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TE210

Thermal insulation in New Zealand homes: A Status Report

A report prepared for Beacon Pathway Limited

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About This Report

Title
Status report on thermal insulation in New Zealand homes

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Abstract
This paper considers thermal insulation for New Zealand homes, covering technical and policy aspects of new build and retrofit insulation. The policy focus is mainly on the incentives and other means to encourage retrofit insulation into existing houses, and includes a review of policies in the UK to encourage high levels of insulation and heating retrofits. The research identifies that the last few years have seen a more purposeful focus on improving and incentivising insulation in New Zealand following a period in the mid-1990s to early 2000s where there was only a modest level of activity. New initiatives launched in 2007 will further provide for improved insulation. The paper includes suggestions for additional ways in which improved insulation practice might be achieved.

Reference
McChesney, I., Cox-Smith, I., Amitrano, L. March 2008. Thermal insulation in New Zealand homes: A Status Report for Beacon Pathway Limited.

Disclaimer
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1 Introduction

One of Beacon's two main goals is "to help bring the vast majority of New Zealand homes to a high standard of sustainability by 2012." In relation to energy demand Beacon has set a target for homes as follows:

> *"90% of NZ homes use energy efficient systems for water heating, space heating, lighting and appliances, and have a high standard of insulation (to maintain minimum temperature of 18ºC), by 2012. Thus reducing the demand on reticulated energy from homes by 40%."*

Insulation is a key determinant of health, comfort levels and energy use in homes and hence an important aspect of overall energy sustainability. Recent Beacon reports have addressed the range of benefits available from insulation (e.g. TE106 (McChesney and Amitrano, 2006); Allen & Clarke et al (2007)).

For new houses, minimum standards of insulation are defined by the requirements of the Building Code. Standards were first introduced nationally in 1978 and have been revised periodically since, with the latest revision taking effect over the period Oct 2007-Oct 2008. Some houses built prior to 1978 had insulation installed during construction but most did not. Many houses have since had some level of insulation retrofitted, but large numbers of houses overall have sub-standard levels of insulation compared with current expectations.

The objective of this research is to review:

- Technical aspects of insulation including product availability and choices, industry practices and cost effectiveness, with the analysis to be relevant to the predominant types of housing found in New Zealand (in particular light timber frame construction).
- Initiatives operating to improve house insulation in New Zealand, including a comparison with insulation programmes operating in the UK. The UK analysis is partly drawn from a visit made by one of the authors to the UK in March 2007 to study residential energy efficiency initiatives.

The four main components of a building envelope where insulation is applicable are ceilings, walls, windows and floors. This report focuses mainly on ceilings, walls and floors. Windows have been the subject of a previous Beacon report which covered multi-pane window options, thermal performance, and issues within the New Zealand market (TE180; Burgess and Bennett 2006).

2 What does insulation do?

Thermal insulation is used to control three components of heat transmittance through the building fabric:

- Conduction of heat through solid material
- Convection via air movement (both natural and mechanically driven)
- Radiant transmission, typically through glass but also through other elements of the building fabric such as across still air-spaces or through low density (porous) materials.

Insulation acts to increase the thermal resistance of particular elements of the building (i.e. reduce thermal conductivity), thus slowing the rate of heat transmittance. Thermal resistance is expressed as an 'R-value' where the higher the R-value the higher the thermal resistance[1]. Insulating materials with higher R-values reduce the rate of heat loss (or gain in summer) from a building. This reduces the need to provide supplementary energy for either heating or cooling and improves the ability to maintain a comfortable temperature range for humans (typically 18-24°C). In general the benefits of insulation are greatest the more that outside temperatures diverge from the temperature range for human comfort.

Diminishing returns: The rate of heat transmittance is inversely proportional to the R-value. That means that for each building element, increasing levels of insulation displays strong diminishing returns effects. An example is shown in Figure 1 where the heat flow through an uninsulated wall is compared with successively adding increments of insulation with an effective R-value of 1.0 m^2 °C/W. The uninsulated wall is assumed to have an R-value of 0.4 m^2 °C/W, while the particular conditions chosen assume a heat flow through the uninsulated wall of 1000 Watts. Adding the first increment of insulation with R1.0 reduces the heat flow by approximately 710W (71%); adding a further increment reduces heat flow by only about another 120W (12%). When the insulation is increased from R3.0 to R4.0 the heat flow is reduced by only about 30W (3%). Therefore, determining "optimum" levels of insulation involves assessing marginal cost effectiveness of each increment of insulation, for each element of the building.

Insulation substitution between building components: Heat loss from a building is determined by the sum of losses from each element of the building envelope. Because the loss from each element is proportional to its area, and since diminishing returns principles apply to each building element, it is not possible to substitute higher insulation values in one element (say ceilings) to compensate for no insulation in another (say walls). However there is the ability for limited trade-offs as long as each element has some basic level of insulation.

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[1] *The units of thermal resistance are (m^2 °C/W) where m^2 measures the surface area of the particular insulated element, °C measures the temperature differential between the inside and outside of the building, and W is the measure of heat flow in watts.*

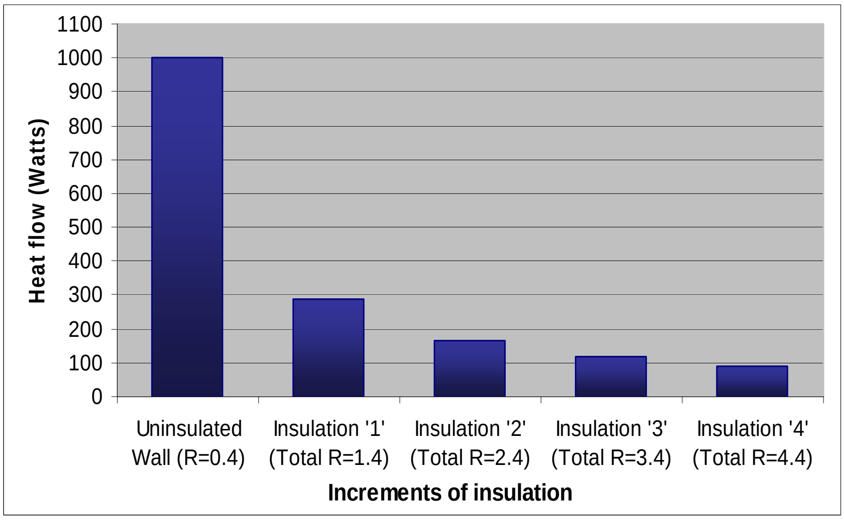

Figure 1. Diminishing returns effects from adding increments of wall insulation[2]

Prediction vs practice: For most types of houses the theoretical effect on energy use as a result of improving insulation is relatively easy to determine using a thermal calculation tool such as ALF3[3]. However, in practice the effects of insulation may be somewhat different to that predicted. The reasons can be technical or behavioural. The technical reasons include:

- The insulation material may be damaged prior to or during installation, or may deteriorate over the lifetime of the building.
- Installation practices may be sub-optimal, resulting in the insulation material not performing to its specified R-value.
- Insufficient account might be taken of the inherent structural characteristics of the building envelope components, which can affect insulation performance, e.g. the amount of framing and its thermal bridging.

The main behavioural reason is that people living in under-heated houses will often respond to retrofit insulation not by reducing energy consumption by the predicted amount but by "taking back" most of the theoretical energy savings as increases in warmth and comfort in the home.

Another difficulty is that other aspects affecting the thermal performance of the building may be poorly specified and not well integrated with insulation. For example if a building is over-glazed and receives too much direct solar gain it may overheat. High levels of insulation in the remainder of the building may exacerbate this undesirable outcome. Thus it is very important that insulation decisions not be dealt with in isolation from other factors affecting overall thermal performance and desired outcomes.

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[2] *Based on theoretical relationship between heat flow, temperature differential and R-value.*
[3] *Annual Loss Factor (ALF) thermal calculation tool from BRANZ.*

3 Insulation in New Zealand

3.1 Current status of insulation in homes

Various recent estimates have been made of the insulation status of New Zealand homes, but because of the invisibility of some types of insulation (e.g. insulation in walls and skillion roofs) there is still considerable uncertainty about some aspects. The year 1979 provides something of a break-point since this was the first year after insulation was mandated in new homes, and insulation status is often segmented into categories of pre- and post-1979 houses. However, insulation was being installed in increasing numbers of new homes prior to it being mandated; also substantial retrofit insulation was being carried out from the late 1960s onwards. The 1976 Census recorded over 300,000 dwellings having some level of either ceiling, wall, or both ceiling and wall insulation - comprising one-third of total dwellings at that time.

Most of the early insulation, and some that has been more recently installed, is now inadequate due to the thinness of the initial installation, settling and deterioration over time. The BRANZ 2005 House Condition Survey (Clark et al, 2005) found that 60% of houses had ceiling insulation with a thickness of less than 75mm across the entire roof-space (75mm roughly equating to the 1978 Standard of R1.9, and being substantially less than current standards). Eighteen percent of houses surveyed had either no insulation at, or installed in less than 50% of the roof area. If these percentages applied across all the housing stock then over 250,000 houses in New Zealand have no ceiling insulation at all or insulation in less than half of the available ceiling space, and over 900,000 have inadequate thickness.

Levels of wall insulation are harder to determine. Post-1979 houses should have wall insulation, although about 70,000 of those have solid walls so insulation is likely to be minimal. Most pre-1979 houses (about 1 million) will not have had wall insulation originally installed, but over time houses that have had additions or remodelling work may have had wall insulation installed in particular areas of the house. Taking this into account it has been estimated that some 700,000 houses have no, or little, wall insulation (McChesney and Amitrano, 2006).

Based on the 2005 House Condition Survey it has been estimated that some 700,000 houses are constructed with concrete slab-on-ground floors, 200,000 have suspended floors with some form of insulation and some 740,000 houses with suspended floors are uninsulated (Beacon unpublished report). A proportion of the uninsulated floors will be unable to be insulated because of access difficulties, mainly dependent on the age of the house (how close it was built to the ground) and topography (flat areas generally have more restricted access). Overall, it is estimated that about 650,000 houses without floor insulation will be able to be insulated, and in addition a proportion of those that are insulated will probably need re-insulating because of damage and deterioration to the original insulating material.

Despite some uncertainties the inescapable conclusion is that large numbers of houses throughout the country are currently inadequately insulated. Each area of the country will have slightly different characteristics reflecting the age of the housing stock, local geography and topography and climate (there is a greater propensity for insulation in colder areas). As an example Figure 2 shows the pattern of insulation installed in private rental properties retrofitted under Environment Canterbury's Clean Heat scheme in Christchurch from 2003-06[4]: The graph shows six age bands and plots the percentage of houses within each age band where various forms of insulation were fitted[5]. Key points to note are:

- Underfloor insulation – the pattern of installations rises from less than 50% of pre-1920s houses to a peak of almost 90% of 1950s houses, declining again in the 1970s. Up until 1970 this pattern is probably almost entirely access-related; older houses being built too close to the ground to allow access for installers. The lower rate for 1970s houses is likely to be for two reasons: some houses will have had insulation installed when built, and others will have been constructed with concrete floors.
- R3.2 ceiling insulation – this level of insulation is installed in houses with no previous ceiling insulation. The data suggests a pronounced correlation with house age.
- R2.6 ceiling insulation – this level of insulation is installed into houses that have existing, but deficient levels of insulation. There is no clear trend with age of the house.

It is emphasised that this is a single, location specific 'snapshot', and somewhat different patterns might be found in other parts of the country.

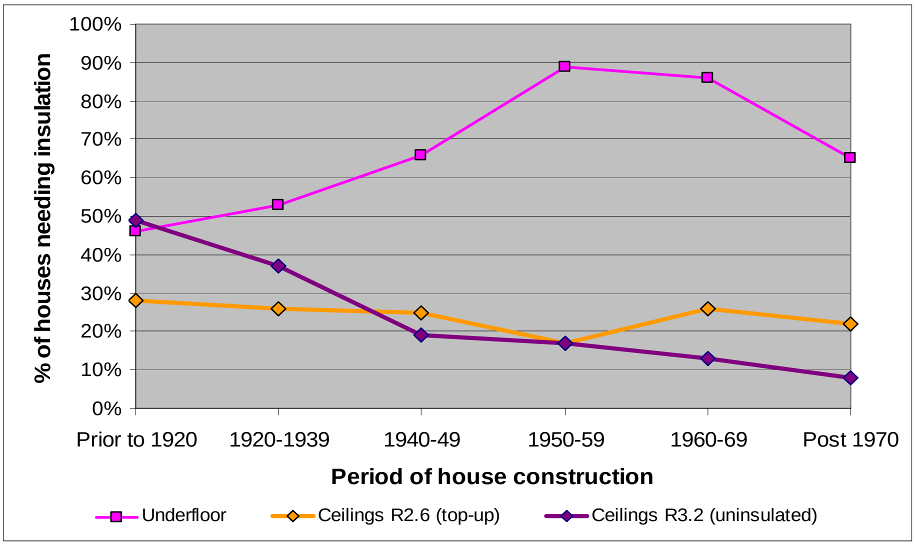

Figure 2. Ceiling and floor insulation requirements according to house age – private rented houses in Christchurch 2003-06[6].

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[4] Reported in Fyfe and McChesney (2006) from data provided by Environment Canterbury
[5] Note that the graph has not been adjusted to also reflect the total number of houses within each age category. Far more houses were constructed in the post-1950s period than prior to 1950, so this adjustment would need to be made in order to calculate actual numbers of houses requiring insulation within each age category.
[6] Percentages refer to the percent of houses within each age category

3.2 Implications for energy use

In terms of overall energy use in the home insulation primarily affects energy used for space heating or cooling[7]. Space heating energy use is estimated at about 23PJ, or 35% of the energy used in homes. This amounts to some 4% of all consumer energy used in New Zealand. A range of energy sources are used, with electricity and wood being the most important both in terms of the amount of energy used and the proportion of houses using those fuel types. Table 1 shows data from the last three Censuses, indicating changes in the percent of houses using various fuel types. The most notable trend is the consistent decline in the proportion of houses using solid fuels (wood and coal). Between 2001 and 2006 the proportion of houses using electricity rose by almost 3%, but the most significant underlying trend (not indicated by these numbers) is the growth in use of heat pumps as primary forms of heating in houses.

Table 1. Percentage of houses using various fuel types for home heating

Fuel Types	1996	2001	2006
	Percent of households (%)		
Electricity	77.2	72.0	74.8
Mains gas	11.6	13.5	13.2
Bottled gas	22.3	28.3	27.7
Wood	48.7	44.7	40.9
Coal	13.0	9.3	7.0
Solar power	0.7	0.9	1.1
No fuels used in this dwelling	0.9	2.8	2.4
Other fuel(s)	1.9	1.1	2.1

Source: Statistics New Zealand: http://www.stats.govt.nz/census/2006-census-data/quickstats-about-housing/quickstats-about-housing-revised2.htm?page=para011Master

In New Zealand to date household cooling has not been a major consideration, but in the future it may become more important for the following reasons:

- Population trends (and projections) indicating a larger proportion of the population living in warmer parts of the country (particularly around Auckland and in the Bay of Plenty)
- The progressive effects of climate changes and overall warming
- Summer overheating of houses, in part due to little attention having been paid to window design, placement and shading to avoid excess solar gain (particularly in houses built over the last 2-3 decades)

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[3] *Insulation also impacts on the efficiency with which other sources of heat within the houses are retained e.g. heat losses associated with hot water storage, cooking etc. Insulation, along with thermal mass, also has a major effect on retaining the solar heat captured through windows.*

- Very rapid growth in the availability of reverse cycle heat pumps in homes, which now provides householders with the ability to use mechanical cooling devices.

