature setting increased from 21°C in 2003 to 22.5°C in 2004, likewise the median low-temperature setting increased from 19°C in 2003 to 21.5°C in 2004. Although this cannot be verified through actual temperature recordings, it does indicate the desire for higher comfort levels.

Electricity consumption: From a limited sample of houses, total electricity use over the winter period (generally 7 months) increased by 11% in 2003, and 17% in 2004 (compared with 2002). Note that the winters of 2003 and 2004 were both colder than 2002, with 3% higher heating degree days.

The increased electricity consumption in 2004 would be consistent with householders maintaining higher temperature settings on their heat pump as reported above. The surveys also indicated that additional heating to supplement the heat pump was used in 2004 compared with 2003. Mostly it was plug-in fan and radiant electric heaters, which may have some implications for peak period power demand.

Total energy use: There appears to have been an overall reduction in energy use compared to the prior (open fire) situation, but this is not reliably quantified because the energy consumption of open fires and other sources such as LPG heaters has been assessed through cost estimates and recall from the householders. One reasonably robust finding has been the very large reduction in the use of LPG heating since the insulation/heat pump upgrade. In the first year after the insulation/heat pump retrofit, reduction in LPG use appeared to be over 90% (Walker, 2004), and this appeared to be sustained into the second year as well (Fyfe, 2005).

4.5.3 Conclusions

Because of the very small sample size, these surveys can only be regarded as ‘indicative’. However, they have particular value because the surveys have begun to assess multi-year behaviour from the same set of householders. The key findings have been the high level of comfort benefit achieved, which has been sustained into the 2nd year, and some evidence of comfort ‘creep’, with householders looking to move beyond the levels of comfort achieved in the first year after retrofitting to gain greater comfort in the following year.

4.6 Private dwelling retrofit study 1997-2000 - BRANZ

4.6.1 Description

From June 1997 to June 2000 BRANZ undertook continuous monitoring on a Wellington house that was initially uninsulated, and then insulated in 2 stages (Cunningham, 2001). The house was a fairly conventional 3 bedroom, timber framed weatherboard home constructed in 1929, which had an addition constructed in 1996. The retrofit began in

1998 with the fitting of fibreglass ceiling insulation to R2.6/R3.6 and underfloor insulation comprising 100mm fibreglass insulation and foil (effective R2.6). In 1999 all walls were fitted with 110mm fibreglass batts (R2.6). Overall, these insulation values are considerably in excess of the minimum requirement set out in NZS 4218.

Continuous monitoring of temperature and humidity was set up, with several individual rooms in the house separately measured. The house was heated entirely by electricity, and all electricity consumption was monitored including separate meters for space heaters and water heaters.

It is important to note the following qualifications about the findings of this study:

- The study is a single house, consecutive year study, without a control group on which to baseline findings (i.e. as a means of correcting for year-to-year changes in factors affecting temperature and energy outcomes)
- A significant variable that needs to be taken into account is the difference in ambient winter temperatures recorded over the 3 years of monitoring – in the baseline year (1997) temperatures averaged 10.2ºC, in 1998 11.5ºC and in 1999 12.0ºC. This indicates significantly warmer ambient conditions in the two winters with insulation installed, which might have influenced the householder's heating behaviour and subsequent energy use.

4.6.2 Findings

Temperatures: Cunningham (2001) analysed temperature gains after insulation was installed by deducting measured indoor temperatures from outdoor temperatures, thus calculating a temperature 'excess'. The post-insulation temperature excess was compared with the pre-insulation excess (

Table 6). The actual recorded temperature excess is shown, as are calculations to show the effect on temperature if a) no heating input was applied, and b) if the heating input was maintained at the pre-insulation level. The temperatures given are a whole house average.

Figure 2 shows average inside and outside temperatures for the 3 winter months over the 3 years and indicates the relative effect of the warmer external temperatures compared to the temperature excess post-insulation (in years 2 and 3).

Table 6. Observed and calculated temperature excess June/July/August (whole house)*

Heating regime	Insulation regime			Net gain after insulation
	No insulation (Year 1)	Ceiling & floor insulation (Year 2)	Ceiling, floor & wall insulation (Year 3)	
Observed:				
Chosen heating level by occupants	2.0ºC	2.4ºC	3.3ºC	0.4 / 1.3ºC
Calculated:				
No heating**	1.5ºC	1.9ºC	2.0ºC	0.4 / 0.5ºC
If heating input maintained at pre-insulation levels***	2.0ºC	2.8ºC	4.2ºC	0.8 / 2.2ºC

* Measured as the average daily internal house temperature compared with the average daily external temperature.

** Calculated by regression (from Cunningham, 2001)

*** Assumes an average daily heating power input of 1,200W (i.e. 29kWh per day), representing no energy saving on the pre-insulation energy use (deduced from Fig 11 in Cunningham, 2001).

Humidity: Relative humidities dropped from 68% during the 3 winter months in 1997 to 64% in 1998 and 60% in 1999. It is unclear to what extent the more favourable ambient conditions in 1998 and 1999 also contributed to this decline.

Energy: Results of the monitoring of energy used pre- and post-insulation is shown in Table 7 broken down by the peak 3 month winter period and the balance of the heating season. An interesting result was the very large recorded increase in energy used in bedrooms in years 2 and 3. It was discovered that a teenage child in the family was studying over those two years, and the increased electricity use was directly attributable to that period[17].

