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100$ Worth of Comfort: The Real Value of Energy Technologies

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100$ Worth of Comfort: The Real Value of Energy Technologies

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ABSTRACT: Energy-efficiency measures are often associated with energy cost savings. Connections to other lifestyle benefits are often only treated as peripheral add-ons. However, this is generally not the way the home occupant perceives their impact on their homes.

The Zero and Low Energy House (ZALEH) project has for the first time in New Zealand captured a wide range of these other lifestyle benefits in a quantitative manner. The authors conducted in-depth interviews to quantify benefits of, and barriers to, energy technologies. The surveys included occupants of three groups of houses: a group of known New Zealand low energy houses, a group of Housing New Zealand Corporation (HNZC) houses (which received insulation upgrades), and results from an online internet survey.

The research examines the overall non-energy benefits (NEBs) as well as the sources of NEBs – including factors such as improvements in comfort, bill control, health, noise, maintenance, the environment and other factors. Both positive and negative impacts were investigated using a set of detailed questions to identify the value that the occupant placed on each of the net impacts or benefits. The results suggest that most residents place a much higher value on the lifestyle benefits from energy-efficiency features of their homes than on energy savings, and that the relative level of benefits is in the order of those seen in United States programs.

Conference theme: social, cultural and political issues

Keywords: non-energy benefit, low energy, survey, occupant, comfort

1 INTRODUCTION

The 21st century is seeing a worldwide trend towards achieving a sustainable environment and eco-societies. New Zealand is an island country with limited usable resources and is also a developed country facing strong population and natural consumption growth. Therefore, New Zealand has pressures placed on energy, housing and water often with deleterious effects on a wide range of environmental aspects, as well as social and economic effects.

The Zero and Low Energy House research project (ZALEH) studies in-depth the effects of advanced energy technologies and simple insulation retrofits on residents, and compares them with the expectations of normal house residents for utilising low energy technologies. This project aims at better understanding the use of low energy technologies in New Zealand houses. We are mainly interested in the real life performance of these technologies, rather than their technical potential in the laboratory. The research results therefore quantity real life values that can be achieved for New Zealand buildings, home occupants and the construction industry. The challenges and opportunities of an eco-building environment are presented to create an improved sustainable environment in the future.

2 BACKGROUND

International research suggests that home occupants do value the benefits of low energy technologies, not only in respect to lower energy bills but also for a range of other energy unrelated reasons.

A recent study of new houses in Florida found a much higher gain in the resale value of low energy houses compared with the conventional comparison homes, despite the similarities between the two groups of homes in location, original sales price and floor area [Coburn et al]. The authors suggest that this difference in resale value can at least be partially attributed to the energy features of the homes. The occupants mainly quoted noticeable energy cost reductions as the reason for the increased property value.

Similar results were found by a 1998 study [Nevin et al]. According to this study, residential real estate markets assign to energy-efficient homes an incremental value that reflects the discounted value of annual fuel savings. The capitalisation rate used by homeowners was expected to be 4%–10%, reflecting the range of after-tax mortgage interest rates during the 1990s and resulting in an incremental home value of $10 to around $25 for every $1 reduction in annual fuel bills.

Benefits other than energy cost reduction have also been successfully been quantified in overseas studies. A study conducted as part of the European SAVE programme evaluated employment benefits of energy-efficiency programmes [Energy Saving Trust]. The report suggests that the direct employment benefit is between 10 and 58 person-years for each £m invested for each of the investigated programmes. In addition, there are indirect employment benefits of more than twice the direct employments effects.

The New Zealand study reported on in this paper focuses on direct home occupant benefits. Quantifying these occupant perceived benefits, and any problems, is considered to be an important step for addressing market uptake barriers. The study therefore focuses on consumer perceptions rather than physical outcomes, such as actual energy cost savings or indoor temperature increases. This is because it is ultimately the consumer perception which will motivate or otherwise the consumer to change their behaviour and purchasing patterns.