Recent work by BRANZ has indicated that a majority of householders with access to heat pumps will use them at least periodically for household cooling[8]. The source of energy for cooling (assuming use of heat pumps) will be electricity, and in the future some parts of NZ may follow the U.S. and Australian trends which have seen peak energy use now occurring during summer because of the rapid adoption of active cooling. The progression toward active cooling increases the need for insulation to be integrated into new build and retrofit solutions.

Insulation can thus influence the demand for a range of energy sources – renewable and non-renewable - and can indirectly affect the adverse effects from the use of those sources, including CO_2 emissions and localised air pollutants such as fine particulates.

3.3 Pathways to improving insulation

A simple framework showing the pathways to improved insulation is outlined in Figure 3. Further discussion on new houses is provided in the remainder of this section. Retrofitting is discussed further in S5.

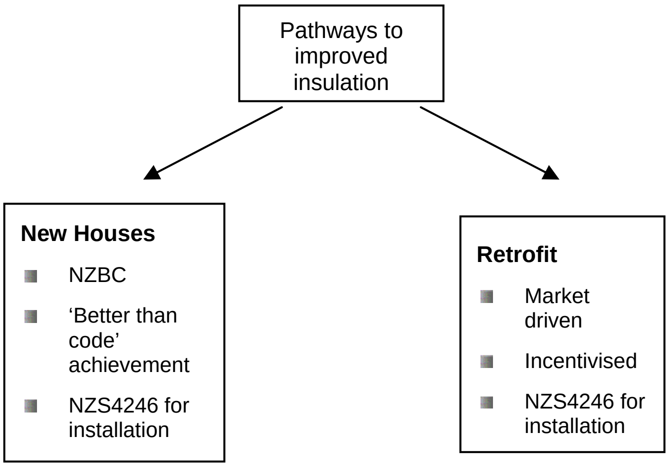

Figure 3. Simple framework showing improvement pathways for new houses and retrofits

3.3.1 New Houses

New Zealand Building Code: The basic pathway is through the New Zealand Building Code (NZBC) which establishes minimum insulation requirements according to three climate zones established for the country based on climate data and taking into consideration territorial authority boundaries. Climate Zone 1 applies to northern North Island areas with Heating

[8] *Pers Comm Lisa French, BRANZ.*

Degree Days (HDDs)[9] up to about 1200 pa. Climate Zone 2 applies to the balance of the NI apart from a central plateau zone. HDDs are typically in the range of 1200-1800 pa. Climate Zone 3 applies to all of the South Island plus the central plateau area of the NI. HDDs are from about 1800pa upwards.

The NZBC contains an energy efficiency Clause (H1) which specifies the minimum energy performance required of new housing and additions to existing houses. Minimum insulation requirements and acceptable solutions for compliance with H1 are set out in NZ Standard NZS 4218 Energy Efficiency – Housing and Small Building Envelope. Further guidance is contained in the BRANZ Home Insulation Guide (BRANZ, 2007).

Periodic updates of the NZBC provide one pathway to improve basic insulation levels in new homes. New provisions of the NZBC, to apply as a result of a review in 2005-06, were announced in May 2007 and will be introduced over the period 31 October 2007 – October 2008. These same provisions apply to additions to existing houses. As an example of the scale of change, Table 2 summarises changes in the NZBC R-values for Climate Zone 2 from its inception through to the 2007 revisions (similar changes occurred for Climate Zones 1 & 3), while Table 3 outlines the insulation requirements resulting from the 2007 revisions for two main types of new housing, for all three climate zones. The current H1 upgrade (2007-2008) also takes into account the benefits of thermal mass (solid construction) when it is on the internal surface (Department of Building and Housing, 2007).

Table 2. NZBC insulation requirements (example shown is for light timber frame houses, Climate zone 2)

Component	1978	1996	2007
Roof (ceilings)	R1.9	R1.9	R2.9
Wall	R1.5	R1.5	R1.9
Floor	R0.9	R1.3	R1.3
Windows	na	Na	R0.26

[9] *'Heating Degree Days' are calculated as the difference between the mean daily temperature and a base temperature (commonly 18°C) in any given location. For example an average daily temperature of 12°C for 4 four days results in (18°C – 12°C) * 4 days = 24 HDDs. The higher the HDDs, the colder the temperature, and the higher the potential heat loss from buildings. In New Zealand there is nearly a four-fold difference in HDDs between the far north and coldest areas of the country (southern areas and the central plateau). Kaitaia, for example, has around 900 HDDs, Auckland 1,100 HDDs , Christchurch 2,300 HDDs, Invercargill 2,900 HDDs, and 3,300 HDDs for Lake Tekapo in the Inland South Island. A comparable measure 'Cooling Degree Days' can be used to indicate the possible benefits of insulation in reducing heat gain in buildings.*

Table 3. Insulation requirements - 2007 revision of NZBC.

Building thermal envelope component	**Minimum R-values (m^2 °C/W)**		
	Climate zone 1	Climate zone 2	Climate zone 3
Light Frame Timber houses			
Roof (ceilings)	R2.9	R2.9	R3.3
Wall	R1.9	R1.9	R2.0
Floor	R1.3	R1.3	R1.3
Windows (vertical)	R0.26	R0.26	R0.26
Solid wall construction (excludes solid timber – "a" Option only)			
Roof (ceilings)	R3.5	R3.5	R3.5
Wall	R0.8	R1.0	R1.2
Floor	R1.5	R1.5	R1.5
Windows (vertical)	R0.26	R0.26	R0.26

Source: Department of Building and Housing, 2006.

Tables 2 and 3 highlight a number of features of the way insulation requirements have been incorporated into the NZBC, notably:

- Some components have changed little over the almost 30 years that insulation has been required e.g. walls and floors (e.g. Table 2)
- The lack of a significant differentiation in code requirements between climate zones (Table 3), yet the difference in heating needs (measured in HDDs) is typically 2.5-3x higher in Climate Zone 3 compared with Climate Zone 1. Some further comment on this issue is provided in later sections.
- Insulation trade-offs are allowed for houses constructed using solid walls, where lower wall R-values can be traded off by higher R-values for ceilings and floors (Table 3). These trade-offs have been determined by cost-benefit analysis. As noted in Section 2 of this report, because of diminishing returns effects only limited trade-offs are possible in order to retain the overall integrity of the energy efficiency requirements of the NZBC.

Better-than-code achievement: While the NZBC prescribes minimum acceptable standards some new home buyers will construct houses with insulation levels considerably in excess of code values. For instance, well before the requirement for double glazing in the NZBC, increasing proportions of new houses built in the South Island were incorporating double glazing. The 2002 New House Survey (NFO, 2002) found that 68% of new homes in Christchurch were installing double glazing on all windows, with a further 6% installing double glazing on some windows. This survey also reported a reasonable proportion of new house buyers specifying "*higher levels of insulation*" for their homes, although it is difficult to know what this meant in practice. The drivers for new home buyers wishing to exceed the building code energy requirements appear to be a combination of factors including local climate conditions (much more likely to exceed building code in colder climates), a desire for a warmer home, and non-energy factors such as reducing window condensation, adding value to the home etc. Higher insulation specifications are probably also more likely in higher value housing stock compared with budget new houses (in particular double glazing). However, any potential energy saving benefits may be offset by these houses being larger and possibly more energy intensive in other ways.

Guidance on better-than-code achievement has, to date, been provided through the publicly available specification (PAS) *Insulation of Lightweight-Framed and Solid-Timber Houses* (Standards New Zealand, 2003). This document outlines specifications for "better" practice and for "best" practice with respect to insulation levels[10]. These levels were defined with reference to the NZBC levels applying at that time but will not necessarily represent 'better' or 'best' practice relative to the new code levels applying from October 2007.

NZS 4246: Although not yet referenced in the NZBC, the recently released standard NZS 4246[11] is intended to provide better performance from insulation by defining the appropriate quality level for installation, for both new and retrofit situations. It should provide a useful mechanism for ensuring a high level of installation quality in those homes that require a building consent. Under this guidance the building official signing off the work is required to check that insulation installation meets the standard of "no folds, bends or tucks" and other quality aspects. However there is still a greater role for industry to ensure the standard is used, and is useful.

[10] *"Better" practice is described as what can be achieved using common construction practice (e.g. within the limits of 100mm stud width for walls), while "best" practice is described as what can be achieved using the best possible current construction techniques for thermal performance (see Department of Building and Housing, 2006).*

[11] *Available at: http://www.eeca.govt.nz/eeca-library/residential/eeca-library/residential/energywise-home-grants/guide/installing-insulation-in-residential-buildings-07.pdf*

4 Technical review of insulation

This section provides an overview of insulation options available for new homes and for retrofitting into existing homes. Four generic types of insulation materials are discussed covering:

- Fibre
- Cellular
- Reflective
- Solid

The assessment reviews product characteristics such as durability and longevity, end of life disposal and sustainability, and cost effectiveness. Considerations that are important with regards to environmental consequences include energy and resource requirements for the insulation materials, impacts of manufacturing on the environment, the ability to reuse or recycle at end of life, and any constraints on disposal of materials.

While these considerations are important, long-term thermal performance remains the priority because of the potential for substantial loss in the flow of long-term benefits if thermal performance becomes compromised. Also for some insulation components the cost of rectifying poorly performing insulation might be relatively high. Criteria for long term performance include:

- Stability of product and expected effective life.
- Vulnerability to factors affecting performance including moisture, movement and compression of fill, and vermin attack.
- Durability of treatments such as flame retardants.

Assessment of durability forms a part of product appraisals undertaken by BRANZ. Products are assessed against the requirements of the NZBC which currently requires either 5, 15 or 50 year durability. The durability requirement includes the thermal performance, not just the physical integrity of the material. For some materials NZS4859.1 specifies additional tests such as moisture absorption or corrosion. However, long-term test data on specific insulation product durability is often not available.

A number of further issues related to product installation are discussed because the quality of installation is a major factor determining the long term performance of insulation. There is a brief section on new products with potential to provide for high levels of insulation, long-term.

4.1 Product characteristics[12]

4.1.1 Fibre products

The product family includes glass, synthetic and natural fibres[13]. Most products have an open structure and have relatively high air permeability. As a result, site detailing of air barriers may be important in ensuring long-term performance.

Plant and animal products are sourced from renewable raw materials. Their production typically has a low embodied energy and low impact on the environment (Rawlinson, 2006), although because for a given R-value the weight of material needed will vary from one material to another, it is important to compare embodied energy on an R-value basis rather than simply on weight (a point that has often been overlooked). A large proportion of both glasswool and wool products are sourced from recycled waste. Chemical binding agents are required to form insulation segments and blankets.

Cellulose and wool-based insulants require chemical treatment to protect them from fire, rot and rodent infestation. The long-term performance of the chemical treatments is potentially vulnerable to degradation because of the presence of moisture. The thermal performance of wool and cellulose are more susceptible to degradation by moisture than glasswool and polyester because they will absorb a greater quantity of moisture. In the past claims have been made that the cyclic absorption and desorption of moisture in wool insulation provides additional thermal resistance. Whilst it has been shown to occur the research also showed that the actual impact was negligible relative to the benefits of simply using thicker or denser insulation.

These products are available as segments and rolls, and some available loose as blown product. End-of-life recycling or disposal is generally easy and without harmful by-products.

Durability factors: Key factors in determining durability are:

- compaction
- moisture/water effect
- impact of temperature variations and extremes
- stability of binding material.

The performance of fibrous insulation materials reduces if they are compacted. One source of compaction is leaks which allow sufficient water ingress to saturate the insulation. Even when the insulation becomes dry again after the source of water is eliminated the material may not re-loft to its original thickness. Polyester insulation appears to be able to re-loft after saturation better than wool or glasswool but it will depend on factors such as density and fibre diameter. In general, denser and coarser fibres are more robust, but these factors generally decrease insulation performance so a trade-off must be made. If glasswool or wool insulation has

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[12] *Some of the material in this and the following section is derived from Rawlinson, 2006.*
[13] *Fibre materials discussed are the conventional insulants used in timber frame buildings – cellulose based insulants, glasswool, wool and polyester.*

become saturated when a house has flooded or leaked BRANZ believes the insulation should be replaced rather than removed and dried because of the likely permanent loss of insulating value.

Stability under temperature extremes is an important consideration, particularly the elevated temperatures found in roofing situations. Polyester insulation durability has been assessed for the impact of elevated temperatures under metal clad skillion roofs, for example. It is important that the binders are durable but at the same time the product must not over-loft as an air-space must be maintained between the insulation and the roof underlay. NZS4859.1 only requires the label to have nominal thickness and currently there are no manufacturers supplying information on maximum thickness.

Deterioration due to settling: Cellulose fibre begins to settle the moment it is installed so it is important that the settling rate is determined and allowed for when the material is installed. This means the initial thermal resistance at installation must always be greater than the required or claimed performance. Settling is 10% or more and will depend on the density it is installed at. Loose-fill rockwool (mineral fibre) insulation generally settles less than cellulose but again the amount will depend on the installed density. Loose-fill glasswool is extremely variable in its settling behaviour because it is available in both new and recycled form. New loose-fill glasswool can be blown, but at extremely low densities it is particularly vulnerable to settling and being blown about by wind. Wind blow is a problem for all loose fill fibre insulants if the roof space is poorly sealed from the outside environment.

There is no data on the durability of glasswool. Early glasswool products installed in ceilings in the 1960s and 1970s have invariably deteriorated, but manufacturing processes have changed significantly since then including the addition of more stable binders. Even so, while products are appraised against a 50 year service life there are no universal durability tests simulating 50 years. The commonly used local products (Australian & New Zealand) are low density products with densities as low as 6.5 kg/m^3.

4.1.2 Cellular products

The most common cellular products are plastics comprising extruded and expanded polystyrene. Plastics products are available as foam, rigid sheet and loose fill. Plastics-based products typically have a lower rate of thermal conductivity than fibrous materials e.g. higher R-value per equivalent thickness, giving up to 50% better insulation performance. This enables high performance to be achieved using a thinner section; consequently plastics products are particularly suitable for super-insulation applications. Plastic products are dimensionally stable and are generally not affected by water ingress, rot or vermin attack.

Plastics products are created mostly from oil-based raw materials. Hydrochlorofluorocarbons (HCFCs), which contain CFCs used as blowing agents, were used in producing early plastics-based insulation material, but these products are now either banned or their use restricted because of ozone depleting properties. Over time, production has switched to the use of neutral hydrocarbons or CO_2 as blowing agents. Reconstituted products may contain older materials or those sourced from elsewhere and therefore the original blowing agent is either unknown or unclear.