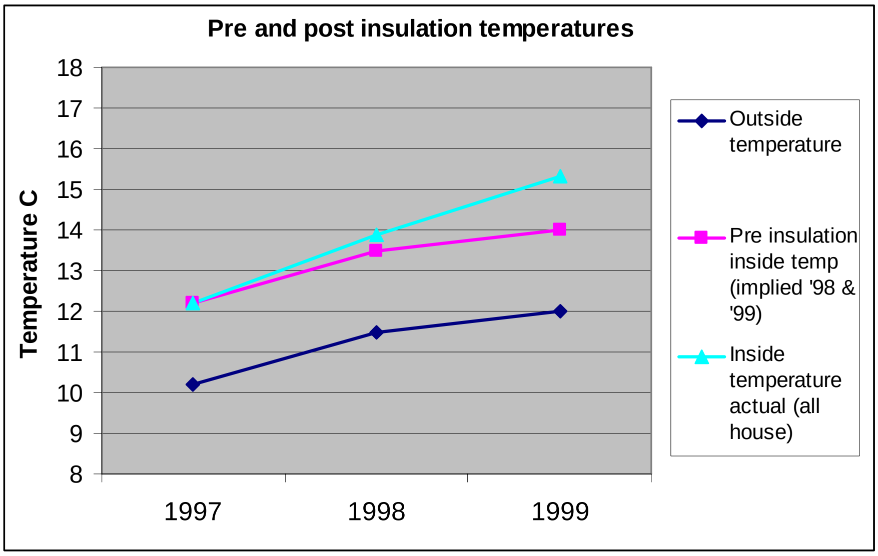


Figure 2. Changes in outside and inside temperatures

[17] Personal communication Malcolm Cunningham, BRANZ.

Table 7. Energy use – BRANZ private dwelling retrofit project 1997-2000 (Wellington)

Energy use (electricity for heating)	Insulation regime			Net reduction after insulation
	No insulation (Year 1)	Ceiling & floor insulation (Year 2)	Ceiling, floor & wall insulation (Year 3	
	kWh			
Peak winter (June, July, August)	2,078	1,198	1,388	880 / 690
Non peak winter heating: bedrooms	17	596	530	na
balance	922	751	713	171 / 209
TOTAL (annual use)	3,017	2,545	2,613	1,051* / 899*

* Excludes heating energy used in the bedrooms

Excluding the effect of bedroom heating, the energy reduction in Year 2 was 35%, while in Year 2, with the addition of wall insulation, the energy savings were actually lower at 30% (c/w Yr 1). This was because of the choice by the occupants to maintain a significantly higher temperature regime during the winter of 1999.

4.6.3 Conclusions

While this is just a single house study, its value is in data quality and depth of analysis/understanding of the pre- and post-insulation situation. It is also the only study that has intensive, quality, multi-year data and the only study in which wall insulation was included as a retrofit option.

The study has particularly highlighted the trade-off between energy savings and increased comfort as matters of choice made by the house occupants. The fact that, after the addition of wall insulation, electricity use actually increased was no reflection of the effectiveness of the wall insulation[18]. It was entirely due to the choice by the householders to have a significantly higher internal temperature regime over that period – some 1.4ºC higher than the previous winter (0.5ºC as a result of external temperatures). These findings do raise questions about the longer term behavioural response to insulation, and whether there is a longer term tendency to take back the benefits provided by insulation as temperature gains, perhaps until optimal comfort levels are reached. The study findings also reinforce caution about first year energy savings as a reliable guide to longer term energy savings.

The study also highlights the dynamic nature of energy use related to family circumstances - life cycle, children etc., which change from year to year – and which can easily confound simplifying assumptions related to insulation effects.

18 Analysis reported by Cunningham (2001) suggested that the insulation value of the added wall insulation was at least as high as the ceiling and floor.

5. DISCUSSION AND CONCLUSIONS

5.1 Observations on the studies

The studies/projects reviewed have provided useful insights, but all have some significant methodological issues which means they need to be interpreted very carefully. None of the studies provide a 'definitive' evaluation. Key issues are as follows:

- The studies have a strong weighting towards retrofitting in low income households. These households often have lower levels of heating and energy use, and display certain types of behaviours in relation to the improvements made. There is little information on the effectiveness of insulation on middle-higher income/higher energy use households.
- Most of the studies have methodological issues around the measurement of energy savings, in particular the often short length of monitoring undertaken, and the accuracy of the non-metered energy sources (such as bottled gas and wood). Few studies have measured beyond the peak winter period, yet insulation effectiveness can be very pronounced in the shoulder parts of the season.
- There are still major gaps in our understanding of outcomes beyond the first year after retrofitting. Only two studies were found (with 15 houses in total) that have collected data beyond year 1, and one of those studies has very little data definition.
- Little empirical information exists about the effectiveness of retrofitting insulation beyond the 'basic package' of measures. There is only one study that has gone beyond ceilings and floor insulation to include walls (one house). There have been no studies where the retrofit option has included double glazing.

There is also the general issue of comparability between studies, with a number of subtle differences between variables measured, time scales, influence of external factors etc.

5.2 Findings

Despite the methodological issues the studies overall have produced a number of consistent findings, and findings that generally conform to prior expectations gained via energy modelling.

Temperature gains: there are generally consistent findings in terms of temperature effects. Basic insulation (ceiling plus foil under floors plus some draught-proofing) installed in houses at no-to-low levels of heating will typically result in a basic ~0.5ºC average temperature increase during the 3 peak winter months (June-August). This gain comes about essentially through improving the heat retention of solar gains and the heating applied, and other secondary heating sources.

Beyond that, temperature gains are largely a function of the way in which people take the benefits of insulation – whether they reduce energy inputs and take the benefits largely as energy cost savings, or whether they maintain their previous energy inputs and take the benefits as additional warmth and comfort. At the level of heating of the houses studied, the indicative total potential temperature gains if energy inputs were maintained appeared to be in the range of +1-2ºC.

Health benefits: Results from the HIH study suggest that the longer term flow of health benefits alone from basic insulation are of a similar level to the initial cost of basic insulation measures (e.g. a benefit-cost of 1). It has been postulated that reduced exposure to both low temperature and high humidity extremes may be a key explanatory factor in the health benefits achieved. If this is the case, it also seems that much more could be done to increase this health benefit (in houses retrofitted) because significant undesirable temperature and humidity exposure was still existing despite the insulation.