An extensive meta-study conducted in the United States in 1999 collated non-energy benefits such as carbon dioxide or arrearage reductions, increased jobs in the community and other benefits not related to a unit of energy from almost 100 individual studies of low income household energy improvement projects [Riggert et al]. In conclusion, the meta-study found that when all of the benefits are counted, the non-energy benefits alone often exceed the cost of a typical energy-efficiency improvement program by a wide margin and provide significant private, public and environmental benefits.

3 METHODOLOGY

Because the objective of this survey was to quantify the occupants' value perception of energy technologies, the appropriate methodology had to be based around a survey approach rather than physical performance metering (energy, temperatures, etc). An analysis of only the physical performance changes of the building would not permit a value association.

Unlike some similar projects in New Zealand, the ZALEH project aims at quantifying the value perception of these benefits to the consumer rather than the saved cost. The Wellington School of Medicine and Health Science research, for example, has conducted an extensive study on the health benefits of insulating homes [Howden-Chapman et al]. That study is able to show significant health benefits due to insulation, which are based on the saved cost of medical treatment. The ZALEH study, in contrast, takes a value-based approach independent of the actual health cost, but based on the value perception of the home occupants. It is therefore more applicable for marketing planning rather than public health policy development.

An ideal survey sample would include houses that:

- have experienced low energy technologies
- are without bias, i.e. do not have invested a significant amount of money and might therefore post-rationalise the outcome. This phenomenon is known as "cognitive dissonance"
- are representative of the population.

In reality there is no such sample group that would fulfil all these requirements. It was therefore necessary to survey a number of different groups, which each met some of the criteria. The table below shows the types of households surveyed in this project.

Table 1: Group of houses included in the three survey streams

	Experienced	**Unbiased**	**Representative**	**#**
1. Low energy houses	x			23
2. Randomly selected		x	x	58
3. Retrofit project participants (low income)	(x)	x		25

Each of the groups had some limitations. The low energy house group members were generally very compassionate about the energy technologies, and because they had invested in the technologies may not have been completely unbiased in their value perceptions. The randomly selected house group included mainly houses which did not have any particular energy technologies implemented. Their responses therefore reflect expected technology performances rather than actually experienced performances. The low income group consisted of a number of HNZC houses in Dunedin which had, over the last few years, received insulation and hot water cylinder upgrades. These occupants were probably providing unbiased feedback (the interviewees were assured that the survey responses were processed anonymously). However, the energy upgrades were comparatively small and cannot therefore be seen as representing feedback for low energy technologies. Furthermore, this group was obviously demographically skewed towards low income occupants.

This methodology combines benefits from full statistical representative survey sampling and selective focus groups. Survey participants were selected for their particular interests and experiences. However, the one-to-one interviews guaranteed that there was as little cross-subject influence as possible. This seemed to be important when surveying a complex value-focused topic such as this. The fact that the non-energy benefit value estimates by the individual survey subjects have large variations highlights this issue, and provides additional quantitative information which would have been more difficult to obtain during interactive group sessions.

The surveys focussed on two main aspects: the first was the identification of barriers and the opportunities to overcome these; the second to quantify the value which occupants placed on the benefits of low energy technologies or simple energy improvements.

These benefit measures included those which were experienced by the occupants of low energy and retrofitted houses (Groups 1 and 3), as well as perceived benefits by those which were theoretically expected by occupants of randomly selected houses that had not received any particular energy technology upgrades (Group 2). Due to cost and logistical issues, the surveys were conducted using three methods: via telephone interviews with a corresponding mail questionnaire in the low energy house research; face-to-face visiting interviews for the retrofitted HNZC houses; and an online web-based survey for the randomly selected houses. All surveys covered barriers to energy technologies, as well as the non-energy benefit evaluation.

It should be noted that there is a clear difference in data quality between the telephone and face-to-face interviews on the one hand and the online surveys on the other. A number of online survey respondents commented that the survey questions were complex, and that they felt unsure whether they had answered them correctly. However, the telephone and face-to-face interviews took on average two hours. The online survey option was therefore considered the most effective option, and was considerably simplified compared to the phone and face-to-face surveys. A further simplification was not possible without losing compatibility with the other two survey streams. The online survey also contained an 0800 helpline number, and an encouragement to contact BRANZ in case of questions. However, none of the respondents made use of this.