Some plastic insulants can be difficult to recycle and dispose of e.g. expanded polystyrene sheet (EPS) embedded into concrete blocks or slabs.

Foams: Foam products are reasonably common insulants overseas. In New Zealand a pumped foam product is available to be pumped into the walls of an existing home to provide thermal insulation. To pump the foam into the walls holes (typically less than 6 mm diameter) are drilled through the external wall covering for each area between the studs and the dwangs (nogs or cross members) and liquid foam is pumped into each of these cavities. The foam expands, dries and then hardens to form a solid insulating block within the cavity, with the potential for a relatively high R-value per thickness. If building paper is present (not common in NZ prior to 1970) then the holes will also pierce the paper.

Despite having been available for over 20 years in New Zealand there is no independent information on how effectively it works or any associated issues in New Zealand houses and climate. Some of the questions where independent information is lacking include long term durability, possible health effects from the drying agent, potential creation of moisture pathways when installed into walls with a ventilated cavity, long term effects on electrical cabling, and drying/moisture issues.

4.1.3 Foil

Foils are used largely as a reflectance barrier to reduce radiative heat flows. The most common application is under floors, both in new houses with suspended floors and in retrofitting into existing houses. In this situation the performance of the foil is reliant on the creation of a still air insulating layer to minimize convective losses. It therefore requires that the still air layer is protected to ensure it is not, or doesn't become, naturally ventilated. Although underfloor foil may help to prevent moisture intrusion through the floor, it is not a substitute for polyethylene ground cover. This will be the case even when the joins are taped.

The most commonly used material to date has been simple double sided metallic (aluminium) foil with high reflectance, but a range of alternative forms of foil-backed products are now becoming available. These include relatively simple variations where foil is bonded to conventional bulk fibrous insulation, and new formulations where a reflective layer is bonded into laminated sheets with polypropylene, or other cellular polymer sheets.

One of the issues with foil-based products is the lack of a required, standardised measure of the R-value that can be used to objectively compare alternative products. For example, well installed retrofit foil is assumed to provide a minimum insulation value of R1.0 (EECA, 2006a), although the theoretical value is over R2.0 assuming the full insulation contribution from the still air layer. In practice, BRANZ, EECA and other agencies have used empirically derived data on the insulation performance of foil to account for likely sub-optimal installations, and to account for deterioration and loss of reflectivity over time (see below). However, some suppliers of the newer laminated or bonded products claim much higher R-values (assuming an effective and stable air gap over time), but it is not clear that there is sufficient empirical information available to justify reliable, in-situ R-values.

Durability under floors: In a study carried out for EECA, samples of in-situ underfloor foil (installed both in new houses and as retrofits) were extracted for examination to ascertain durability and the likelihood of deterioration in the R-value (Amitrano, 2006). Foil condition was given a rating and averaged 3.3 across all houses out of a possible 5 points. The range though was 10-fold – from 0.5 to 5, and 54% of cases were considered not to reach an acceptable standard. This finding was not dissimilar to an earlier study by Isaacs and Trethowan (1985) in which in-situ measured R-values of underfloor foil were found to vary from R0.2 to R2.1.

The Amitrano study concluded that durability depended on 1) the quality of the installation, and 2) the choices of appropriate insulant materials when installing into exposed sub-floor environments. Well-installed foil on a house with a closed perimeter sub-floor will likely achieve at least a 15 year life with acceptable insulation performance. However in an open (exposed) sub-floor, bare foil has a high likelihood of premature damage. Thus alternative, more durable products should be used.

4.1.4 Solid

Solid materials generally have poor insulating qualities because the dense composition readily allows thermal conductance. Where solid materials are utilised for the purpose of insulation they are typically characterised as follows:

- Insulated structural concrete or blocks – these rely on an insulating layer (generally EPS) being inserted into pre-cast slabs or bocks i.e. the insulating properties of the product is dependent on the EPS layer rather than the concrete. However, these products can also provide additional energy benefits to a house through thermal storage provided by the internal mass (Bellamy and Mackenzie, 1999).
- Aerated concrete – some concrete products are produced using an aeration method which results in low density concrete with some inherent insulation value, and a compressive strength to enable structures up to 3 storeys to be built[14]. The insulation value is approximately R0.7 per 100mm thickness.

Solid materials are extremely durable and can be expected to last the life of the building.

A summary of insulating material characteristics is given in Table 4. While straw insulation has not been discussed in the body of the report because it is a specialist building application, the insulation characteristics of straw are included in the table for comparison.

[14] *See: http://www.greenhouse.gov.au/yourhome/technical/fs34b.htm*

Table 4. Summary of insulating material characteristics

Basic material	Product type	Applic -ation	New or Retrofit	Form	Durability/ longevity	End of life/ disposal	Sustainability	Insulation value	Comment/issues
Fibre	Glasswool	Ceilings, Walls, Floors	New, Retrofit	Segment, blanket (sometimes foil-backed)	Early product prone to slumpage and deterioration. Current product more slump resistant. Loses insulation properties if wet	Potentially recyclable to form new product	NZ sourced, and overseas sourced from common materials; may contain high proportion of recycled fibre depending on particular manufacturing plant	~R2.5 per 100mm for low density product; denser products (such as specialist wall insulation) have higher R-values per 100mm	Some variation in product e.g. proportion of recycled product
	Wool	Ceilings, Walls, Floors	New, Retrofit	Segment, blanket (sometimes foil-backed), loose fill, often in blends with polyester	Chemical treatment protects from fire, rot and pests; also for slump resistance in segments/blankets. Loose-fill prone to slumpage over long term	Potentially recyclable depending on blended content	NZ-sourced, renewable product; may contain high proportion of recycled fibre;	~R1.8-2.3 per 100mm in blanket form;	Blended content can lead to variation in product quality Long term durability of R-value unclear
	Polyester	Ceiling, Walls, Floors	New, Retrofit	Segment, blanket, sometimes available in wool blends	Stable, long-life product. Prone to compression damage in storage which may compromise R-value	Potentially recyclable	Petrochemical based but low mass product	R1.8-2.0 per 100mm for low density product; denser product available	

Basic material	Product type	Applic -ation	New or Retrofit	Form	Durability/ longevity	End of life/ disposal	Sustainability	Insulation value	Comment/issues
	Cellulose	Ceilings, Walls	Mostly Retrofit	Blown loose fill	Chemical treatment protects from fire, rot and pests; prone to slumpage and moisture retention over time, rendering it less effective	Not recyclable because of chemical content	NZ-sourced, renewable product; may contain high proportion of recycled fibre;	~R2.5 per 100mm but may decline to half that over time	Lower initial cost compared with other fibre products, but expected shorter life. May be useful product for retrofit insulating ceilings with poor accessibility
	Straw	Walls	New	Compressed bale	Generally stable so long as low moisture content initially, and wall linings protect from moisture ingress	Likely to be biodegradable at end of building life	NZ-sourced, renewable product	Typically R3-R4 for 400mm bale width in straw bale houses	Durability extremely sensitive to moisture – protection from moisture ingress at construction especially critical.
Cellular	Expanded polystyrene	Ceiling, Walls, Floors	New, Retrofit (mainly for floors)	Sheets, beads (less common); sheets sometimes embedded into structural elements	Stable, long-life product, especially when fully enclosed; vulnerable to damage if exposed	Potentially recyclable; earlier products may contain CFCs so will require special disposal	Synthetic, petrochemical based but low mass product; often produced with high recycled content	R2.5-3.0 per 100mm	Some shrinkage can occur, and may affect the integrity of some friction fit installations e.g. underfloors
	Polymer	Ceiling, Floors	New, Retrofit	Rolls, generally foil-backed	Assumed stable, long-live product	Unlikely to be recyclable	Synthetic product	Unclear – supplier reports state up to R3.2 but unlikely to achieve this in practice	Independent information on product R-values needed for applications in New Zealand houses

Basic material	Product type	Applic -ation	New or Retrofit	Form	Durability/ longevity	End of life/ disposal	Sustainability	Insulation value	Comment/issues
	Hardened U/F foam	Walls	Retrofit	Blown-in foam	Unclear	Unsuitable for recycling; early formaldehyde based products may require specialised disposal		~R2.9 per 100mm	Independent information on long-term product integrity not available for New Zealand houses
Reflective	Metallic Foil	Floors	Mostly Retrofit; New (sus-dended floors)	Rolls	Reflective surface prone to deterioration; prone to physical damage if not sheltered/protected from wind, animals	Unsuitable for recycling; non-toxic for disposal	Manufactured in NZ; non-renewable but low mass products	Assumed minimum of R1.0 but likely to be highly variable in practice	R-value likely to decline over time, especially in exposed conditions or with poor quality installation
Solid	Aerated concrete	Walls, Floors	New	Blocks, pre-formed panels	Expected to be durable for the life of building	Potentially recyclable	Manufactured in NZ; widely available materials; some embodied energy	~R0.7 per 100mm	Can be used internally or as external cladding.
	Insulated concrete	Walls	New	Blocks, pre-formed panels incorporating insulation (generally EPS)	Expected to be durable for the life of building	Potentially difficult to extract EPS	As above for EPS	R 0.5 – R3.5	Internal thermal mass can provide heat storage

4.2 Factors affecting insulation performance

4.2.1 Walls and elements

Light timber frame houses predominate in New Zealand due to a combination of climate, ready availability of timber, and established industry practices. There are two significant effects on insulation resulting from this situation; the limitations imposed by the standard 90 mm deep frame (100 mm nominal with a dressed width of only about 90 mm); and the combined thermal bridging effects of studs, dwangs and other supporting timber.

100mm studs: The long-standing industry commitment to 90 mm framing is reflected in the minimum insulation requirements of the NZBC of R1.9/R2.0. These standards require insulating material typically of R2.2/R2.4 which can be achieved using fibrous wall insulation segments routinely available from suppliers. The practical limit to wall insulation products with a 90 mm dressed stud depth is a high density product of about R3.0 (dependant on the insulation type), which with normal amounts of wall framing (see below) would provide a maximum wall insulation value of R2.2/R2.3 (see BRANZ, 2007).

Even prior to the most recent revision to the NZBC, 'best practice' as stated in SNZ PAS4244:2003 was for wall insulation of R2.6. Achieving this with a 90 mm frame would require adding an insulation layer on either the inside or outside of the timber frame. The most common form of external insulation is EPS sheeting; 40 mm sheet will increase wall insulation by ~R1.0. Internal options include attaching horizontal timber to add a 45 mm deep frame to the interior face of a standard 90 mm stud wall. This makes a wall with 135 mm depth and with the staggered framing reducing thermal bridging. Another option is installing polystyrene backed plaster board. Both of the internal options will result in the loss of some internal space and also the likelihood of some significant re-edging around windows. The other alternative is increasing stud depth to 140 mm, which would increase the maximum insulant product R-value up to R4.5, and enable a wall R-value of up to about R3.5.

Current building practice poses a significant 'break point' around increasing wall R-value beyond about R2.2, and cost-effectiveness considerations need to factor in more than just the cost of a higher R-value product. Also, as illustrated earlier in Fig 1 the actual improvement in energy efficiency through increasing wall insulation beyond NZBC levels will be governed by diminishing returns effects.

Framing and thermal bridging: Although wall R-value calculations for NZBC purposes typically assume that studs are at regular spacings of either 450 or 600 mm (and dwangs/nogs at 600 or 800 mm), the "effective" average space between framing members is usually significantly less because there is additional framing associated with doors, windows, wall junctions etc. Whilst a plain wall with none of the additional framing may have a ratio of framing to insulation of only 14%, a wall with 25% window area may have a framing ratio of 24% for the opaque part of the wall. The impact on the wall of this additional framing would be an overall reduction in R-value of at least 20% since insulation with R-values between R1.8 and R2.8 is being bridged by timber with an R-value of about R0.7 (for 90 mm framing).

Construction techniques are available for reducing the thermal bridging effects of framing but they are not commonly used in NZ because they represent a significant change to standard construction techniques. One simple and possibly cost effective means for reducing the impact of thermal bridging by framing is to decrease the framing ratio by using 140mm deep studs instead of 90mm and thereby use the same total volume of timber to give the same strength but with framing representing a smaller fraction of wall area, i.e. the studs would be spaced further apart. This would also enable better design of the thermally bridged perimeter areas such as wall junctions, and top and bottom plates. Without these improvements much of the benefit of increasing the insulation product R-value may not be realised. Using a 140mm stud would allow a total R-value of 3.0-3.2 compared with a maximum R-value of typically 2-0-2.2 for a 90mm stud.

Another cause for a discrepancy between simplified calculations and actual performance is the fact that the surface area of real walls is always greater than the planer projection because windows and doors have sills etc. Whilst the thermal performance of insulated sheathing or lining is less affected by framing than insulation in the frame cavity, the bridging associated with sills etc is still present[15].

Ventilation of wall space: Passive ventilation of walls associated with the use of cavity type wall construction may have a significant impact (up to 45%) on the thermal performance of exterior EPS sheathing. The impact can be easily mitigated by the use of insulation in the frame cavity and while it does undermine one of the cost benefits of Exterior Insulation and Finishing Systems (EIFS) which provide insulation as part of the sheathing, overall thermal performance will be improved. Even with direct fixed EPS systems where there is no cavity behind the sheathing (and no loss of thermal performance from ventilation) the use of additional insulation in the frame cavity will significantly improve the overall thermal performance. Since it is usually not practical to simply increase the thickness of the EPS, using insulation within the timber stud frame is the most practicable option for improving the R-value.

Walls with no building paper: Many pre-1970s houses will not have building paper in the walls. Building paper and wraps do not offer much of a barrier to air-movement through the wall since it is driven by interior to exterior pressure differences and not ‘wind wash’, but they have a key role in moisture control. NZS 4246 outlines a method for installing a building wrap into the wall cavity prior to retrofitting wall insulation.

Window elements including curtains: Since the thermal resistance of glazing is typically 1/20th of the opaque part of a well insulated wall (e.g. R0.16 compared with R3) the windows will usually be the limiting factor in improving the overall performance of the wall. This is true even when adopting high thermal efficiency glazing (typically ~R0.4-0.5) since the glazing R-value will still be only about 1/7th the value of the opaque parts. Well designed windows do however provide options for enhancing solar gain and high performance windows can reduce energy use simply by changing the radiant heat transfer and therefore the apparent temperature that is felt by occupants.

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[15] The framing in ceilings and floor is typically more regular and the difference between the simple calculations and actual performance is likely to be much smaller

Well fitting curtains can be as effective as high performance glazing for reducing heating energy needs but they should extend down to the floor and be enclosed at the top by pelmets[16]. Also, since they are only effective when the curtains are closed they generally do not provide benefit during daylight hours[17]. The well fitting aspect of so called ‘thermal drapes’ is more important than the fact the drapes are made from a heavier fabric. Using a heavier material ensures a better fit but cheaper fabrics lined with a good backing material can be made to achieve a similar thermal effect. The lining on some of the more expensive types of thermal drape are designed to better withstand UV and therefore enable use as a sun block and reduce solar gain in summer. It is common in newer suburbs and higher density housing such as apartments to see curtains and blinds used on a semi-permanent basis during the day to compensate for poor solar design (typically excessive areas of glazing) and loss of privacy.