While the health benefit findings are not generalised to the overall population requiring insulation (or insulation upgrades) because participants in the HIH had a pre-existing medical condition, nevertheless the group of vulnerable households throughout the country to which these benefit findings would apply, is quite large.

Energy savings: The findings on energy savings suggest a short term (1st year) reduction in total household energy use over the peak winter months of typically 12-20% as a result of basic insulation measures (~20-30% savings on heating energy). This is a little less than the theoretical savings, but is explained by the degree of 'take back' of savings as warmer houses and greater personal comfort. There is some evidence to suggest that in subsequent years further take back of those energy savings may occur as householders look to progressively improve warmth and comfort ('comfort creep'), at the expense of energy and cost savings.

As noted above, most studies undertook measurements for the 3 peak heating months – June, July, August – but this fails to capture the much longer period of the heating season in many areas, especially in colder areas. The latest Household Energy End-use Project (HEEP) report (Isaacs et al, 2005) has found actual heating season in monitored houses to vary from typically 5 months in the far north, 6-7 months in the lower North Island, 7-8 months in the upper South Island and Canterbury and 8-9 months in Otago-Southland. In terms of understanding the full value of insulation this lack of monitoring in the shoulder period of the heating season could be significant. While less heating is carried out in these times, the relative energy savings from insulation might be higher because the temperature gain from insulation is more significant in relation to the smaller temperature differentials between ambient and desired room temperatures at those times.

One study investigated the effect of insulation on peak-period electricity loads and found an average 0.4kW/household reduction in the first year after the retrofit. However, although the study involved meticulous monitoring, it coincided with a number of external events (low lake levels and electricity savings campaigns) which has meant the results are generally regarded as not robust.

Comfort benefits: There is strong evidence from several of the studies reviewed that improved home comfort is a major priority for householders. When insulation improvements are made, many householders place a higher value on comfort gains than on energy cost savings per se. However, particularly when incomes are constrained and energy costs are high, potential comfort benefits are being foregone for energy savings – at least in the short term.

Environmental benefits: The potential for environmental benefits from energy efficiency retrofitting rests with a reduction in the consumption of energy that produces harmful environmental effects (e.g. particulate emissions, CO_2 emissions). Therefore, realisation of these benefits is strongly correlated with appliance efficiency and the heating fuels used, and the household-level trade-offs between comfort and energy savings.

Other private benefits: There is some evidence related to other benefits people derive from insulation – mainly private benefits related to house value, and occupant retention in houses (avoiding the cost of moving).

Summary of benefits: An overall assessment is summarised in Table 8. It has been impossible to determine an overall quantitative assessment of the benefits of retrofitting because it is very context specific. An assessment undertaken on the HIH study suggested a benefit-cost of ~1.7 but some likely benefits were not included (and some of the benefits included may not necessarily have been directly attributed to insulation). Also, some private benefits were not covered, and potential future benefits are not currently included (for example, warmer temperatures from climate change may increase the value of insulation for maintaining a cooler house during extreme hot periods).

Table 8. Summary of potential insulation benefits and 'status' as indicated by the studies reviewed

Potential Benefit	Private or public	Status	Comment
Energy saving	Private	Clearly shown, and conforming with energy models, but heavily affected by householder behaviour. Trade-off with comfort (probably until adequate comfort levels achieved).	Strong desire to realise insulation benefits as energy savings from some participants within HIH study, but may be subject to 'comfort creep'.
	Public		Electricity industry caution about robustness of reduction potential.
Peak load reduction	Public	Indicated (0.4kW/household) peak period reduction but regarded as 'soft' by industry and lacking robustness	Potential indicated but needs follow-up further study (and perhaps focusing on higher use part of the market).
Comfort and well-being	Private/ public	Clearly shown - ~0.5ºC temperature lift with basic insulation retrofit, and further increases up to +(1-2ºC) depending on energy saving trade-off.	Basic insulation package alone is not sufficient to address comfort and well-being outcomes in many situations. Needs a more flexible approach targeted to market segments and household needs, and including the heating appliance.
Health	Public/ private	Clearly shown for vulnerable groups, with potential benefits possibly understated. Not generalised across all households however.	On strength of HIH findings some households might be better off taking more comfort and less energy savings – suggests a greater effort should be put into setting, and achieving desired indoor environmental outcomes.
Property value	Private	Inferred through qualitative assessments – quantification unclear	Largely unrealised because of the lack of rating tools
Occupant retention	Private	Indicated through qualitative assessments	Offers rationale for (some) landlord investment
Environ-mental	Public	Inferred – conditional as a direct function of energy and peak load reductions achieved	Insulation is generally accepted as contributing to environmental objectives when part of a package of measures – not necessarily a strong contributor on its own
Noise mitigation	Private	Inferred through qualitative assessments of low energy homes – not identified as a quantifiable benefit in retrofits to date.	May be a useful co-benefit to promote specific forms of energy efficiency upgrades e.g. double glazing.

6. RECOMMENDATIONS

6.1 Better recognising the temperature/energy savings trade-off

A key aspect identified was the nature of the trade-off between temperature and energy savings when insulation was retrofitted, and the way this trade-off is realised in practice. Figure 3 shows indicative values for heating energy-temperature relationship for an uninsulated condition, and a condition of basic ceiling and floor insulation. The lines define the choices that householders can make regarding comfort and energy[19]. What appears to be happening, initially after insulation, is that households (on average) move to some intermediate point between maximum energy savings which would be typically 40-45% (dotted arrow to left) and maximum temperature gains (dotted vertical arrow) – as indicated by the solid red arrow.