4 RESULTS FROM LOW ENERGY HOUSES

4.1 Low energy houses

The houses were selected via public advertisements to participate in this study. All accepted applications went into a draw for some incentives to participate in the project. A series of minimum acceptance criteria was used for inclusion in the project. These included:

- solar or heat pump water heating
- insulation significantly better than NZ Building Code requirements
- double-glazing throughout
- solar design features such as trombe walls or others
- energy bills of less than $15 per month per occupant
- renewable energy technologies such as photovoltaic panels, wind energy etc.

Participants did not have to meet all of these criteria since the objective of the study was not to find the most energy-efficient houses in New Zealand, but rather to identify value perceptions by people who have experienced some low energy technologies. Approximately half of the house applications were finally accepted using a simple unweighted scoring system for the six criteria. In some cases a house was accepted because it featured one or two interesting technologies, although overall it could not be classified as “low energy”.

All 23 accepted houses have insulation installed in their houses, most of them levels clearly above NZ Building Code minima, and 90% of households have double glazing and/or sun-tempering technologies. Only one household uses an electric hot water cylinder without solar water heating and other heating systems. Therefore, almost 90% of households in the sample have installed water heating technologies such as a solar water heater, wetback or wood fired hot water heater. However, there were no instances of heat pump usage, evaporative cooling systems, active air systems, embedded phase-change materials or other advanced technologies.

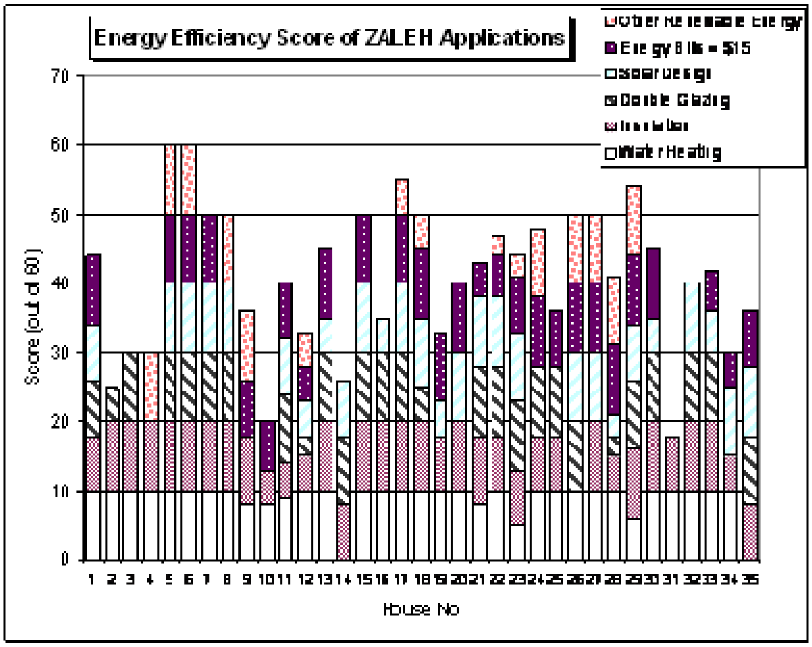

Figure 1: Acceptance criteria for the Zero and Low Energy Project (note that some of the initial applications did not include sufficiently detailed specifications to be included in the scoring system). Threshold for acceptance was set at 30 points.

The median market value of the surveyed low energy houses (excluding value of the section) is about NZ$350,000. This value is based on property value estimates and technology costs reported by the surveyed households. The median floor area is almost 250 m^2. Most energy technologies have a low relative cost and lead to reasonable energy savings per year, as shown in Table 2. The percentage increase in the cost of building the house is very small, between 1% and 2.5%.