4.2.2 Floors and foundation edging systems

The thermal storage ability of a concrete floor slab is significantly enhanced by the use of insulation but it is important to thermally break the slab from the perimeter foundations. The primary path for heat loss from a floor slab is through the perimeter and directly to the outside air rather than through the soil under the slab. Larger floors have higher thermal resistance than smaller ones because they have a smaller ratio of perimeter to total area. Simply putting insulation under the slab is relatively ineffective unless a thermal break is added to the perimeter.

Although in principle it is possible to add insulation to the outside of a wall footing, in practice it is difficult to protect for durability and difficult to make it look stylish. So called ‘waffle-slab’ or ‘pod’ floor systems use up to 300mm thick sections of EPS but with concrete between the sections for support and usually with a wide beam of concrete around the perimeter to support the exterior walls above. These perimeter beams largely negate the thermal benefit of adding the significant thickness of EPS so these systems would benefit greatly from the development of a suitable thermal break. BRANZ has proposed a method of adding a thermal break using timber around the junction between the slab and the footing[18] to improve the effectiveness of the EPS. While the thermal break on its own only adds R0.2-0.3 it then makes it worthwhile to put insulation under the whole slab whereas without the thermal break whole slab insulation is no better than just edge insulation.

Effective details for insulating slab floors have only recently been developed and further work is required to assist their uptake. Meeting the NZBC requirements for heated floors usually requires the addition of insulation.

Floor systems - rib vs sheet, aerated concrete: Some EPS products intended for application under suspended timber floors have ribs which create a small air space between the top of the insulation and the underside of the floor. This air space provides an additional thermal

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[16] See Sustainability Victoria:
http://www.sustainability.vic.gov.au/resources/documents/Window_protection.pdf
[17] Note though that temperature differentials between the inside of a house and outside are generally higher at the time when curtains are most in use (due to a combination of heating regimes in houses and typical diurnal temperature swings), thus adding to their effectiveness.
[18] See BUILD 100 June/July 07 (p32-33 & 103-105)

resistance of R0.2 but only if the air leakage is prevented. This may not be possible for some floors especially older tongue-and-groove or where it is difficult to tightly butt the EPS sheets together. There are also EPS products that don't have ribs but instead are made thicker to provide the same performance. Having an air space above the insulation would make it easier for the insulation to be blown down by wind exposure on an open or semi-protected floor. Clips are specifically designed to be used with these systems but their cost is significant and there does not seem to be good advice available as to when they should be used.

A foamed concrete product is available which is designed to be pumped under suspended timber floors as a ground cover. Although it will add some small thermal resistance to the floor system, its primary purpose is to reduce moisture evaporation from the ground to help protect the timber in the floor and to prevent ponding of water (more commonly, polythene sheet is laid).

Effect of carpets and underlay: Carpets and underlays are not included in an R-value calculation for building code compliance but add an additional R0.2 - R0.3 depending primarily on thickness. The NZBC requires more insulation under a heated floor and for the thermal resistance between the heating element and the interior to be minimized. This means that the insulation under the floor may need to be increased to compensate for additional thermal resistance provided by underlays and carpets.

4.2.3 Ceilings

Blanket vs segments: Most ceilings are insulated using fibre because of ease of installation and cost effectiveness. Traditionally, segments cut to fit between joists have been used but blanket (roll) products have become popular for the retrofit of ceilings because the insulation is generally faster to fit and easier to get through manholes. Blanket products can be cheaper to start with than segmented products because they cost less to package, store and transport because they are packaged at higher density. A drawback of blanket products made from polyester and wool is that whilst it is easy to cut or tear across the blankets it is much harder to cut along their lengths, making it harder to fit them between framing without adding the compromise of tucks and folds.

In principle blanket insulation is able to cover ceiling joists and provide insulation cover to the ~11% of ceiling area that may otherwise result in some thermal bridging, but care is needed to avoid convective losses from any air space underneath (e.g. if there is no insulation fitting tightly between the framing). A well fitted segmented product that is thicker than the framing will expand sideways where it extends above the height of the framing and thereby giving some insulation cover to the framing. If a single layer of a relatively thin (less than framing height) blanket product is to be installed into a ceiling where there is no existing insulation then it might be better to cut the material to fit between the framing for the simple reason that it enables extra insulation to be safely added at a later date because the location of framing will be obvious. It is not always possible to put blanket insulation on top of the framing near the perimeter of a ceiling because of the need to avoid the insulation coming into contact with the underside of the roof. Covering over framing using blanket products also requires extra care where there are recessed lights and sometimes adds the disadvantage of hiding electrical wiring and plumbing.

Air space in skillion roofs: The BRANZ helpline regularly receives calls about new houses where the builder or insulation installer has not installed the high R-value product that the homeowner and architect has expected simply because there is insufficient room to ensure that there is the required 25 mm gap between the top of the insulation and the underside of the roof. This applies in particular to skillion roofs. As well as the nominal thickness required for the insulation product to meet its claimed R-value, allowances must be made for both variation in thickness (maximum thickness is generally not specified in the technical literature for insulation products) and variation after installation, e.g. polyester & wool undergoing further lofting because of elevated temperature. Whilst using deeper joists with a skillion roof enables the use of higher R-value insulation products, in general it is not done because it adds to the overall cost.

Recessed lights: Installing recessed light fittings into ceilings negatively impacts on the effectiveness of ceiling insulation in two ways. First, it requires an uninsulated gap to be left between the light fitting and the insulation. For example a ratio of one recessed light fitting for every $5m^2$ of ceiling reduces the effective thermal resistance of R2.5 insulation by approximately 10%. NZS 4246 sets out recommended compensating R-values for ceiling insulation to account for this. Second, in the case of open recessed light fittings there is an air gap between the room and the ceiling space which allows free air movement upward from the warmed room. Different forms of recessed light fitting (CA rated which stands for closed-abutted, or FR – fire resistance rated) can greatly reduce these energy losses but are often not installed because they are more expensive than open fittings.

4.3 Interaction of whole house elements

4.3.1 Draftiness and ventilation (effect of air changes)

The thermal effects of air changes depend on how much occurs and the path(s) taken. Ongoing research into building ventilation is improving the accuracy of predictions of ventilation rates but is still limited by the availability of empirical data. Current research into ventilation of walls is focusing on finding out the actual leakage path rather than simply the air change rate. For example past research has shown that the thermal performance of under-floor foil insulation is very dependent on ventilation rate and the particular path it takes since in many older houses there can be significant air exchange between the subfloor area and the roof space (e.g. Isaacs and Trethowan, op cit).

In the US and Canada the air leakage through the building envelope and particularly through walls is treated with almost as much importance as the thermal performance of insulation products. In the colder parts of North America it is common that new houses are checked for air-tightness using a blower door test or similar as part of the building consent. Some of the research suggests that inadvertent air change can account for more than half the heat loss through a building envelope[19]. One particular focus has been the caulking around electrical boxes in walls and around penetrations such as water, waste and gas pipes. These areas are also

[19] *Much of this is because as the R-value of the envelope is increased, energy losses from air leakage assume relatively greater importance.*

important to the acoustic performance of walls, particularly ones using solid construction techniques such as brick, masonry or tilt panel. The widespread use of rigid sheathing in US and Canadian residential walls limits the applicability of their empirical air leakage data to NZ construction.

Recent experiences in New Zealand with retrofitting underfloor insulation and laying a groundsheet to prevent moisture ingress has been observed in some situations to dry out tongue and groove flooring and create air gaps. Where the underfloor insulation is foil this would also likely compromise the insulation value of foil because it would affect the still air layer between the foil and the floorboards. In recent research on retrofit insulation measures carried on two houses in Dunedin (Lloyd et al, 2007), stripping existing internal wall linings to add insulation to the frame, followed by re-lining, was found to increase air infiltration because of gaps around the new plasterboard. Both these examples show the need to consider the possibility of increasing air infiltration following insulation retrofitting, and if necessary taking mitigating steps e..g. taking care during the retrofitting process, and monitoring the condition of previously damp flooring that dries over a period of time after underfloor insulation is installed.

Older ‘leaky’ houses will benefit from caulking of the obvious holes. Typically small and simple houses built after 1980 are more likely to suffer from insufficient ventilation than older houses. From an energy efficiency standpoint it is desirable that the majority of ventilation is designed (and controlled) rather than simply being an inadvertent consequence of the complexity of the design and the quality of finish or the haphazard behaviour of the occupants opening windows.

4.3.2 Insulation and thermal mass effects

A common misconception is that mass alone is a thermal benefit. Whilst some lightweight masonry materials can have significantly lower thermal conductivity than say structural masonry it is not until the density gets below about 1000 kg/m3 that the thermal conductivity is at a point where reasonable thermal resistance can be achieved using a practical thickness of wall. At that density, the thermal mass is significantly less and much of the structural strength is lost. Therefore in practice an insulation layer must generally be added to masonry wall systems as opposed to integrating the insulation into the material such as adding EPS beads to concrete admixtures. A secondary benefit in incorporating the insulation in that way is that the location of the insulation layer can be chosen to optimise the thermal mass benefits.

Placing the insulation layer toward the inside improves the speed at which a cold room can be heated up but in effect isolates the thermal mass from the room and therefore negates the ability of the thermal mass to moderate the extremes of room temperature. An example of this is where a block wall is insulated on its interior face using strapping and lining or sheet insulation. This approach is best suited for the situation where the room (or building) is only conditioned when it is in use and does not have good, direct solar gain. The thermal performance of the wall will be roughly the same as a lightweight wall with the same total R-value.

Placing the insulation layer toward the outside of the wall buffers the thermal mass from the extremes of exterior temperature and couples the thermal mass to the room, thereby moderating temperature. This approach is best suited for the situation where the room is used regularly and continuously conditioned. The thermal performance of the wall will be better than a lightweight wall with the same total R-value.

4.3.3 Acoustic benefits of particular forms of insulation

Some forms of insulation also offer acoustic benefits, in particular dampening sound intrusion from the outdoors or between rooms in a house. This is particularly true of fibre insulation materials. For example, adding thermal fibre insulation to a frame cavity will noticeably improve the acoustic performance, and although manufacturers often claim improved acoustic performance from specialist products in practice the difference is generally minimal.

Caulking air leaks can both improve the acoustic performance and also reduce heat loss.

Doubling glazing is slightly better acoustically than single glazing but to achieve significant improvement requires the use of double panes where the gap between the panes is 100 mm or more.

4.3.4 Product substitution

An issue in achieving long term thermal performance of houses is the wide spread practice of product substitution. A common cause is a lack of detailed specifications. Feedback to the BRANZ helpline suggests that the poor specifications are the result of insufficient product information. Sometimes product literature is minimal in scope, ambiguous and contradictory to actual practice, and does not properly specify products (e.g. it is common to not see a weight listed). Another reason is a general lack of knowledge of insulation products and installation practices by the people responsible for the designs and specifications. There is also an issue with changes to product specifications - sometimes the appraisal certificates are used as the sole source of product details but it is not always possible for the certificates to keep up with the manufacturers' changes to their products.

When specifying products for areas such as skillion roofs it is important to know the maximum thickness of the product but manufacturers generally only give the 'nominal thickness' and even then it is not clear if they intend it to mean average or minimum. This also makes it more difficult for installers to differentiate products. Tasman Insulation provides a system of identification using strips on the surface of the products, but it is not on all products.

4.3.5 Certification

Two years ago the Australian Building Codes Board introduced a voluntary product certification scheme called CodeMark to extend the existing certification of management systems (ISO 9000) into the certification of products (ISO 17025). The need for the scheme was highlighted when independent testing of insulation products commissioned by the Australian Green House Office found that many products did not pass the testing despite manufacturers' claims that their products complied with the insulation standard AS/NZS 4859.1. To date, despite the initial enthusiasm from manufacturers, the scheme has certified only one insulation product – AirCell, a bubble-foil material, which is sold and installed in New Zealand mainly under floors. However it was noted earlier (S4.1.3) that products such as this, which rely on a stable air gap to achieve the certified R-value, currently lack a consistent basis for specifying an appropriate R-value in NZ conditions, and relative to other products.

There is no product certification scheme in NZ which means in practice the BRANZ appraisal often becomes the default certificate even though there are significant differences between an appraisal and certification.

4.3.6 Integrated thermal performance

With new houses the variables affecting thermal performance are able to be optimised within an integrated design process. Window size and placement, internal thermal mass, heating systems, location considerations, as well as levels of insulation can all be considered together to arrive at an optimal solution.

In a retrofit situation window size and placement, internal thermal mass and location are generally fixed. Therefore insulation and heating upgrades are the key to improving thermal performance. Retrofit upgrade trials undertaken by Lloyd et al (2007) in Dunedin has tended to validate evolving retrofit practice in colder areas of the country where integrated upgrade packages involving ceiling and under-floor insulation, draught-stopping, and the installation of efficient heating systems appear to be the most cost effective measures to undertake initially (see further discussion in S4.6 and S5).

4.4 Ease of installation/ installation issues

As noted earlier although not yet referenced in the NZBC, standard NZS4246 is intended to provide better performance from insulation by defining the appropriate quality levels for installation. Installation quality is as important in new homes as it is in retrofitting existing homes, although the issues tend to be different. For new houses the problems tend to be around detailing i.e. ensuring installation is carried out properly and to quality guidelines. For retrofit, as well as these issues, there are added difficulties around accessibility and health & safety.

4.4.1 Accessibility

Ceilings: The majority of houses have accessible roof spaces but houses with skillion roofs and those with low angle pitched roofs present problems for retrofitting. Unpublished Beacon research suggests that 23% of houses could have skillion roofs, and while some of these houses may have part skillion-part roof cavity it is a potentially significant number of houses in total. If they require insulation the options to gain access to the roof space are generally expensive and involve either removing the roof cladding or the internal linings. Alternatively insulation-lined plasterboard could be attached beneath the existing lining. Another option is installation of a false ceiling. While it may not always be practical or aesthetically acceptable to do this[20], findings from Beacon's Papakowai retrofit project indicated that insulation and lining against existing exposed rafters was a successful retrofit procedure[21]. The cost effectiveness of false

[20] *Key issues will be the height of the existing ceiling; also some people will not want exposed rafters covered.*
[21] *Pers Comm Beacon Pathway.*

ceilings will be specific to individual situations (e.g. whether there was already some existing insulation in the skillion roof), and would need to be carefully checked since total costs would likely be several times higher than the cost of the installed insulation material alone.

Larger numbers of houses, particularly built in the 1960s and 1970s, have low angle pitched roofs where access to install segment or blanket insulation to the outer edges of the ceiling cavity is extremely difficult. This is a situation where blown-in product could be particularly useful, although any product must be installed to maintain an air space between the top of the insulation and the roof underlay. Light fittings would be another area of difficulty as it would be necessary to put protecting baffles around all down-lights.