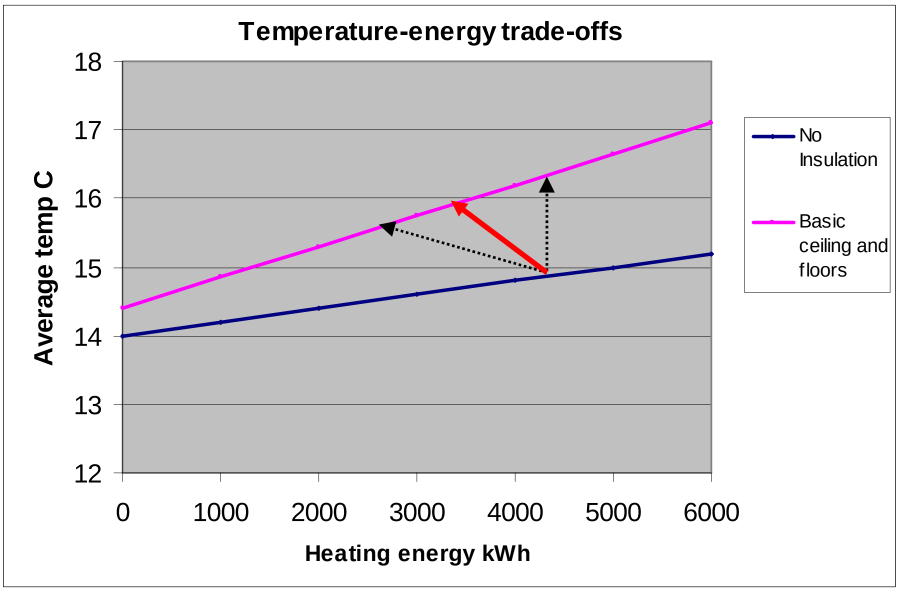


Figure 3. House temperature-energy relationship in moving from uninsulated to basic insulation (note the values in the figure are indicative, not 'typical' or 'average')

The evidence is very unclear after year 1. Only 2 studies presented here have consecutive yearly data (for the same house(s)), and in total these studies report on only 15 houses. However, both studies showed an increase in heating energy use in year 2 – not necessarily back to pre-insulation levels – but consistent with the concept of comfort 'creep' discussed earlier. In Figure 7, the 1st year response to insulation is indicated by the left black arrow. Comfort creep would then result in a movement up the insulated temp-energy line towards increased comfort and less energy savings, indicated by the red arrow.

---

19 The conceptual formulation of Fig 6 (and subsequent Figs 7 & 9) derive from the analysis and graphs provided in Cunningham (2001)

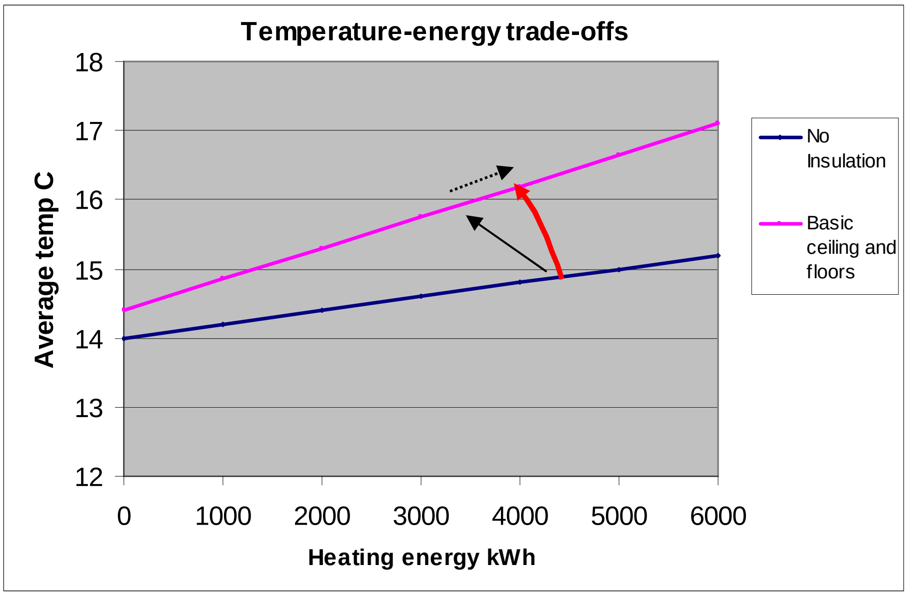


Figure 4. Possible comfort creep effects.

If this is happening in reality it suggests that, until sustainably comfortable temperatures can be achieved in houses, apparent short term energy savings will be at risk of being sequestered back as increased heating and comfort in the home. At this stage this finding is reasonably strongly indicated, but not conclusively shown.

Of course one of the key factors to keep in mind is that virtually all of the quantitative research has been undertaken on homes that are low income/heat deprived. It could be that this is a characteristic of a particular market segment, although the desire for comfort appears to be across a range of market segments. Also, as noted by Isaacs et al (2005) cold homes are found across the socio-economic spectrum. Nevertheless, in terms of quantifiable results, there is very little information available beyond a fairly narrow segment at present.

Recommendation: Further research is recommended to quantify 'comfort creep' effects, and ascertain the benefits to the energy system from insulation investment (from peak load reduction, energy demand reduction and environment mitigation). As it stands at present, if there are true long term peak demand reductions available from insulation, they are currently going unrealised, and need to be quantified in the energy price assumptions used in cost-benefit analyses.[Key parties: EECA, Electricity Commission].

6.2 Insulation on its own is not necessarily enough

One of the characteristics of energy efficiency retrofitting in New Zealand has been a tendency to promote the 'standard package' of measures. While this appears to provide useful benefits, and perhaps is perfectly adequate in warmer parts of the country, it is clearly not sufficient in many other locations. Achieving an average 0.5-1ºC temperature gain is not sufficient to lift indoor temperatures into an acceptable zone of comfort (or health). There is a need to recognise a diversity of circumstances and particularly the chronically cold, hard to heat houses, more concentrated in southern parts of the country (but not exclusively so), lacking insulation, poorly aligned to the sun and maybe suffering from winter shading (low sun angle).