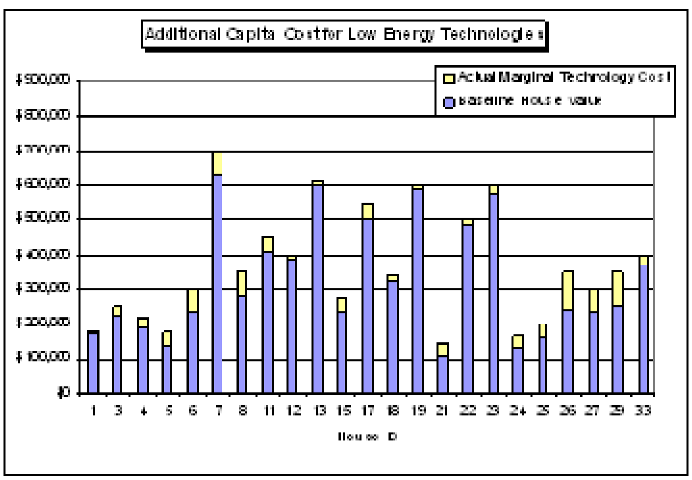

Figure 2: Technology cost

Table 2: Median costs of reported technology (or related design) costs and energy savings from sample households

Technology name	Technology cost	Annual energy savings (as reported by the occupants)
Insulation	$5,500	$450
Double glazing	$5,500	$300
Water heating	$4,000	$400
Space heating and cooling	$4,000	$200
Special house design feature	$10,000	$300

The most challenging aspect of the study is quantitatively valuing the “cannot see” positive and negative non-energy benefits (NEB). Skumatz Economic Research Associates Inc (SERA) has conducted extensive research to develop several measurement methods to quantify and “value” a wide range of participant and other NEBs. SERA pioneered the application of three different approaches in querying and measuring non-energy benefits, including “willingness to pay”, comparative and labelled magnitude scaling approaches [Skumatz]. For this project, two of these methods were used: a variation of the willingness to pay and the comparative methods. The results were designed to provide information on the net value of the non-energy benefits emanating from the advanced technologies as recognised by the ZALEH residents.

The interviews asked about specific NEBs (both positive and negative) associated with individual measures. In the questionnaires we asked, for each NEB category, whether there was a change and if it was positive or negative. The prompted benefit categories included:

- Appearance: changes in appearance of the home
- Bill control: measures (and bill impacts) led to a feeling of greater or lesser control over the energy bill
- Comfort: house features led to greater or lesser comfort in this home than others
- Environmental: features led to environmental benefits or problems
- Features: energy equipment or measures had better or worse features, options
- Health: features were perceived to make the home more or less safe or healthy to live in
- Maintenance: the features had lower or higher maintenance requirements
- Moving: the energy features led to the occupants being able to avoid a moving, either because of lower bills, greater benefits, value, and service from the home, or other reason
- Noise: the homes had lower or higher noise levels, either from outside the home, or from the energy using equipment inside the home, or both
- Notices: the energy usage changes due to the technologies led to lower bills, which changed the occupants' ability to pay and therefore may have reduced late payment notices or similar calls from the utility on bill-related issues
- Other: other unprompted benefits or problems categories included higher cost (the major one), and a variety of other benefits or negative impacts and changes.

Figure 3 shows the reported benefits from all low energy technologies which were installed in the sample houses. The figure shows that on average the value of the sum of the non-energy benefits by far outweighs the energy cost savings.

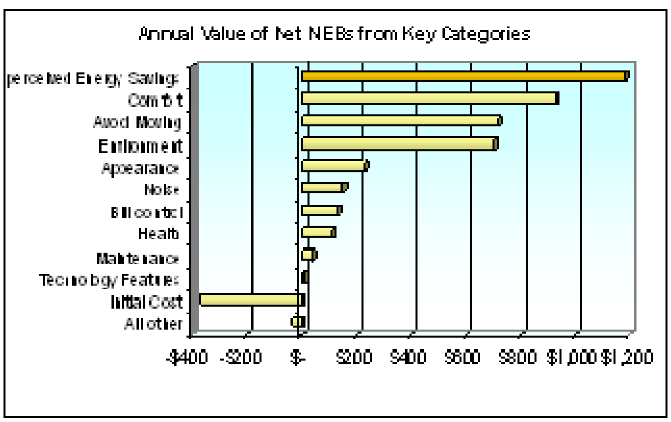

Figure 3: Non-energy benefits

4.2 Low income houses with only ceiling and floor insulation upgraded

These surveys were conducted via face-to-face visiting interviews in a number of HNZC houses in Dunedin. These houses were only retrofitted by installing insulation into the ceiling, and some with floor insulation and/or a hot water cylinder wrap.