Walls: Access to wall space is generally very costly unless linings are being removed for other reasons. Lack of access and expense of lining removal is the main barrier preventing much greater uptake of conventional wall insulation retrofit products.

There are a number of blown-in products which require only small access holes to be drilled either on the interior or exterior of the wall. However, it is important that any vapour barriers or wall underlays are not to compromised, and that ventilated wall spaces remain open and free draining to prevent water transport through the wall. Pumped products are available but have not been subject to independent evaluation. Some expanding foams require a significant quantity of water to expand the foam so it is important that this water is not trapped in the wall. Loose fill EPS bead is a possible alternative but there are a number of technical issues that would need to be resolved. One of the issues in not having an underlay is containment of the insulation.

Floors: As noted earlier in the report a proportion of houses, probably mostly pre-1950s, are unable to be retrofit insulated because of limited access within the underfloor crawl space (a minimum of about 300mm is required). Also, houses with solid perimeter foundations and limited crawl space are very difficult to install with bulky underfloor products (e.g. polystyrene sheets, bulk fibre products). It can be an extremely difficult, unpleasant, and time-consuming task - and hence costly.

4.4.2 Installation practices, training/quality assurance processes

Previously it had been BRANZ practice to provide quantitative data on the impact of poor installation practice but the need to do this has largely been superseded by the new installation standard NZS 4246. This standard requires that products be installed without gaps, folds or tucks. Currently it is debatable whether it is being fully implemented in practice but at least there is now a baseline standard against which installation quality can be compared.

Probably the most comprehensive assessment of installation quality in relation to “best practice” is that undertaken by EECA in auditing ceiling and underfloor retrofit insulation installed under the EnergyWise Home Grant (EWHG) scheme. Over three consecutive audits beginning 2005/06 EECA found a significant improvement in quality. The latest audit indicated over 70% of houses had no faults or minor faults, with just under 30% having moderate or significant faults. The main issues are shown in Table 5.

*Table 5. Installation issues uncovered in recent EECA EWHG audits**

Ceiling insulation	Underfloor insulation
Labels missing No insulation at edges Large areas left uninsulated for no reason Hatches left uninsulated No clearance left around chimney	Large areas missed Poor installation quality No strapping on edges along support framing Joins not taped

* Source: EECA

Much of the required installation 'good practice' for achieving thermal integrity is in the detailing e.g. avoiding cold bridges, air-flow paths, opportunities for settling or compression of fill, and other movement during and after construction. There are also other considerations such as allowing for the ability to undertake remedial work without significant disturbance to the insulation e.g. leaving an underfloor insulation gap around plumbing fixtures so that plumbers can access fittings and not damage insulation (as recommended by Amitrano, 2006).

Packaging and storing bulk fibre materials: The short and long-term insulation values of bulk fibre materials can be affected when they are compressed for packaging and storage. Compression saves on product storage and transport costs, but may compromise R-values. Even although there may be products that have been designed to still loft to the minimum required thickness even after a reasonably long period such as 6 months or a year most products have a 'shelf life' in a compressed and stored state. Some manufactures of polyester and wool products deliberately do not use wholesalers and distributors for some products and instead supply direct to order to both avoid the need for storage space and to minimise the impact of compression packaging. A significant issue has been the use of so called 'double bagging' where multiple packs are combined and further compressed for transport. It is important that these packs are opened immediately on receipt but because of the need for additional storage space there is the temptation for wholesalers to leave the stock in the compression sleeve. Manufacturers do not always provide warnings on the compression sleeves.

4.4.3 Health and Safety issues

Electrical safety: The use of metallic foil (or foil backed product) under floors has created a particular safety hazard for those installing these products – electric shocks caused by the staples holding up the foil piercing live electric cables. There have been 4 recorded fatalities to mid-2007 as well as an unknown number of non-fatal shocks received. Most installation organisations have strict rules and procedures for preventing contact with live electric wires including scoping and marking all wires initially, and securing dangling wires away from the staple zone. The pre-laying of a polythene sheet on damp under-floor areas has also become standard practice for a number of installer organisations, partly to provide installers with a degree of insulation from the ground in the event that contact with a live cable occurred.

Despite the preventive measures, however, the difficult installation conditions encountered under floors (e.g. limited crawl space, poor light, physical tiredness etc) means that installers can be at constant risk. Others that might be exposed to the underfloor area at some later time (e.g. plumbers) might also be as risk if there is a faulty installation that later becomes live. EECA is currently in the process of trialling non-conductive underfloor products as an alternative to the use of foil products and stapling. These products are also aimed at improving the durability of fitted underfloor insulation.

Ceilings can also provide electrical risks for insulation installers. Some houses may have illegal or unsafe wiring such as unearthed light fittings and old/perished sheathing around electrical cables.

Thermal extremes: Temperatures in ceiling cavities on hot days in the middle of summer can easily reach 50°C or more creating dangerous working conditions for installers. Most retrofit insulation businesses now schedule summer ceiling insulation for early in the morning before temperatures in the ceiling cavity have built to extreme levels.

Hazards: Installers encounter a range of hazards in ceilings and under floors which can impact on health and safety. These include sewer overflow and waste pipe leaks, rodent or other animal droppings, sharp objects such as nails or broken glass, and waste building material containing asbestos.

Fire risks: Fire risks exist in ceilings where insulation might be incorrectly installed around lighting fixtures (e.g. downlights, transformers) causing overheating. Some insulation materials are fire resistant but others are susceptible and must be separated or protected from heat sources. Particular care is needed when retrofitting ceiling insulation over old cellulose insulating material where there are recessed light fittings. Any disturbance of the cellulose material which causes contact with the light fitting poses a high fire risk.

Health and safety is thus a high priority for the retrofit insulation industry. The electrical hazard associated with underfloor foil is now the key factor driving consideration of new products and materials for this retrofit component.

4.5 Emerging Technologies

Vacuum panels: These have thermal conductivity 1/3rd to 1/7th of typical insulation products but they are relatively expensive and fragile and so are currently restricted to specialist areas where space is at a premium such as fridges and freezers for boats. Research is being carried out on residential applications but initially the focus is specialist applications where traditionally it has been difficult to achieve good thermal performance because of space restrictions. An example is at the outer edge of a pitched roof.

Aerogels: perform nearly as well as vacuum panels but are even more expensive. They have the benefit of being extremely light and semi-transparent.

Structural Insulated Panels (SIP): are prefabricated panels that can fit together easily during construction, combining structural elements with high levels of insulation. Early forms of SIP included steel covered polystyrene sheets used mainly for cool store wall and roofs, but which have occasionally been used in residential houses. Overseas, SIPs designed for residential buildings have been constructed using plywood for structural elements and dense, fibrous insulation. SIPs have the potential to be a very effective means to improve thermal performance of houses because the location and thickness of the insulation can be tailored to the particular need. Some of the less sophisticated systems though have significant thermal bridging through panel joints.

A recent paper by Guthrie (2007) proposed that SIPs should have a greater role in New Zealand as a sustainable solution for the building industry. The advantages cited included excellent insulation and air-tightness, efficient use of NZ's wood resources with minimal waste generation, and a speedier on-site construction process because of pre-fabrication. Perhaps the main barriers are the relatively small scale of the construction industry in New Zealand and the current levels of wall insulation specified in the NZBC which do not force innovation beyond standard 100mm stud solutions.

4.6 Cost effectiveness

4.6.1 Pricing of insulation

Insulation costs to the consumer (i.e. pricing) represents a mix of the costs of materials and production, transport costs, product specification, and market factors (i.e. pricing to the competition, bulk purchase etc). In general glasswool has the cheapest production cost of the main fibre products but may not necessarily be the cheapest product to purchase at any particular time or place due to the other factors mentioned above.

For most insulation products price increases approximately proportionately with increasing R-value – in other words there do not appear to be significant economies of scale in purchasing higher R-value products. An example of some publicly available pricing is shown in Figure 4, derived from Control Insulation's website[22]. This plots the price per unit of R-value across glasswool, wool and polyester ceiling insulation products ranging from R1.8 to R4.6 (segments). For polyester and glasswool products there appears to be some improved cost-effectiveness up to about R3.2 but beyond that cost per unit of R-value appears to rise again.

In the case of retrofitted underfloor insulation products, costs vary significantly. Retrofitting basic foil typically costs about \$8/m^2 (for a nominal insulation value of R1.0)[23]. Basic bulk insulating products (EPS sheet, fibre or foil backed fibre products with insulation values of typically R1.3-R1.6, or the foil/polymer products with claimed insulating values of R2.0 or higher) can generally be installed for \$15-20/m^2. Thicker bulk insulating products (>R2) will typically cost \$25/m^2 or more to install. Given the broadening band of prices beyond basic foil retrofit (and uncertainty over some R-values), the cost-effectiveness comparison can be difficult for consumers to make.

[22] *See Control Insulation: http://www.controlinsulation.co.nz/favicon.ico*
[23] *With a further \$3-4/m^2 if plastic groundsheet is also laid.*

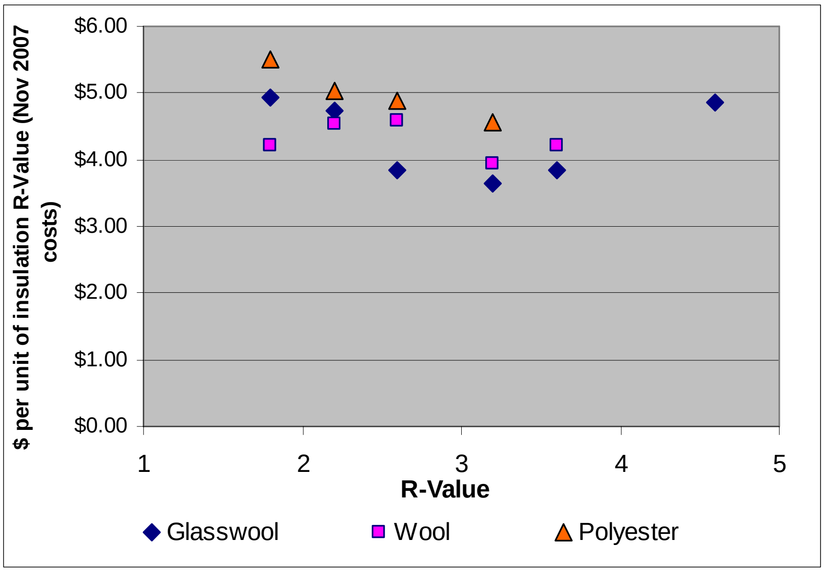

Figure 4. Cost per unit of insulation R-value for ceiling insulation segments

As the new requirements of the NZBC take effect, and with possible changes in products approved under the Government's EnergyWise retrofitting programme, these cost characteristics may change in the future.

Relative costs: According to Page (2006) insulation costs have decreased by about 15% over the last decade. However, a simple comparison of glasswool ceiling insulation products suggests that installed costs are still 30-50% higher in NZ compared with Australia, mostly due to higher product costs. This may reflect scale economies, and other issues of cost effectiveness in the building industry as a whole (e.g. overall building costs in Australia are substantially lower than in NZ).

4.6.2 Cost effectiveness of insulation

Determining cost effectiveness requires consideration of all of the potential benefits. The EECA model of net benefits, for example, developed to assess the case for insulation retrofits and other forms of energy efficiency, identifies five potential benefits streams – energy, environment, health, house maintenance and employment. However, the main non-energy benefit streams are closely related to energy savings in some form e.g. CO_2 emissions benefits relate to actual energy savings, while health benefits are realised largely when some or all of the theoretical energy savings from insulation are foregone and taken as increased warmth rather than actual saved energy. Regardless of the make-up of the benefit stream from insulation, insulation costs, effective energy costs, geographic location and diminishing returns are still defining considerations around the marginal benefit/cost of increasing insulation, and overall relative cost effectiveness.

New houses: Comment was made in S3 on the lack of differentiation in insulation requirements between Climate Zones in the NZBC. For example, even although heating degree days in climate zone 3 are typically two-three times higher compared with climate zone 1, insulation R-values for the various building components are at most 15% higher. The NZBC insulation levels were essentially determined by a benefit:cost analysis (Department of Building and Housing, 2006), which is included as an appendix to the consultation document (Page, 2006). When the b:c analysis is examined three main reasons for the lack of differentiation are clear: the assumptions used in the analysis[24], the sometimes disproportionately higher costs associated with non-standard (higher) insulation levels, and the effect of diminishing returns.

Nevertheless, higher levels of insulation will be justifiable in many cases for new houses in climate zones 2 and 3. Another factor to consider is that if the highest, cost-effective standards of insulation are not installed at the outset, for some building components the cost of rectifying via retrofitting is likely to be several times higher. There is a need for guidance – perhaps through updating the 'better' and 'best' levels of insulation previously provided through SNZ PAS 4244:2003, although a further level of sophistication and geographic delineation might be desirable, particularly to account for more severe micro-climates. The HERS process (see section 5) might be one way for this form of guidance to be provided to consumers.

Retrofitting: To date it has been generally considered that ceiling insulation (including a 'top-up' of existing, low R-value insulation) and underfloor insulation were the only 'cost effective' retrofitting options. These are the only two forms of retrofitting approved under the Government's scheme for insulation assistance (EnergyWise Homes schemes). However, the cost-effectiveness of retrofitting walls in the South Island - assuming a cost of ~$5-6,000 for the average house - is likely to be equally as good as installing R2.6 bulk ceiling insulation over old insulation in Auckland, which is an approved and subsidised activity. This suggests that some of the assumptions regarding insulation cost effectiveness need to be re-thought, and more serious consideration given to additional retrofit solutions especially in colder areas of the country.

Cost effectiveness 'pathway': An approach recommended from Lloyd et al (2007) is an 'upgrade path' approach, whereby a step-by-step process was taken which compared options based on marginal cost effectiveness. In these trials upgrading heating systems (using a wood or pellet burner; heat pump) was ranked as next most effective option after insulating ceilings and under floors, and ahead of insulating walls or double glazing.

4.7 Summary of key points

Key points arising from the technical review are as follows:

- Many product options are now available for insulating each element of the building envelope and with new technologies the range of options from which to choose is expanding.
- The proliferation of products raises issues about how well consumers can compare relative performance and appropriateness. For instance, there is a lack of:
  - Consistency/authority regarding claimed R-values for some products

[24] *The key assumptions include Zone 3 houses being heated with heat pumps (with effective energy costs of about 5.8c/kWh excl GST), the capital cost assumptions included for heating appliances, the fairly coarse steps in insulation improvement that were analysed.*

- Reliable and consistent information on which to compare long-term durability, and issues that affect durability such as storage
- Guidance on appropriate choice of insulation materials for particular situations.

- In-situ measurements for both under-floor and ceiling retrofit insulation is required to determine actual performance and variability dependent on different installation methods in order to improve the quality of installation, and to improve the quality of advice offered on the best insulation options for particular situations. Some measured results for ceilings with recessed lights may help highlight energy loss issues associated with this form of lighting.
- Better customer information is required on retrofit options for in-situ walls, skillion roofs and underfloors. For wall and floors there is a need to trial and develop new retrofit insulation solutions combining attributes of durability and performance, improved cost-effectiveness and improved installation safety.
- For retrofit insulation in particular, the adoption of appropriate 'retrofit paths' for optimising thermal performance is recommended. This would provide a logical investment pathway based around desired outcomes, prioritised according to marginal cost-effectiveness. It would account for diminishing returns effects of insulation, high costs associated with retrofitting insulation into some areas (e.g. walls), and incorporate appropriate heating upgrades into integrated solutions.