Some energy efficiency retrofit programmes in New Zealand now include a heating appliance upgrade as an integral part of the package. To date these have mainly been clean air-related projects with local government co-funding. The combined efficiency/heating appliance package appears to provide a much better set of multiple outcomes (e.g. environmental outcomes and comfort gains) than a basic energy efficiency package alone, especially in colder parts of the country. For example, a comparison of outcomes between a thermal efficiency retrofit programme in Dunedin and a combined retrofit/heating appliance retrofit in Christchurch suggested a large difference in environmental outcomes and a significant difference in the perception of comfort from the householders (Figure 5).

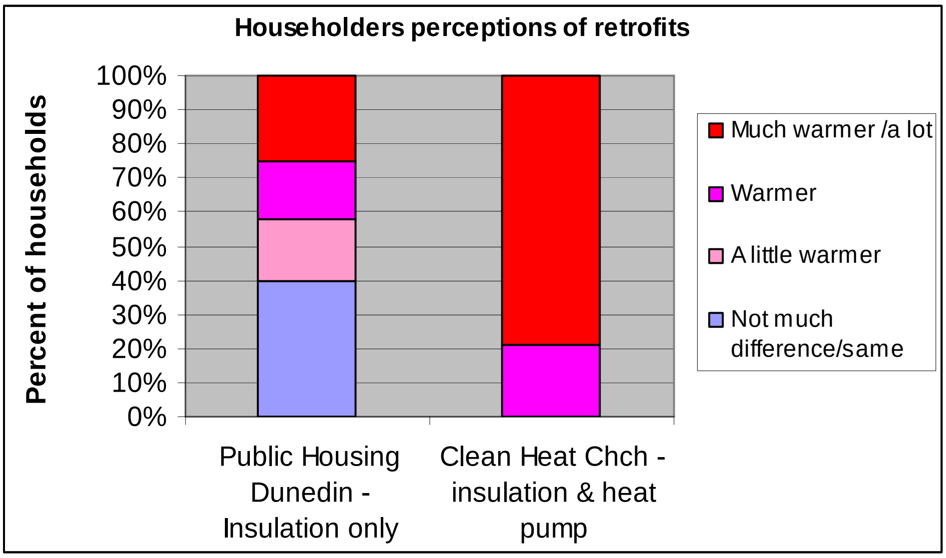


Figure 5. Comfort perceptions after retrofitting – basic insulation c/w basic insulation plus heat pump.

These findings are not surprising, and tend to reinforce a growing body of evidence both in New Zealand and overseas about the need to link together packages of integrated solutions for householders. These would be underpinned by good thermal insulation and efficiency upgrades but would not rely on these actions solely to achieve desired outcomes. Overall, it suggests that retrofitting needs be less of a standardised package across the country, with more attention given to geographic location, the characteristics of the house, and individual household circumstances. This integrated approach should also be trying to provide vulnerable households with heating fuel choices in the group of 5-10c/kWh options (e.g. heat pumps, efficient enclosed burners, pellet burners) rather than the higher cost 17-25c/kWh options (gas, on-demand electric resistance heating), as this will likely encourage the maintenance of healthy indoor temperature environments. In order to achieve this outcome a more flexible approach from funding institutions will be required, with less emphasis on solely insulation-focussed solutions.

The temperature-energy relationships of a house with a heat pump as part of the basic insulation package is explored in Figure 6. The exact temperature-energy relationship would depend on the specific characteristics of the heat pump, but because of its inherent efficiency this ‘package’ of measures potentially can provide significant gains for both temperature and energy savings than from insulation alone (the example operating point on Figure 6 (red arrow) shows a temperature increase of 2ºC and an energy saving of 25%). Note, however, that this combination would not be immune from temperature creep or other behavioural effects, as greater areas of the house would likely be heated, and summer cooling undertaken as well.

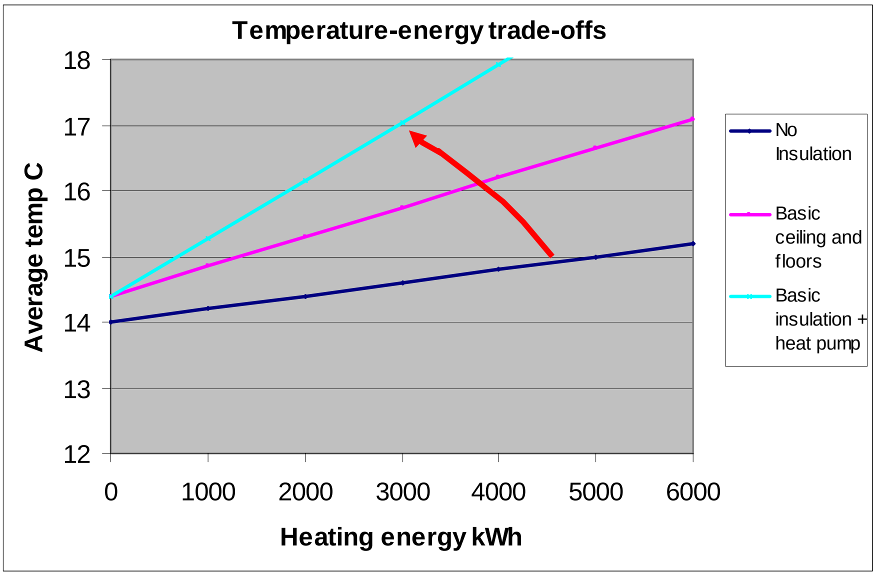


Figure 6. Temperature-energy effects of incorporating a heat pump with the basic insulation package (red arrow indicates shift in heating-temperature operating point).