Forty-eight percent of the respondents said that they had not experienced an energy cost change since their houses were retrofitted, compared to 36% of participants where the energy cost had decreased, and 16% of households where the energy cost had increased. Note that these results are based on respondents' feedback rather than actual energy bill analysis. These results seem plausible, because only the insulation was upgraded which may not necessarily lead to significant energy savings.

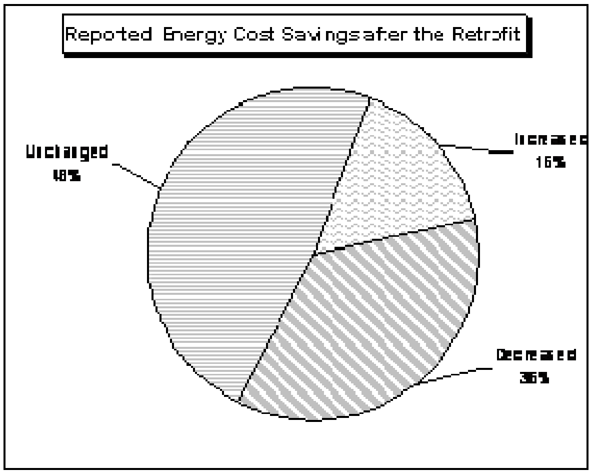

Figure 4: Reported energy savings

Most respondents did not experience any energy cost saving. However 78% of respondents experienced that their living conditions changed significantly better than before since the retrofit, such as warmer floor temperatures in winter (“Kids do not wear socks as much now”, “It takes a lot less longer to heat whole house from just the fire”, “Our health has improved” etc).

4.3 Randomly selected households

This group consisted of 58 houses which were randomly selected nationwide. These households participated in an online internet survey. Most of them had not installed superior insulation, double glazing or solar water heaters and had also not applied particular solar design techniques. The responses from this group are therefore a reflection of perceived, rather than experienced, benefits and problems with low energy technologies.

4.4 Cost saving comparison between the three sample groups

Figure 5 shows the reported energy saving estimates from the three survey groups. The graph only shows savings from insulation improvements, but as noted before, the insulation levels which were considered varied widely between the HNZC houses on one hand and the low energy and randomly selected houses on the other. It is interesting to note that the experienced energy savings in the low energy houses is quite similar to the savings which were expected by the randomly selected houses. A similar pattern also appeared for savings from double glazing and solar water heating.