Long term durability and performance of insulation is critically dependent on installation quality. Where quality is being monitored under EECA's EnergyWise Homes Grants programme, there has been a marked improvement in installation standards over the last two years. In ordinary market conditions, where there is no external quality checking occurring, it is not clear that similar quality standards are being adhered to. The recently released standard NZS 4246 could provide a useful mechanism for ensuring a high level of installation in those homes that require a building consent.

5 Review of interventions

As noted earlier in Figure 3 (S3.3) the pathway to improved insulation through retrofitting is through either market driven initiatives, or through incentivised activities. This section provides an overview of retrofit activities, including information on initiatives that are in the pipeline or just getting underway. The specific objectives of the research are to:

- Review insulation interventions currently operating in NZ with a particular focus on existing homes (i.e. retrofit insulation).
- Outline the technical base of schemes, the incentives offered, who is involved, and experience and outcomes (numbers of homes reached etc.).
- Identify any gaps in the schemes with respect to the targets and approach Beacon has adopted towards improving the energy performance of homes.

The following three sections provide an overview of interventions as follows:

- S5.1 (Background) - comment is provided here on earlier intervention schemes and pilots because the learning and legacy from those initiatives has, in many cases, informed the nature of interventions we currently see operating.
- S5.2 (Current initiatives) – comment is provided on initiatives operating up to the present time. Generally these initiatives have some years of track record and experience to report on.
- S5.3 (Future initiatives) – new initiatives underway or announced in 2007, but without a track record of achievement yet to report on.

5.1 Background - earlier intervention schemes and pilots

The first Government interventions occurred from the mid-1970s to the mid 1980s, coinciding with the first period of high oil prices and generally raised pubic awareness over energy issues. A ceiling insulation interest-free loans scheme was launched in 1975 (preceding the mandatory insulation requirements of the NZBC), and the state housing provider retrofitted ceiling insulation into South Island state houses in the early 1980s.

The late 1980s/early 1990s were characterised by a sharp drop in oil prices and a pull-back by Government as it set about market reforms in the energy sector. Government's main focus turned to information and promotion to overcome barriers to energy efficiency in households (e.g. Harris et al, 1993). For a time the electricity industry looked like becoming lead players in energy efficiency. Some power boards provided energy efficiency advice and information, and the Electricity Corporation of New Zealand (ECNZ) developed the first home energy rating scheme, which included a retrofit trial in Wanganui. However, industry de-regulation in the mid-1990s saw electricity players largely disengage from this kind of demand-side activity, and initiatives such as the home energy rating scheme HERO (which was set up to be provided by electricity industry players only) foundered.

The first household energy efficiency retrofit project as such was a 24 house low income pilot based in the inner city east area of Christchurch in 1993. It was modelled on the community based initiatives that had been underway in the UK since the 1980s (Community Energy Action, 1994). It was funded through local sources (local government and the local energy company) and EECA – EECA's first residential retrofit funding. This pilot project concluded that the do-it-yourself approach to energy efficiency upgrades, which was the generally accepted wisdom in New Zealand at that time, was in itself a significant barrier to progress because of the skills, confidence and motivation required of the individual. The recommendations from the pilot - that energy efficiency retrofits required skilled installers and an organisational focus around projects and programmes of action – largely established the framework for retrofit activities that are commonplace today.

In late 1995 EECA established the Energy Saver Fund (ESF), a bid-in mechanism providing $18M over 5 years. The ESF supported the initiation of a range of retrofit projects throughout the country, and indirectly supported the establishment of several energy efficiency retrofit organisations. The ESF scheme evolved through a number of formulations and in the last few years has been re-established as the EnergyWise Home Grant programme (EWHG) (see S5.2)

A summary of the key schemes and initiatives during the period of late 1970s to late 1990s is given in Table 6.

5.2 Current Initiatives

5.2.1 EnergyWise Home Grants (EWHG)

The current EWHG programme, administered by EECA, supports 'whole-house' retrofits for low income households[25] or those with a specific health condition. Whole-house retrofits include ceiling and underfloor insulation, draught-proofing and underfloor groundsheets in particularly damp locations, as well as hot water cylinder wraps and pipe insulation, low-flow shower heads, and low energy light bulbs. Heating is currently not included. The programme is run as either:

- an annual tender round plus some one-off tenders throughout the year (for short-term 1-2 year contracts)
- negotiated Strategic Partnerships – larger and longer term funding commitments but at a lower overall subsidy rate than the tender round (ratio of $3:$1 co-funder: EECA).

[25] *'Low income' is defined as having a Community Services Card.*

Table 6. Summary of early insulation-related schemes in New Zealand

Initiative	Date	Description and results
Insulation interest-free loans	1975-1983	Government provided interest free loans to retrofit ceiling insulation into houses without insulation. In total 133,000 houses were insulated[26] - insulation depths were typically 50-75mm (R-value in the range R1.0-1.8).
Public rental – Housing NZ	Early-1980s	Housing Corporation installed retrofit ceiling insulation (blown cellulose fibre) in a large number of its state housing properties in the South Island
Energy Saver Fund (ESF)	Began late 1995	Initial Government energy retrofitting fund run by EECA – evolved over the years into the current EWHG scheme.
Public rental – local authority	Mid-1990s onwards	Christchurch City Council initiated action with a programme of ceiling and underfloor insulation on their stock of approximately 2,600 housing units. Other councils around the country also retrofitted council houses (some with ESF funding), although coverage was patchy[27].
Power Board initiatives	Up to mid 1990s	A number of local power board/energy company activities mainly around energy efficiency advice and information.
Home Energy Ratings	1993	Launch of initial home energy ratings scheme (HERO - Home Energy Rating Options) by ECNZ.

By early 2007 more than 30,000 homes had been insulated through this scheme with activity having ramped up over the last few years (EECA, 2007). Because of the EECA requirement for a local co-funding contribution for its EWHG programme, a large number of additional parties are tied in to supporting insulation retrofits throughout the country. These parties include local health agencies (e.g. District Health Boards and Primary Health Organisations), energy trusts, local councils, energy companies, community grants funding organisations and many others. EWHG projects are carried out by a mix of non-profit organisations (mainly independent trusts), commercial energy efficiency entities, local authorities and energy companies. The user contribution is capped at $500, and in many projects participants will pay considerably less than this.

A summary of activities over the last 3 years is shown in Table 7. The average funding per house provided by EECA has dropped over the 3 years, due perhaps to EECA's drive to increase the level of co-funding and increase the relative share contributed by Strategic Partnerships. The average total spend per house has been about $1,500 over the last 2 years, and since the value of

[26] *From Isaacs, 2003.*
[27] *In Dunedin for instance, according to Shannon et al., (2003) the local council had a small portfolio of housing units (89) but only 30% had ceiling insulation.*

a full retrofit is typically over $2,000 per house, it indicates that a reasonable proportion of houses receive a partial package of measures. The main reasons for receiving just a partial package of measures will be the presence of some pre-existing insulation, lack of access to ceilings or under floors, or the unsuitability of some measures (e.g. low flow shower heads are generally unsuitable for low pressure hot water systems).

Table 7. EWHG retrofit activity 2004-2007

Period	Houses receiving upgrades	Govt funding $M	Av Govt funding ($/house)	Estimated Co-funding $M*	Cumulative houses treated under EWHG (end of year)
2004/05	5,059	$3.3M	$650	$5.4M	17,000
2005/06	8,845	$4.95M	$560	~$8M	~26,000
2006/07	9,375	$5.05M	$540	~$9M	~35,000

Sources: EECA 2005, 2007 and EnergyWise Homes Grants information supplied by EECA
* Based on a funding ratio of $1:$1.60 (EECA: Co-funders) for 04/05 and 05/06, and $1:$1.80 in 06/07.

Community projects: An important emphasis of the EWHG programme to date has been support of localised projects. EECA requires project participants to specify a particular geographic area of focus, and this combined with co-funding requirements (often comprising parties with a focus on a specific community of interest) tends to support a localised approach. Community-based projects have been initiated in many parts of the country including Auckland, Huntly-Waikato, Whakatane-Eastern Bay of Plenty, Taranaki, Marton, Masterton, Wellington, Nelson, Christchurch, Timaru, Dunedin , Central Otago and Bluff. While most projects focus on the standard retrofit package, some initiatives have sought to broaden the scope of measures by also including heating[28].

Some specific (but diverse) examples where EWHG insulation funding is used as basic support for community projects include:

- **Healthy Homes Taranaki[29]:** A recently developed partnership involving a range of central and local government organisations, and other Taranaki-based partners. It has a goal for "*all homes in Taranaki to have a healthy and safe environment by 2014*" and has set a target to insulate 10,000 Taranaki homes over the next 10 years. The project will be operated by the charitable trust Better Homes.
- **Bluff Healthy Homes Project[30]:** A three year project to insulate 600 houses in Bluff, three-quarters of the town's houses. In addition to assisting those eligible for EWHG, those on higher incomes can pay with a three-year interest-free loan. Also the project has engaged an

[28] *Two community energy trusts operate curtain banks to provide curtains for needy households. Note though that heating and curtains currently do not qualify for financial assistance under the EWHG.*
[29] *See: http://www.betterhomes.co.nz/healthy.asp*
[30] *See: http://www.eeca.govt.nz/news/energywise-news/january-2006/features/bluff-introduction.html*

education field officer to provide individual advice sessions for householders. Major local sponsorship has been provided by NZ Aluminium Smelters and the Southland Community Trust. The project is managed by Te Runaka O Awarua Charitable Trust.

- **Winter Warmth Project for Older People**[31]**:** A partnership between Age Concern, Community and Public Health, and Community Energy Action (CEA) in Christchurch, and has been running for 3 years. It uses a referral system to identify at-risk elderly households, which CEA then assesses for energy improvements. The scheme goes beyond just insulation retrofitting and also includes heating where this is assessed as being desirable (mainly heat pumps). Contact Energy is a major sponsor.

In late 2007 EECA instituted a review of the EWHG scheme with the intention of identifying and addressing issues. Key issues raised by non-government stakeholders and partners in the scheme are around the very high requirements for local co-funding to enable schemes to proceed, and to date the lack of assistance for heating (meaning that holistic, integrated packages of measures for householders are very difficult to provide).

5.2.2 Housing New Zealand Corporation (HNZC) energy efficiency programme[32]

This programme, which began in 2001, is a 10 to 12-year project to improve insulation in all Housing New Zealand homes built before 1977. It involves checking all properties and upgrading where necessary ceiling insulation, under-floor insulation, hot water cylinder wraps and insulating hot water pipes in cylinder cupboards. Improvements are reportedly also being made to heating and ventilation including fixing draughty windows, addressing condensation, and preventing infiltration of dampness from under houses.

In 2004/05, 2,317 properties had energy efficient features added. By 2012 it is expected that some 45,000 homes will have been upgraded. Other properties are also benefiting from new insulation through the Healthy Housing, Rural Housing and Community Renewal programmes. The Rural Housing Programme is a broader, multi-departmental government effort to upgrade sub-standard housing in rural areas, and is thus reaching some of the hardest-to address households.

5.2.3 Local Government

Local government's current involvement in insulation retrofitting stems from four main areas of responsibility:

- Regional council responsibilities for achieving National Environmental Standards (NES) for air quality by 2013. The main relevant air quality issue is PM10 (fine particulate) concentrations. Most PM10 derives from domestic heating through use of wood or coal. Retrofitting insulation, which will reduce the heating demand of houses, is regarded as one of the means of mitigation. Environment Canterbury began the first 'Clean Heat' retrofit scheme (Box 1) and a number of other councils have begun initiatives (Nelson, Otago,

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[31] See: http://www.cea.co.nz/projects

[32] The Housing Corporation Act 1974, as amended in 2001, requires the Corporation to, "exhibit a sense of environmental responsibility by having regard to the environmental implications of its operations".

Waikato). At least 18 areas around the country breach the air quality standard for PM10, and a further 20 or so areas are potentially at risk and are being monitored.

Box 1: Clean Heat Programme – Environment Canterbury

In November 2003 Environment Canterbury (ECan) launched its Clean Heat programme which is the largest non central government insulation retrofit programme in the country. The programme aims to assist approximately 26,000 households in Christchurch change away from polluting solid fuel heating before 2013. ECan provides an integrated package of measures including ceiling and floor insulation, and a clean air compliant heating system (typically a heat pump, flued gas, pellet fire or low emission wood burner), mainly funded via property rates. The scheme has 3 streams:

- Full assistance - a fully subsidised retrofit of ceiling and underfloor insulation and a replacement complying heating system for homeowners with a Community Services card
- Partial assistance – set level subsidies for insulation and heating (as above) for all other homeowners
- Landlords – insulation and heating subsidies but at a slightly different level than the partial assistance scheme.

In early 2006 a loans option for the partial assistance scheme was introduced for the partial assistance group. It provides interest-free terms on a 10 year loan, with repayments being made via a targeted rate to the individual property owner. Currently around 40% of the partial assistance stream uses the loan facility.

Conversions have now reached about 3,000pa. About 60% of houses accessing Clean Heat assistance receive insulation as part of the package. The reasons for not receiving insulation will be either the house has adequate levels, or that access to the ceiling or floor space was insufficient to allow installation. Initially the main Clean Heat conversions were through the full assistance stream replacing open fires from older houses. As the programme progresses, the partial assistance stream is expected to account for the majority of Clean Heat conversions. This has already started to happen and was stimulated by the introduction of the loans facility in 2006.

ECan has forecast a total cost of $58 million expenditure Clean Heat Project over the 10 year period 2007-2016 to meet this requirement, although they note that in order to achieve sufficient conversions to meet the NES by 2013 a higher rate of conversions and additional funding will be required.

- Local authorities as landlords – some 14,000 rental dwellings are owned by local authorities and a proportion of these remain uninsulated. (80% of local authorities own some housing stock).
- General sense of care for the local community – local authorities are involved in a number of insulation retrofit projects throughout the country, generally as minor players or co-funders, but recognising a wider general sense of care for the local community.
- Climate Change – 29 councils (covering around 75% of the country's population) are now members of the Communities for Climate Protection programme[33]. The programme commits councils to a 5 milestone process involving conducting a greenhouse gas emissions inventory, setting emission reduction goals, developing a local action plan to achieve these goals, implementation, and monitoring progress towards the reduction goal. To date only a

[33] *See: http://www.iclei.org/index.php?id=3922*

few councils have reached the 3rd milestone (developing an action plan), but typically, support for home energy retrofitting is identified as a future action (e.g. Kapiti Coast Action Plan[34]).

Saville-Smith et al (2007) reported that 32 councils are involved in energy efficiency retrofitting activities (either on their own stock or in support of retrofit within their community).