Recommendations: A review and restructure of the scope of present retrofit programmes is recommended. Tailor insulation retrofit packages to particular market niches – recognising geography, etc. Move beyond the "one size fits all" approach. Integrated packages of heating and insulation should be available in order to provide a true focus on 'outcomes' – health, comfort, clean environment, etc. with a consistent funding approach. [Key Parties: EECA, MfE, EECN (Energy Efficiency Communities Network), Contact Energy – Beacon could play a key role in bringing parties together at a forum to facilitate new approaches]

6.3 What could be done to better support retrofitting?

This review has not explicitly addressed gaps within the retrofit market, but this question is relevant to Beacon's overall objective. The main observations from this review are:

- Consistency of message – over the last few years there has been a clear trend towards emphasising the warmth, health and comfort benefits of retrofitting. Commercial players, with their more market-focused approach, have been attuned to this for some time – they emphasise warmth and comfort in the marketing of insulation, underfloor products, double glazing, for example. This review reinforces the predominance of the health and comfort messages, but some segments of the market might also be influenced by environment concerns. The cost-saving messages, which tend to have been emphasised by government agencies, appear to have limited appeal. Those households most influenced by cost-saving messages are not necessarily financially able to make the investment needed on their own.
- Achievement standards – to date retrofitting has largely been characterised by the standard package of measures. The recommendation for a more flexible approach was outlined above. But allied to this is the need for outcome measures and simple, easy to apply methodologies that allow these outcomes to be consistently achieved. Over the years home energy rating tools have been proposed as a means to achieve this, but getting traction for a suitable energy rating tool for New Zealand is proving difficult. Perhaps a pragmatic alternative is the focusing of

specific information, targeted to the individual householder based around achieving internal and external 'health' standards. This approach has been recommended for the Warm Homes programme (Taylor Baines et al, 2005). This could mean, for instance, setting an internal temperature achievement standard, and an external environmental emission standard, and focussing the retrofit effort around achieving least cost solutions that are affordable to the householder. Given that tailored, individualised advice has consistently been shown to be an effective mechanism for reaching householders, the availability of a sophisticated yet quick and mobile evaluation tool to be used by a trained assessor would seem to be desirable (e.g. laptop based). Ideally, of course, this could be followed up with a rapid implementation service[20].

Recommendation: Tools that provide leverage for non-profit/private/commercial market players to better promote retrofitting and 'best practice' solutions are needed. Prominent would be development of achievement standards and methods that enable householders to receive tailored, high quality advice and follow-up. [Key Parties: BRANZ, Beacon, EECN or EECA].

---

20 Environment Canterbury has found with the Clean Heat programme that the complexity for householders can be a significant barrier. ECan has since moved to provide a 'one stop shop' service that co-ordinates and manages the retrofits for households.

REFERENCES

Beattie, Diana. 2005. *'The best thing that could have happened for me and my whanau': An Evaluation of the Rotorua Healthy Homes Project – Pilot 2005*. Rotorua Healthy Homes Steering Committee. 96pp.

BRANZ. 2006. BRANZ materials survey - Monthly survey of new housing. BRANZ Ltd. Survey responses from January – June 2006.

Caddet, 1997. *Saving energy with energy efficiency in hospitals*. http://www.fire-italia.it/eell/ospedali/energy_efficiency_in_hospitals_maxi_brochure_5_CADDET.pdf

Chapman, R., Howden-Chapman, P., O'Dea, D. 2005. *A cost-benefit evaluation of housing insulation: results from the New Zealand Housing, Insulation and Health study*. Report to EECA February 2005.

Clark, Susan J, Jones, Mark, and Page, Ian C. 2005. *New Zealand 2005 House Condition Survey*. Study Report 142. BRANZ. 146pp.

Community Energy Action. 1994. *Report of the Te Whare Roimata Neighbourhood Energy Improvement Project.* Community Energy Action, Christchurch. 25pp.

Cunningham, M. J. 2001. *A Report for Tasman Insulation on Insulation Retrofitting to a Private Dwelling*. BRANZ Report, Judgeford, Porirua.

Cunningham, Malcolm., Viggers, Helen., Camilleri, Michael., Matheson, Anna., Howden-Chapman, Phillipa. 2004. *Changes of exposure to low temperatures and high humidities on retrofitting houses with insulation*. World Health Organisation. pp423-433.

EECA & the Ministry for the Environment. 2001. *National Energy Efficiency and Conservation Strategy*. Energy Efficiency and Conservation Authority, Wellington. 24pp.

EECA. 2005. *Briefing to the incoming Minister of Energy from the Energy Efficiency and Conservation Authority. 16 Sept 2005*. Energy Efficiency and Conservation Authority, Wellington. 24pp.

EECA. 2006. *Consultation paper on proposed changes to EnergyWise home grants.* Energy Efficiency and Conservation Authority, Wellington. 16pp.

Fyfe, Caroline. 2005. *Heat Pump Survey – Report 2: Winter 2004*. Community Energy Action. Christchurch. 22pp.

Fyfe, Caroline and McChesney, Ian. 2006. *An Assessment of Current Levels of Home Insulation in Christchurch.* Community Energy Action, Christchurch (in prep)

Howden-Chapman, Philippa, Crane, Julian, Blakely, Tony, Cunningham, Malcolm, O'Dea, Des, Woodward, Alistair, Saville-Smith, Kay, Waipara, Nick, Douwes, Jeroen, Matheson, Anna, Viggers, Helen, Marshall, Cara, Skelton, Pounamu. 2002. *A national study of the health effects of insulating homes: the baseline data (Report 1)*. *He Kainga Oranga* Housing and Health Research Programme, Department of Public Health, Wellington School of Medicine and Health Sciences, University of Otago

Howden-Chapman, Phillipa, Matheson, Anna; Crane, Julian; Viggers, Helen; Cunningham, Malcolm; Blakely, Tony; O'Dea, Des; Cunningham, Chris; Woodward, Alistair; Saville-Smith, Kay; Baker, Michael; Waipara, Nick; Kennedy. Martin; Davie, Gabrielle. 2004. *Retrofitting houses with insulation to reduce health inequalities: a community-based randomised trial*. Paper presented at Second WHO Conference on Housing and Health. Vilnius, Lithuania, October 2004.