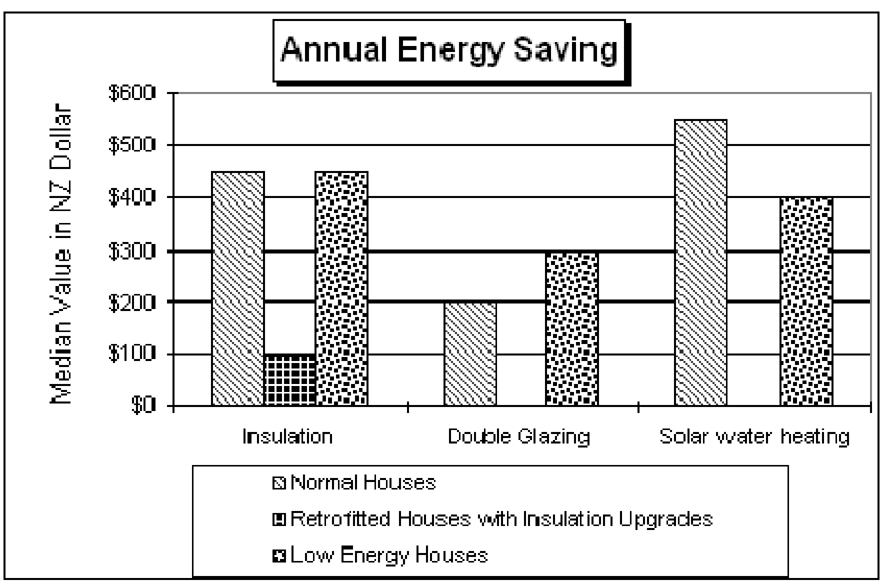

Figure 5: Comparison of the energy cost saving between three different survey groups

4.5 Non-energy benefit comparison between the three sample groups

The following figures compare the value perceptions of the non-energy benefits by the low energy house occupants and the randomly selected group. The graphs show how the respondents weigh the value of individual non-energy benefits and problems compared to the reported energy savings.

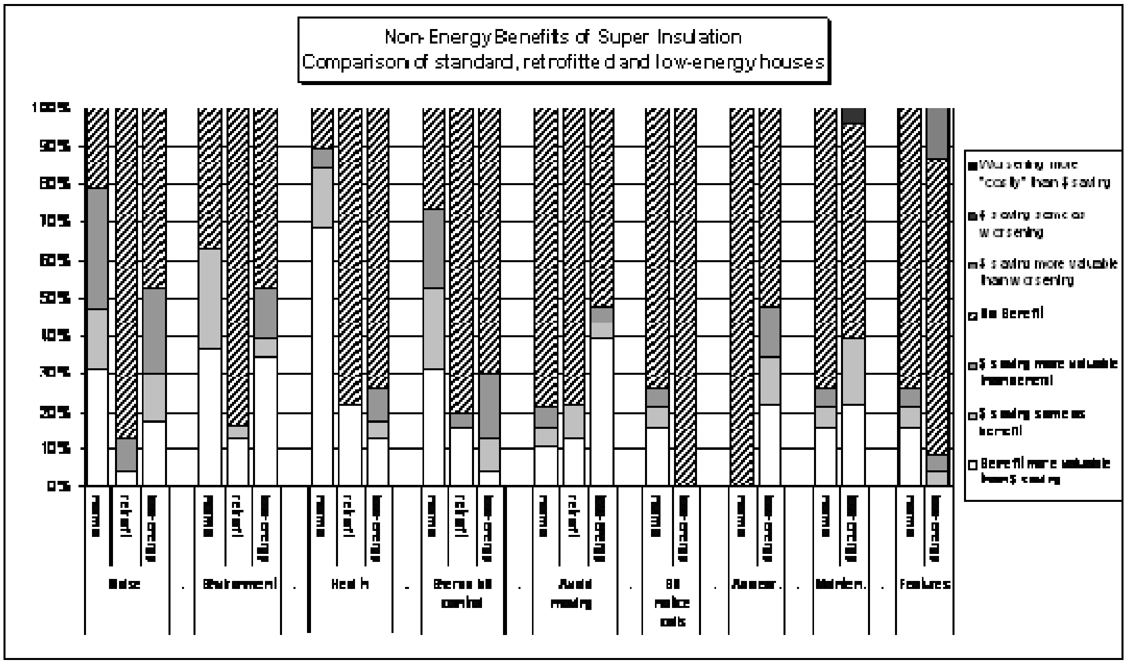

Figure 6: The value of non-energy benefits compared to the energy cost savings[1]

Some interesting differences become apparent from this analysis. While most of the non-energy benefits are rated similar by both groups appearance, bill control and health are clearly seen as different.

Appearance: A number of houses in the low energy house group featured extra thick walls or uncommon construction methods such as straw-bale or rammed earth walls. These were considered positive by the respondents. It may be that normal house occupants did not consider other construction methods and referred mainly to insulation products hidden in the building structure. Therefore they reported no positive or negative value.

Bill control: The demographic analysis of the low energy house group shows that the members have household incomes significantly above the New Zealand average. It is therefore not surprising that for these respondent electricity bill payments were not of high concern.