5.2.4 Warm Homes

In 2004 the Ministry for the Environment initiated the *Warm Homes* project as an adjunct to the establishment of National Environmental Standards for air quality. The Warm Homes concept was to drive integrated solutions of information, heating and insulation in areas where the NES is exceeded (i.e. very similar to the Clean Heat model).

An initial Warm Homes pilot project was undertaken in Tokoroa in late 2005, applying a comprehensive package of insulation retrofitting and heating system replacements. A second pilot was subsequently run in Timaru, supplementing an existing EWHG funded community insulation project.

5.2.5 Electricity sector initiatives

Long-standing initiatives: Over the last decade a number of electricity sector players have supported insulation retrofitting activities. These initiatives have included:

- long-term sponsorship of community-based insulation activities (e.g. Orion support CEA in Christchurch)
- various energy trusts (established from the electricity reforms of the 1990s) actively supporting local energy efficiency/insulation initiatives using returns from their ownership of lines assets (e.g. Eastern Bay of Plenty Lines Trust, Hutt Mana Charitable Trust, Lines Trust South Canterbury)
- various customer-focussed initiatives supported by electricity retailers, and direct co-funding of local retrofit projects by lines companies (e.g. Mainpower in North Canterbury). As well, most retailers promote insulation through information on their websites.

***Healthy Homes* - Contact Energy:** In 2004 Contact Energy launched their *Positive Energy* campaign, which initially focussed on energy security issues, but was relaunched in 2005 as *Healthy Homes*. This was a high profile and well received campaign focussed on creating warm, healthy homes and with clear insulation retrofit messages. As well as the messages, Contact offered rebates off the electricity bill for Contact customers who undertook insulation retrofits (tied in with other commercial partners such as Mitre 10 for insulation "specials"), although it is unclear the actual numbers of householders incentivised in this way.

During 2006/07 Contact Energy supported 10 community energy retrofit programmes around the country.

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[34] *See: http://www.kapiticoast.govt.nz/NR/rdonlyres/0BC21C34-AF21-47F2-8ED3-A97F33B9A208/44025/KapitiCoastClimateChangeActionPlanApril2008.pdf*

5.2.6 Public good information/ advice initiatives

To date modest levels of advice /information have been provided to the market through public good information on insulation. EECA has provided brochures and website information over the years, and research/testing organisations such as BRANZ (and latterly the Health, Insulation and Housing research conducted by Wellington School of Medicine) have helped to raise the profile of the benefits of information.

Two city councils are notable for their information efforts related to housing energy efficiency – the Christchurch City Council which has run an information showhome for several years, and the Waitakere City Council which has actively supported sustainable building design and construction.

Overall, most information has been of a passive nature (written materials, brochures, websites etc), with more targeted information coming via energy labels for appliances such as whiteware.

5.2.7 Unassisted market activity

Some of the most effective information that supports the market for insulation has come from market players themselves through sales brochures, advertising etc. in support of unassisted market sales. In recent years there has been a considerable amount of television advertising (e.g. Pink Batts, Expol underfloor insulation). A feature of much of the marketing material is the focus on the beneficial outcomes of more efficient energy services – increased warmth, comfort, convenience, lifestyle etc. The energy efficiency or cost saving focus is often well down the list of potential benefits.

The 2005 House Condition Survey (Clark et al, 2005) found that of the houses surveyed with fitted insulation to suspended floors, 6% had fibreglass-foil and 10% had EPS[35]. Since none of this product is subsidised, it indicates reasonable inroads being made by manufacturers' efforts.

Walls: apart from home renovations where wall linings are being stripped to enable fibre insulation to be installed, there is little activity. This is largely because the costs of in-situ wall retrofit options are relatively expensive, remain unsubsidised, and hence are attractive to only a relatively small proportion of home owners[36]. The 2005 House Condition Survey (Clark et al, 2005) found that 56% of the houses surveyed had no wall insulation.

[35] *The balance of underfloor insulation was plain foil.*

[36] *In-situ spray-in foam, for example, has been installed in only about 7,000 houses across the whole country over about 20 years - http://www.airfoam.co.nz/favicon.ico*

5.3 Future initiatives

5.3.1 Government assistance

EWHG: EECA has identified some 100,000 houses occupied by people on low incomes as its primary target. With 35,000 houses currently retrofitted EECA believes it is on target to deliver on the other 65-70,000 by 2012 (EECA, 2007a) – see Table 8. With the EWHG scheme currently under review some changes are likely from mid-2008 onwards.

Table 8. Planned EWHG activity until 2010

Period	Target Houses	Govt funding $M	Co-funding $M	Ratio EECA: Co-funders	Cumulative number at end of year
2007/08	14,700	$9.1M	~$15M	$1:$1.90	~50,000
2008-2010 (planned for next 2 years)	~12,000 per year	~$7.5M*	$18M*	$1:$2.40* (implied)	~75,000

* Estimated from information in EECA, 2007a

NZEECS/Budget 2007: Funding of $23M was announced in Budget 2007 to operate an interest-free loan scheme to help home-owners install or upgrade energy efficient products (including insulation, efficient lighting, hot water heating systems) and clean heaters in their homes. The NZEECS has specified targets of 70,000 'insulation and clean heat installations' (EECA, 2007b). This initiative can be seen as a significant first step to address a lack of assistance available for middle income households to date. It also provides for a reasonably holistic package of measures. A request for proposals was released to the market in late 2007 to give effect to this scheme.

Budget 2007 also included a Warm Homes package of $5.4M over the next 4 years to support the installation of clean heating appliances in areas afflicted by poor air quality. Some 800 homes are targeted in 2007/08, with budgeted expenditure of $1.1M. The scheme will be administered by EECA. It is likely it will sit alongside the EWHG insulation retrofit scheme so will serve to broaden the scope of projects in some areas, but will not add to further insulation retrofitting per se.

5.3.2 Public good information and advice

A significant number of public good information and advice initiatives were launched in 2007 including:

SmarterHomes website[37]**:** was established in mid 2007 as a collaboration involving government and non-government entities, and is aimed at homeowners and consumers. The website provides a range of household sustainability information including energy.

Level website[38]**:** was developed for the construction industry by BRANZ Ltd as a sister website to Smarterhomes. Level provides information on designing and building homes which have less impact on the environment, are healthier, more comfortable, and have lower running costs.

Sustainability Portal[39]**:** launched by the Government in December 2007 and aimed at sustainability in all aspects of household living.

Home Energy Ratings: Government has formally assigned EECA the task of bringing a national level HERS into operation. It was launched in December 2007, and will operate initially as a voluntary scheme. EECA is to report to Cabinet by 30 June 2008 on the feasibility of a mandatory HERS.

Sustainable Energy Advice Centre Network: this initiative began on 1 July 2007 with 12 months seed funding from MfE's Sustainable Management Fund. It is being run by a trust which comprises seven community energy efficiency organisations (EECN – Energy Efficiency Community Network).

5.3.3 Regulations

Minimum Energy Performance Standards (MEPS): The Government has signalled through the NZEECS that it will investigate imposing MEPS for existing homes, especially rentals which are particularly problematic for energy efficiency because of the "split incentive" barrier. While the details are unclear at this stage (a report and recommendations on a MEPS is scheduled for the end of 2009), a MEPS could be based around achieving a minimum energy rating as measured by a HERS. If this was the case insulation would likely be one of the main routes to achieving the MEPS.

5.3.4 Market activity

Meridian Energy launched its 'Right House' initiative in late 2007, a 'one-stop shop' to provide information on new home planning and choice of energy equipment/appliances. Meridian is also intending that the business is involved in retrofitting existing houses with energy efficiency and to that end has established supply relationships with various suppliers of products and services[40].

Other new initiatives by players in the market are expected over the coming year.

[37] *See: http://www.smarterhomes.org.nz/*
[38] *See: http://www.level.org.nz*
[39] *See: http://www.sustainability.govt.nz/*
[40] *See: http://www.righthouse.co.nz/*

5.4 Conclusions

After a period of steady, but lowish level of insulation retrofitting in the early years of this decade, and a long period through to the current year where there was little change in the insulation requirements of the NZBC, a more dynamic environment is now emerging. The Government signalled through the Budget 2007 and the NZEECS a broader base of assistance for insulation, while a number of new market players are now involved. In addition, a national HERS was launched in a voluntary phase in late 2007, and other information/advice initiatives are in the pipeline. While it remains to be seen whether this new level of activity will be sufficiently resourced and whether all of the barriers to insulation/efficiency will be addressed, it nevertheless represents a significant step forward.

6 UK experience

There are both similarities and differences between the UK and NZ. The similarities include aspects of the policy-making culture, a common issue with cold, under-heated homes, and some aspects of programme design and delivery. The differences include a generally much colder climate in the UK (hence insulation generally shows greater cost-effectiveness), to date a much stronger commitment by the UK Government to address fuel poverty[41] and CO_2 emissions, a stronger role played by local government, and in general a broader framework and more mature infrastructure in the UK to deal with the issues. In part these latter differences also stem from a longer involvement in these issues in the UK. The first community insulation retrofit programmes were carried out in the late 1970s.

6.1 Outcomes framework

A key point of difference is that the UK policy framework is moving much more clearly to identified 'outcomes' as the driver of policy. This drives a more purposeful focus for interventions. In particular, the two main outcomes are:

- Government policy commitment to eliminate fuel poverty with statutory targets being set for achievement by 2016 (with an intermediate target to eliminate fuel poverty for vulnerable households by 2010).
- In March 2007 a Government bill was introduced to Parliament that would establish statutory reductions in CO_2 emissions of 60% by 2050.

This outcomes framework flows through to the design and structure of funding and incentives offered for energy efficiency.

6.2 Incentives

Warm Front: Warm Front is the UK Government's main grant-funded programme for tackling fuel poverty[42]. Warm Front is a grant based assistance scheme providing measures up to £2,700 per household for those eligible (and up to £4,000 for qualifying households requiring oil central heating[43]). Eligibility is for those owning their own home or renting from a private landlord, as well as being in receipt of at least one of a range of benefit entitlements[44].

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[41] *'Fuel poverty', as generally stated, means a household cannot afford sufficient warmth for health and comfort. A formal definition of fuel poverty has been adopted in the UK: a household will be in fuel poverty when it needs to spend in excess of 10% of household income on all fuel use in order to maintain a satisfactory heating regime.*
[42] *Warm Front applies to England with different versions of schemes applying in the devolved regions of Scotland, Wales, and in Nth Ireland.*
[43] *Oil central heating is generally only considered when the house does not have access to the gas grid.*
[44] *See for details: http://www.eaga.com/grants/warmfront/qualify.htm*

The measures funded under Warm Front include cavity wall and ceiling insulation, and heating upgrades (e.g. replacement of old boilers with efficient condensing boilers). Warm Front will pay 100% of the costs up to the grant limit – hence across all of England there is equal access up to a fixed value of measures for all eligible households. However, the measures required in a house often exceed the grant limits so Warm Front grants are often used in conjunction with other assistance provided by energy companies and local authorities (where available).

The standard ceiling retrofit insulation in the UK is 270mm of fibreglass insulation, with an insulating value of over R5, and reflects the standards now required in new houses. For walls the cavity is typically between 50 and 100mm wide and is filled by blown rock or glass based dry product. Blown rock insulation, 80mm thick, has an insulation value of about R2.0.

Energy Efficiency Commitment (EEC): The EEC places an obligation on electricity and gas suppliers to achieve targets for delivering energy efficiency in the domestic sector. It is a pro-rata obligation based on the energy supplier's size of supply and customer base. Suppliers can fulfil their obligations by facilitating a range of energy efficiency measures such as insulation, low energy light bulbs, high efficiency appliances and boilers, high efficiency appliances etc.

One aspect of the EEC is that at least 50% of energy savings activities must be achieved within a designated 'priority group' of low income households. This means that energy suppliers generally need to provide full funding (i.e. 100% assistance) to achieve outcomes in this area. For the balance of their commitment, suppliers seek the optimum balance between cost and customer uptake. The supplier spoken to (EDF) was currently providing around 50% subsidies for the non-priority "able to pay" group, with a current heavy focus on retrofit insulation.

The cost of the EEC is ultimately borne by all residential customers by being spread across their residential energy tariffs. The costs of the current EEC commitment have been estimated to be £9 per customer per fuel per annum[45] (equivalent to approximately 2% of household fuel bills on average).

Local Authority grants/initiatives: Local Authorities play multiple roles in providing energy efficiency outcomes. As owners of most of the stock of social housing, local authorities are required through the *Decent Homes Standard* to achieve standards in four main areas that define a "decent home". One area is achieving affordable warmth, and this covers heating and insulation.

A further requirement is through the Home Energy Conservation Act 1995 (HECA) which places various energy efficiency requirements on local authorities. Many local authorities fulfil their responsibilities through co-funding local energy retrofit projects, often managed by an independent project manager such as an energy NGO. These local area projects often involve a collaborative approach involving many parties and funding sources. The local authority funding in some areas has been specifically targeted to those households that just sit beyond the eligibility for Warm Front or the Priority Group of the EEC.

[45] *Most customers would have two fuels – electricity and natural gas.*

6.3 Organisational framework for delivery of programmes

Warm Front: Wider policy responsibility for fuel poverty is shared between the Department for Environment Food and Rural Affairs (Defra) and the Department for Business Enterprise & Regulatory Reform (BERR – previously the Department of Trade and Industry). Policy responsibility for Warm Front sits with Defra but management of the scheme is contracted out. This has involved a full, open tendering process for the appointment of Scheme Managers. Long-established scheme managers Eaga were appointed across all of England for the current phase of the scheme – a 5 year period[46]. The total contract is worth ~£1.5b.

Eaga operates an England-wide system of referral networks tasked with identifying eligible households and bringing them into the Warm Front process. In addition Eaga now also operates a large benefit entitlement section aimed at increasing household eligibility for Warm Front grants. A National Audit Office Review of Warm Front carried out in 2003 identified that a significant number households potentially in fuel poverty were not claiming benefits they were entitled to and were hence remaining ineligible for Warm Front assistance. This was particularly the case for elderly households. To date the service has helped over 100,000 households and in 2006/07 resulted in an average lift in benefit entitlement of £26.51/week, or £1,378 per annum (Defra and BERR, 2007).

EEC: At present EEC commitments are for 3 year blocks. The first EEC (EEC1) was implemented in 2002[47] and ran until 2005. The current commitment is EEC2, running from 2005 to 2008. The third phase of EEC will run from 2008-11 and will be known as the Carbon Emission Reduction Target (CERT).

Once policy has been decided and targets established for the commitment period it is up to the energy companies to meet their obligations in the best way they see fit. Energy suppliers are not limited to their existing customer base to achieve savings. They are able to target any domestic consumer. Also, over-, or under-achievement is able to be carried through into subsequent commitment periods. For example, in EEC1 all suppliers met their targets and were able to bank additional activity (on average about 25%) into the EEC2 period (and similarly from EEC2 to the third period).

The EEC is monitored and administered by Ofgem, the electricity and gas market regulator.