Howden-Chapman, P, Crane, J, Matheson, A, Viggers, H; Cunningham, M, Blakely, T, O'Dea, D, Cunningham, C, Woodward, A, Saville-Smith, K, Baker, M, Waipara, N. 2005. *Retrofitting houses with insulation to reduce health inequalities: Aims and methods of a clustered, randomised community-based trial*. Social Science and Medicine 61: 2600-2610.

Isaacs, Nigel, Camilleri, Michael, French, Lisa, Pollard, Andrew, Saville-Smith, Kay, Fraser, Ruth, Rossouw, Pieter, Jowett, John. 2005. *Energy Use in New Zealand Households: Report on the Year 9 Analysis for the Household Energy End-use Project (HEEP)*. Study Report No. SR141. BRANZ, Judgeford, Porirua. 123pp.

Kalkstein, L. S., and K. M. Valimont. 1987. Climate effects on human health. In *Potential effects of future climate changes on forests and vegetation, agriculture, water resources, and human health.* EPA Science and Advisory Committee Monograph no. 25389, 122-52. Washington, D.C.: U.S. Environmental Protection Agency.

NFO New Zealand. 2002. *New House Survey Report*. Prepared for EECA.

Orion. 2004. *Effect of improved insulation on peak period demand*. Orion Ltd, Christchurch. 13pp.

Shannon, Sarah., Lloyd, Bob., Roos, Jacob and Kohlmeyer, Jan. 2003. *EVH3 – Impact of Housing on Health in Dunedin NZ.* University of Otago. 39pp.

Shen, Mill and Lloyd, Bob. 2004. *Monitoring of Energy Efficiency upgrades of Public Housing in Southern New Zealand*. University of Otago (Power point presentation).

Storey J., Page I., van Wyk, L., Collins H., & Krehl T. 2005. *RI Housing Retrofit, Housing Interventions, Stocks and Market.* Beacon Pathway Ltd.

Strategic Energy and EnergyConsult. 2005. *Warm Homes Technical Report: Detailed Study of Heating Options in New Zealand: Phase 1 Report.* Ministry for the Environment, Wellington. 48pp.

Strategic Energy and EnergyConsult. 2006. *Warm Homes Technical Report: Detailed Study of Heating Options in New Zealand: Phase 2 Report.* Ministry for the Environment, Wellington.

Taylor Baines & Associates, Smith, Norman, McChesney, Ian, and Butcher, Geoff. 2005a. *Warm Homes Technical Report: Social Drivers Phase 1: Interim Progress Report*. Ministry for the Environment, Wellington. 63pp.

Taylor Baines & Associates, Smith, Norman, McChesney, Ian, and Butcher, Geoff. 2005b. *Warm Homes Technical Report: Social Drivers Phase 2 Report*. Ministry for the Environment, Wellington. 43pp.

Walker, Russell. 2004. *Heat Pump Survey*. Community Energy Action. Christchurch.

Wilton, Emily. 2005. *Warm Homes Technical Report: Home Heating Methods and Fuels in New Zealand*. Ministry for the Environment, Wellington. 223pp.

World Health Organisation. 1990. *Indoor Environment: Health Aspects of Air Quality, Thermal Environment and Noise*. HO/EHE/RUD/90.

APPENDIX1. CLIMATE CHARACTERISTICS

NIWA identify 9 distinct climate zones ranging from the northern zone with a distinctly sub-tropical, maritime influenced climate, to the inland SI zone which is more continental in character with much greater extremes of heat and cold, to cool temperate southern NZ zone. Using this zonal distinction, Table 9 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 9. 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 (%)	Wet-days
		hours	May-June-July-Aug average	Mean °C	M-J-J-A average °C	Very Lowest °C	Diff btwn highest & lowest ºC	days	mean speed km/h	mean speed > 63kph		>= 1.0 mm
KAITAIA	Northern NZ	2070	8.3	15.7	13.0	0.9	29.3	1	15	2	88.2	134
WHANGAREI		1973	8.3	15.5	12.3	-0.1	30.9	11	16	1	88.1	132
AUCKLAND		2060	8.2	15.1	11.9	-2.5	33.0	10	17	2	87.5	137
TAURANGA		2260	8.0	14.5	10.8	-5.3	39.0	42	16	5	84.0	111
HAMILTON	Central NI	2009	7.4	13.7	9.9	-9.9	44.6	63	12	2	89.5	129
ROTORUA		2117	7.6	12.8	8.8	-5.2	36.7	57	13	1	84.9	117
TAUPO		1965	na	11.9	7.9	-6.3	39.3	69	13	2	86.9	116
GISBORNE	Eastern NI	2180	7.8	14.3	10.4	-5.3	43.4	33	15	2	79.9	110
NAPIER		2188	7.6	14.5	10.3	-3.9	39.7	29	14	3	79.3	91
MASTERTON,		1915	6.7	12.7	8.6	-6.9	42.1	60	11	1	80.7	130
NEW PLYMOUTH	South-West NI	2182	7.5	13.7	10.5	-2.4	32.7	15	20	5	84.1	138
WANGANUI		2043	7.5	14.0	10.5	-2.3	34.6	7	18	5	84.4	115
PALMERSTON NORTH		1733	6.6	13.3	9.6	-6.0	39.0	38	17	3	86.9	121
WELLINGTON		2065	6.3	12.8	9.8	-1.9	33.0	10	22	22	86.1	123
NELSON	Northern SI	2405	7.1	12.6	8.2	-6.6	42.9	88	12	2	82.7	94
BLENHEIM		2409	7.2	12.9	8.6	-8.8	44.8	60	13	4	82.1	76
WESTPORT	Western SI	1838	6.3	12.6	9.5	-3.5	33.9	26	11	2	85.2	169
HOKITIKA		1860	5.8	11.7	8.4	-3.4	33.4	54	11	2	86.6	171
KAIKOURA	Eastern SI	2090	6.9	12.4	9.0	-0.6	32.1	27	15	28	70.6	86
CHRISTCHURCH		2100	5.9	12.1	7.7	-7.1	48.7	70	15	3	86.6	85
TIMARU		1826	6.7	11.2	6.8	-6.8	44.0	84	12	6	84.0	81
LAKE TEKAPO	Inland SI	2180	na	8.8	3.4	-15.6	48.9	149	7	1	82.4	78
QUEENSTOWN		1921	6.3	10.7	5.5	-8.4	42.5	107	12	2	82.5	100
ALEXANDRA		2025	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		1614	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 at end 2005, although not necessarily all occupied[21]. An estimate from Quotable Value suggested a total of 1.36M in 2004 (Table 10). In this review a total of 1.4M occupied houses in 2005 has been used.