Health: A similar argument could be made for health improvement. The low energy house occupants were financially well off and presumably could afford to keep their houses at sufficiently healthy temperatures, irrespective of the thermal performance of the building. It is, however, interesting, that the randomly selected respondents placed such a high value on the health improvements through better thermal insulation.

[1] The benefit categories were modified for the retrofit house survey to improve its administration. Therefore some of the categories are not immediately comparable between the three survey streams. The graph therefore does not show data for Bill notice calls, Appearance, Maintenance and Features for the retrofit surveys.

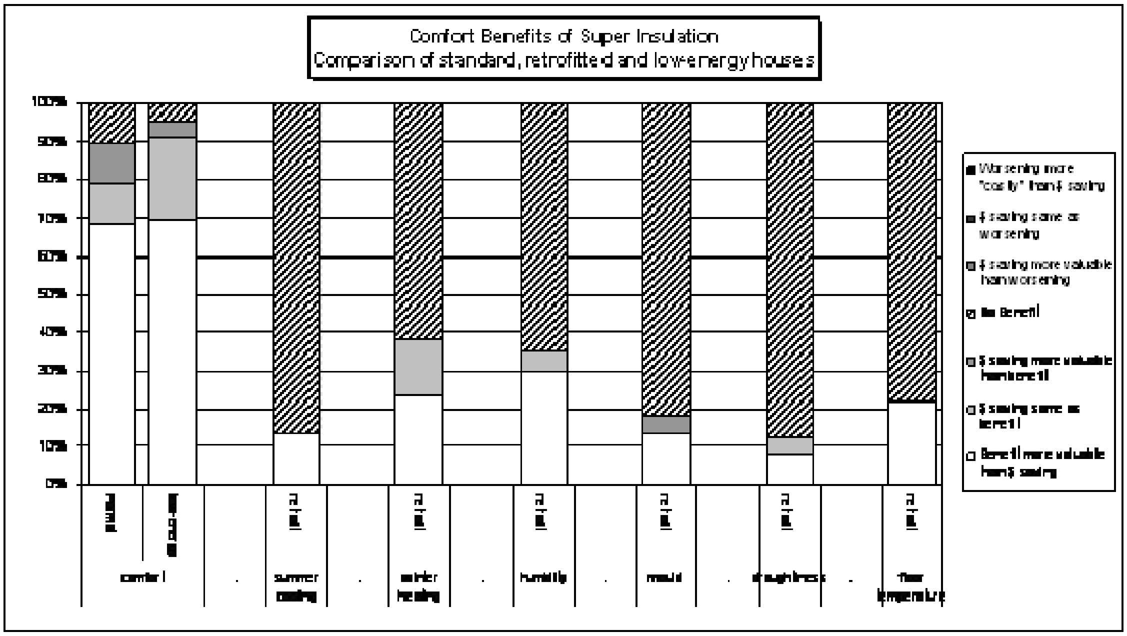

Figure 7: The value of comfort benefits compared to the energy cost savings

Figure 7 shows the value perceptions of comfort benefits from the insulation. The different aspects of comfort were split in the retrofit house sample to improve the response accuracy by the house occupants. The individual comfort components are rated lower than the overall comfort improvement in the low energy and the randomly selected houses. None of the comfort components was improved consistently in all of the retrofitted houses. On average, only about a quarter of houses had reported comfort improvements within each comfort subset. The highest scored improvements occurred for winter heating and humidity benefits. The data suggest that improving the insulation in only one component of the building, namely the ceiling, often does not achieve noticeable comfort improvements.

4.6 Cost/benefit application

The potential application of these results was explored on a typical cost/benefit analysis for insulation improvements. Historically these types of analysis were conducted by the New Zealand regulators to determine optimum insulation levels for the NZ Building Code. The analysis weighs energy cost savings up against insulation cost expenses.