Advice Centres/ information: In the UK there is long-standing commitment to the value of advice and use of the 0800 freephone as the major point of contact for household energy efficiency advice and further follow-up. During 2006/07 a network of nearly 50 Energy Efficiency Advice Centres[48] (EEACs) provided free, independent, impartial advice to

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[46] Eaga started life as the Energy Action Grants Agency, an entity specifically split from NEA in the early 1990s to run the Government's initial insulation grants programme. To date it has been constituted as an employee owned company.

[47] The EEC follows from 3 phases of the Energy Efficiency Standards of Performance (EESOP) which operated between 1994 and 2002 and involved an energy efficiency obligation on energy entities, but at a much lower level of attainment.

[48] The current EEAC network is in the throes of re-organisation, with the number of centres being reduced and the scope of advice offered broadened.

householders. Each EEAC has a specified geographical area to service. The primary point of contact is a nationwide 0800 phone line with each call diverted to the EEAC servicing the area from which the call originates. Secondary advice is offered through face-to-face contact with energy advisors via outreach events and home visits, or via written advice provided in response to self-completion energy surveys returned to the EEAC by householders. Generally, advice centres have an active outreach programme with presentations to groups, mall events, energy efficiency weeks etc.

Core funding for the advice centres is from the Energy Savings Trust (EST). The current EEACs contracted to EST are run by a variety of organisations – mainly not-for-profit NGOs, local authorities, and not-for-profit partnerships (e.g. between NGOs and local government).

Independent monitoring and feedback: While Defra and BERR collectively produce the official government Annual Progress Report on the UK Fuel Poverty Strategy, the UK Government has also formally established an independent advisory body. The Fuel Poverty Advisory Group (FPAG) is an Advisory Non-Departmental Public Body set up by the government in 2002, and sponsored by Defra and BERR. The Group consists of a chairman and senior representatives from organisations such as the energy industry, charities and consumer bodies. Its primary task is to provide an independent monitoring and reporting of progress on delivering the Government's Fuel Poverty Strategy, and to propose improvements to regional or local mechanisms for its delivery[49]. It is also there, as a recent government review noted, "to ask the awkward questions".

NEA(National Energy Action)[50] is the national fuel poverty charity based in Newcastle. NEA developed out of the original community insulation projects of the late 1970s/early 1980s, and is now largely funded via government to provide independent facilitation, training, research and publicity around fuel poverty.

Partnerships: Another important independent process within the overall framework of improving resident energy use is the Energy Efficiency Partnership for Homes (EEPH). The EEPH is a network of over 400 organisations from the public, private and voluntary sectors. The aim of the Partnership is to provide a forum for cooperation and collaboration within the supply chain for energy efficient products and services. The Partnership aims to involve all relevant industry and social sectors and to provide an effective mechanism for cross-sector cooperation and joint delivery of energy efficiency initiatives.

The core work of the Partnership is achieved through the operation of some 19 sector working groups (including sub-sector groups). Groups comprise representatives and key experts from partner organisations, and work on addressing barriers, improving co-ordination, facilitating new information, developing best practices etc. Amongst the EEPH's working groups there is an Insulation Strategy Group[51].

[49] *See: http://www.dti.gov.uk/energy/fuel-poverty/fpag/index.html*
[50] *See: http://www.nea.org.uk/*
[51] *See: http://www.eeph.org.uk/sector/swg.cfm?group_id=8*

Affordable Warmth Strategies: Signalled in the 2001 Fuel Poverty Strategy, and championed for years by NEA[52] is the development of local fuel poverty/affordable warmth strategies. There are many examples of local partnerships that have come together to develop such strategies (e.g. *Action for Affordable Warmth* – partnership between the 7 councils of Gloucestershire and South Gloucestershire, and NGOs (Severn Wye Energy Agency and NEA); the *North East Fuel Poverty Strategy* etc.). Localised action strategies act as a focus to bring stakeholders together, provide a holistic view of what is needed in a particular location, and serve as a catalyst for action. They are also a way in which local authorities can help give effect to their responsibilities under the HECA.

Warm Zones[53]: Warm Zones is a locally-based, area-by-area approach, using doorstep interviews by trained local assessors. Through blanket coverage it aims to identify at-risk households and facilitate an appropriate set of measures. By drawing in a large number of stakeholders (e.g. NGOs, health, local authority funders etc.), Warm Zones integrates the range of funding options in order to provide a comprehensive approach to addressing fuel poverty.

Community Energy Efficiency Fund (CEEF): This tender-based funding mechanism, instituted for 2007/08 only, is built on the regionalised approach to programme delivery piloted through programmes such as Warm Zones and local fuel poverty strategies. It aims to bring an integrated local area approach to the delivery of energy efficiency and heating retrofit services. The scheme is notable because commercial organisations were not permitted to be the lead tenderer; they could only be involved in a joint tender bid with a non-profit or other eligible (public) party. This indicates the weight attached in the UK to the value of local, NGO and other non-profit organisations as important integrating entities on the ground.

The CEEF is also notable in that it is not a fund to pay for measures, since all the measures are paid for from the established mechanisms of Warm Front and the EEC. Rather, the CEEF is about generating local activity and effective take-up of measures to households. It covers both the fully-assisted and the able-to-pay segments of the residential market.

Home energy ratings: The UK has well established home energy ratings procedures. A voluntary home energy ratings scheme has been operating since the 1990s (NHERS). The UK Government uses the Standard Assessment Procedure for Energy Rating of Dwellings(SAP), which is a composite rating combining both house energy efficiency and the cost of fuels used. Since 2005, "SAP 2005" has been adopted by government as part of the UK national methodology for calculating the energy performance of buildings. This rating uses a 0-100 scale. All homes upgraded through Warm Front are subject to before and after SAPs, with 65 being the target score at which fuel poverty is regarded as being most unlikely.

The UK has just begun introducing mandatory Energy Performance Certificates (EPCs), an EU requirement. Effectively this is a mandatory HERS, with the form of the certificate including a CO_2 calculation, as well as a set of recommendations for improving overall energy efficiency and heating.

[52] *See NEA guidance document on developing such strategies:* http://www.nea.org.uk/downloads/publications/9673_AWS_Guidance_Note_Print_LR.pdf
[53] *See:* http://www.warmzones.co.uk

6.4 Low carbon new houses

Lower carbon new buildings: In response to the UK Government's Planning Guidance on Renewable Energy issued in 2004 the small London Borough of Merton was the first to set a target for the use of onsite renewable energy to reduce annual CO_2 emissions. They introduced a rule specifying all new major developments had to provide at least 10% of energy on-site from renewables (for residential a 'major' development means 10 or more dwellings). This has become known (in UK circles at least) as "The Merton Rule"[54].

Since then other councils have moved to give effect to the planning guidance, with Kirklees Council proposing a 30% target for all new buildings by 2011.

The most well publicised example of a near carbon-neutral residential development in the UK is Bedzed (Beddington Zero Energy Development)[55] situated in the area of Beddington in south London. Bedzed is characterised by super-insulation and thermal mass (walls ~400mm thick), south glazing and sunspace capture, low energy appliances, passive ventilation, PV cells incorporated into the building fabric, and a combined heat and power (CHP) plant run from biomass. Unfortunately, technical and contractual problems around the operation of the CHP has resulted in this plant being inoperable for the last 2 years, thus Bedzed is currently falling well short of being carbon neutral in its operation.

Sustainability: In December 2006 the Department for Communities and Local Government released two initiatives – first, the Code for Sustainable Homes[56], a national standard for sustainable design and construction of new homes using a 1 to 6 star rating system to measure the overall sustainability performance of a new home. The Code sets minimum standards for energy use at each level. Second, "Building a Greener Future: Towards Zero Carbon Development", a discussion document that proposed a target to achieve zero carbon housing by 2016 was launched (where zero carbon means that, over a year, the net carbon emissions from energy use in the home would be zero). The report proposed a 2-step phase-in, with a 25% improvement in energy/carbon performance in 2010, and a 44% improvement by 2013. The consultation process has shown a high degree of support for the concept but some concerns about timeframes and other issues related to implementation[57]. At this stage it is unclear whether firm policy commitments will be made by the UK Government.

6.5 Summary – key features from the UK

The positive features and main lessons to take out of the UK approach were:

> **Outcomes framework** - a focus on the "ends" as being the important, and seeing improvements such as insulation as one of the "means" (rather than an end in itself)

[54] *See: http://themertonrule.org/node*
[55] *See: http://www.bioregional.com/programme_projects/ecohous_prog/bedzed/bedzed_hpg.htm*
[56] *See: http://www.communities.gov.uk/planningand building/buildingregulations/legislation/englandwales/codesustainable*
[57] *See: http://www.communities.gov.uk/publications/planningandbuilding/futuretowardszerocarbon*

Long term commitments - establishing commitments and setting realistic timeframes for achievement

Partnerships - an ethos of partnerships, with a recognised role for the independent/ NGO sector

Funding responsibilities – a high level of responsibility for, and funding commitment from central government for achieving social outcomes (fuel poverty elimination)

Integration – a developing emphasis around locally based integration (based on a mix of national-level and local funding, local integrated plans and programme delivery)

Advice – a high value placed on information and advice, with funding streams to local organisations to provide independent, easily accessible advice

Independent analysis and monitoring – in particular the setting up and role played by the FPAG, informed by a reasonably comprehensive monitoring programme.

Overall, what impressed was the systematic and integrated approach taken. On the other hand the UK experience also highlighted some issues where the outcomes were less positive:

Complexity of assistance schemes - concerns were expressed about the proliferation of energy efficiency programmes and the confusion it creates for consumers e.g. through the EEC the six major energy suppliers all have a range of schemes which may or may not apply in a given geographical area at any given time, each with different eligibility and timing etc.

"Incentive addiction" – some government officials, in particular, were concerned that little retrofitting might now be occurring through normal market channels because people were becoming conditioned to expect an incentive regardless of positive cost effectiveness for individuals, or ability to pay.

Targeting – concerns were expressed about a degree of mismatch between the incidence of fuel poverty and the eligibility criteria for fuel poverty programmes i.e. eligibility for programmes such as Warm Front are through proxy criteria rather than through an accurate determination of fuel poverty (as defined in the UK). It was acknowledged that better identification of actual fuel poverty, and subsequent targeting, is needed.

The current situation with fuel poverty funding in the UK also highlights an issue of "natural progression" of costs. Energy efficiency programmes invariably focus initially on the 'low hanging fruit' (e.g. most cost-effective insulation gets carried out first), with the balance remaining being the increasingly expensive retrofit insulation cases. Many of the households that remain to be brought out of fuel poverty occupy houses with solid walls which are both expensive to insulate and may also run up against heritage protection situations. Or, the houses may be off the main gas network and unable to access cheap heating fuel. Non-conventional solutions are required (e.g. biomass heating options), but are invariably more expensive. This is a considerable issue in relation to the UK Government achieving its fuel poverty targets.

7 Recommendations for achieving high standards of insulation in New Zealand

This review of insulation has been carried out within the context of Beacon's goal "to help bring the vast majority of New Zealand homes to a high standard of sustainability by 2012". The last few years have seen an expansion in the range of insulation products and a more purposeful government focus on improving and incentivising insulation. New initiatives launched during 2007 and 2008 will further improve insulation standards for both new build and retrofit. The main areas identified that could enhance the achievement of high standards of insulation, particularly focused on research and information, are summarised below.

A reliable, and broadly agreed database: The lack of a high quality database on numbers of houses with insulation, and the state of insulation, was highlighted in S3. Having an agreed, quality database will be of significant benefit for planning and rolling out future retrofit initiatives, particularly at a local level. By comparison, the UK has an extensive database derived largely from an annual, and detailed, house condition survey.

There are two relatively simple ways to improve the current database. First, an immediate information stream might be possible from the rollout and pilot stage of the HERS. Attention could be given to ensuring a wide range of geographic and house-type coverage within the piloting stage so that a database could be quickly established. Using the HERS process would also enable household heating information to be captured. Second, attention could be given to future House Condition Surveys to try and achieve greater geographic and house-type coverage.

Product research: Several new products have been brought to the market in recent years but the key issue to address is the lack of long term, independently verified reporting for some products, and the lack of consistent in-situ testing. This leads to the absence of authoritative guidance on the best options available for consumers (and the building industry), and is a particular issue with products for retrofitting into walls and under floors. In particular, low cost wall solutions (going beyond the 90mm stud) in new construction might help break through a current barrier. For retrofit, a public research programme that seeks to find cost-effective, long-term retrofitting solutions for walls and underfloors (and monitors in-situ performance), might greatly enhance the options available to consumers, lead to much greater uptake, and improve insulation quality in the existing housing stock.

Advice and information: As above, the lack of independently verified testing leads to shortcomings in the provision of consumer advice and information. Also if high levels of energy performance are being sought consumers need guidance on cost effectiveness priorities. Adoption of appropriate 'retrofit paths' for optimising 'whole house' thermal performance is recommended. This would provide a logical investment pathway based around desired outcomes and prioritising according to marginal cost-effectiveness. It would account for diminishing returns effects of insulation, high costs associated with retrofitting insulation into some areas, and incorporate appropriate heating upgrades. A number of initiatives currently being developed may provide appropriate ways for this to occur e.g. HERS recommendations process, independent advice centres.

NZBC standards and aspiration for 'best practice': While the energy provisions of the NZBC have recently been changed in the most substantive way for three decades there is scope to promote insulation levels higher than code, especially in colder areas of the country. Probably the best way to deal with this is through new guidance around 'better' and 'best' standards, and through the rating scale of the HERS – all of which will hopefully encourage homebuilders in climate zones 3 especially to go beyond the NZBC standards.

UK lessons: The main lessons to take out of the UK relate to the systematic nature of the approach taken, with an integration of players and methods and a strong commitment to outcomes. Partnerships play a vital role, as do independent players/organisations within those partnerships (particularly related to addressing fuel poverty).

Taking the UK lead, Beacon could play a role similar to that of the Energy Efficient Partnership for Homes – an independent facilitator of players in the industry coming together and working collaboratively to address issues. This would be particularly valuable where there was a research focus to the issue.

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Glossary

BERR	Department for Business Enterprise & Regulatory Reform
BPI	Building Performance Index
BRANZ	Building Research Association of New Zealand
CEA	Community Energy Action
CEEF	Community Energy Efficiency Fund
CERT	Carbon Emission Reduction Target
Defra	Department of Environment, Food and Rural Affairs
EEAC	Energy Efficiency Advice Centre
EECA	Energy Efficiency and Conservation Authority
EEC	Energy Efficiency Commitment
EECN	Energy Efficiency Community Network
EEPH	Energy Efficiency Partnership for Homes
EPS	Expanded Polystyrene Sheet
EST	Energy Saving Trust
EWHG	EnergyWise Homes Grants
FPAG	Fuel Poverty Advisory Group
HERS	Home Energy Rating Scheme
HDD	Heating Degree Day
HNZC	Housing New Zealand Corporation
IGU	Insulated glazing unit
NEA	National Energy Action
NES	National Environmental Standards
NZBC	New Zealand Building Code
NZEECS	New Zealand Energy Efficiency and Conservation Strategy
SAP	Standard Assessment Procedure
SIP	Structural Insulated Panel