Based on Table 10, 75% of houses are in the North Island and 25% in the South Island. About 0.55M are in the warmest climate zone in the country (Northern NZ).

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

Table 10. 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%
Hawke's 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 0.9m houses were built prior to 1978 when insulation became mandatory on new houses. The breakdown in Table 10 shows the range in pre-78 houses according to area of the country. Those areas experiencing more rapid population growth over the last two 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).

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

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, however, and these have been used to provide a composite picture of the current insulation status of houses.

Warm Homes Survey 2004/05 (MfE)

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 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 11.

Table 11. Percentage of houses indicating 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 % of don't knows

On the face of it this is a valuable data source, but there are some important qualifiers about the quality of the information. One difficulty is that there may be some sampling bias due to the small sample in each urban area[22]. A second, and perhaps more significant issue, is the lack of knowledge of the respondents. For example, when the Christchurch sub-sample was subject 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).

---

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

Hence it is concluded that the survey does provide a sufficiently accurate quantitative base. It has most value as an indicative comparative guide, showing for instance:

- Generally less insulation in houses in warmer areas e.g. Auckland/Gisborne/Napier c/w most SI 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 10 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 2 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[23]. Also it is a small survey sample with only 3 centres included, and aggregated results are not weighted according to overall population distribution.

A series of 3 tables sets out insulation details by coverage of ceiling insulation (Table 12), thickness of ceiling insulation (Table 13), and extent of other forms of insulation recorded (Table 14). In comparison with the Warm Homes survey, the findings are reasonably similar except perhaps that the House Condition Survey indicated lower levels of wall insulation overall.

Table 12. 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 13. 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

23 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 14. 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 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 15. 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[24], and breakdowns into energy end-use categories also based largely on HEEP.

Based on the heating season characteristic reported by Isaacs et al (2005) and Wilton (2005), Figure 7 has been derived to show the monthly pattern of residential energy use.

Table 15. Estimated energy use in residential buildings 2004 (PJ)

	Coal	Oil	Gas	Geo-thermal	Solar	Wood	Elect-ricity	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).

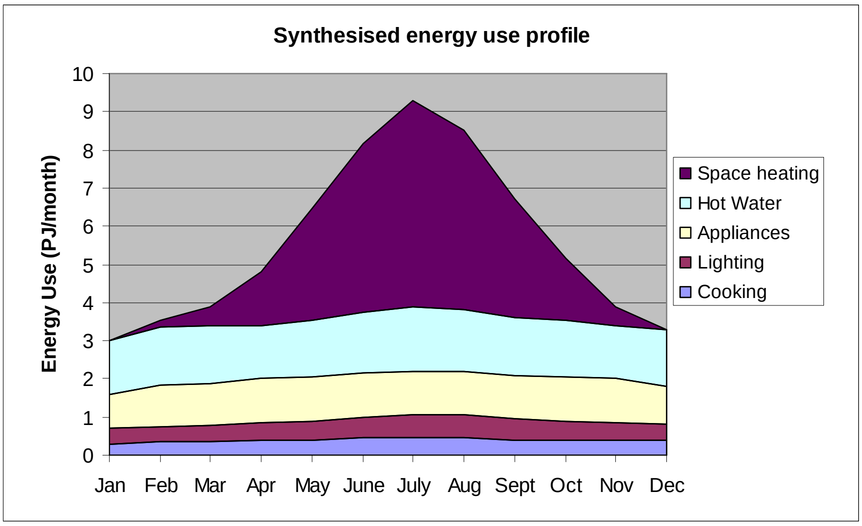


Figure 7. Estimated energy use profile by month (Source: composite based on this study)

24 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.

Space Heating

This analysis suggests that about 24PJ of energy is used 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 7 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 16). 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). Heating running costs using low capital cost appliances is typically 20c/kWh or greater.

Self collected wood plays an important role in the heating energy budget of many homes (Wilton, 2005).

Table 16. 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) This reference doesn’t appear in the reference list

ANNEX 1 WORK PLAN

Stage 1 : Cost benefit analysis at house level

Detailed cost benefit analyses will be developed based on a range of retrofit options that specifically address; energy use and efficiency, water use and efficiency and waste minimisation.

The initial target outcomes or benefits that will be consider in the analysis are financial, health and carbon emissions.

Step 1. Carry out a desk top study of all the existing research programmes that address the benefits of retrofitting houses. Most of these look only at energy efficiency and any are aimed at low income but there are health impact studies as identified under objective one of this proposal.

Step 2. Identify a range of options and the feasibility of each option using the information from Step 1. This will initially be carried out more the “core team “ members but will be circulated to a wider audience for comments and finalising. This will be done in liaison with the technologies workstream so they can identify potential new opportunities in this area. We will use the Beacon objectives as a template to ensure there is a wide range of options identified but concentrate on developing packages for energy, water and waste.

Step 3. Test the range of options against a number of different scenarios dependant on the base case to develop a range of achievable retrofit options or packages dependant on the base case.