Although the intention of this approach is to provide best value-for-money solutions to the consumer, the method has an inherent dilemma: although it is widely accepted that there are significant non-energy benefits from energy technologies, the traditional cost/benefit analysis does not account for these. One of the reasons for the lack of including these wider benefits is that non-energy benefits are inherently difficult to quantify in economic terms. However, excluding them from the analysis effectively assumes a $ value as well, which incidentally is $0. Therefore such an analysis will ultimately not lead to best value-for-money solutions.

The following example illustrates this. The research in zero and low energy houses suggests that house occupants value non-energy benefits from superior insulation more than twice as high as the associated energy savings.

Figure 8 shows the net present value for insulating a lightweight construction in Wellington for a range of whole building R-values. The y-axis shows the net present value based on the capital investment of increased insulation in roof, walls and floor for a standard residential building with single glazing (circles) and double glazing (bullets). The values shown in the example are taken from the last update of the NZ Building Code.

The two graphs show that when non-energy benefits are not included (graph on the left) the slopes of the net present values for the single glazed scenarios have a slight minimum at 0.95ºC/W, and double glazing options are less cost-effective. If non-energy-benefit values at twice the value of the energy savings are considered, the graph changes dramatically and the best value options are double glazed solutions at much higher composite insulation levels. (The lowest NPV option is to the right of the last calculated data point, i.e. higher than the last computed composite R-value of 1.4ºC/W.)

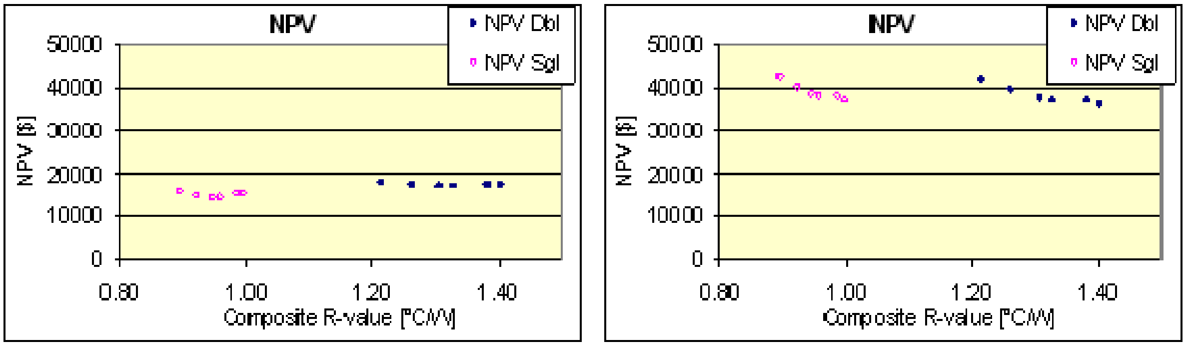

Figure 8: Cost benefit analysis (double glazing scenario)

This interpretation of the non-energy benefit results is presented here as an indicative approach. It is obvious that national Building Code targeting cannot be based on such a small and unrepresentative sample as the low energy house group is. What this research and this cost-benefit analysis demonstrate, however, is that the effects of including non-energy benefits in a more holistic cost benefit analysis are profound and by far outweigh parameter variations for insulation cost, discount rates etc.

Once a sufficiently large and representative sample size is achieved, value perceptions will also be analysed in terms of demographic preferences. It is conceivable that, for example, elderly people place a higher value on comfort than young people.

5 CONCLUSION

This study examined the value of non-energy benefits of energy technologies in three different sample groups:

1. Low energy houses
2. Randomly selected houses
3. Low income houses with insulation retrofits.

The study found that the energy savings experienced by the low energy house sample matched quite closely the perceived potential energy savings by the group of randomly selected respondents who had not employed low energy technologies in the buildings.

The research further demonstrates the potential of financially quantifying the non-energy related benefits from energy technologies. The low energy house respondents reported that, to them, non-energy benefits were on average approximately 2.5 times more valuable than the reported energy savings.

This finding has potential applications in conducting a more holistic cost/benefit analysis to determine best value-for-money solutions for energy-efficiency projects of building regulations, as well as opportunities for well-targeted marketing of low energy technologies.

6 ACKNOWLEDGEMENTS

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