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The efficacy of an energy efficient upgrade program in New Zealand

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Abstract

This paper details the physical effects of a government sponsored, residential energy efficiency upgrade program in New Zealand, with data gathered from 100 houses located in Dunedin. House energy use and thermal indoor environment were monitored over a 2-year period. Houses were found to be 0.4 °C warmer (annual average increase) after the upgrade with a 0.6 °C increase recorded over the winter months, after being corrected for energy consumption and weather conditions. A small, but statistically insignificant, reduction in energy consumption was also found. In absolute terms, indoor temperatures were found to be very low and did not come close to WHO recommendations. The data showed occupants could be exposed to indoor temperatures below 12 °C for nearly half of the 24 h day during the three winter months. The findings were quite surprising as the upgrade program had the goal of making houses warmer and healthier by reducing heat loss through improved thermal insulation. Householders, however, provided very little heating to living areas and even less to bedrooms thus contributing to the less than desirable indoor thermal environment.

Keywords: Energy efficiency; Retrofit programmes; Indoor temperatures; Energy consumption; Low income

1. Introduction

The present paper details a study undertaken by the University of Otago (Energy Studies Group) to measure the efficacy of a New Zealand government sponsored energy efficiency housing retrofit program. The study included the monitoring of 100 state houses in Dunedin (Otago, South Island) for temperature and energy consumption over a 2-year time span, with the aim of identifying improvements in comfort and reductions in energy use after the upgrades.

An IEA report suggested that: ‘‘By 1995 New Zealand had the lowest space heating intensity (measured as energy per square meter per degree day) of all the countries studied, even including Japan, and was about half of Australian levels’’. Residential energy use in New Zealand for 1995 was around 17 GJ/capita/annum compared to around 35 GJ/capita/annum in Australia, 30 GJ/capita/annum in Europe and 54 GJ/capita/annum in the US [1]. The low values for New Zealand residential energy use reflect unusually low levels of space heating. These findings are unusual as New Zealand has had historically some of the cheapest electricity of all of the OECD countries. According to Ministry of Economic Development, however, the energy consumption for the residential sector in New Zealand is likely to increase [2]. In 2005 the residential energy sector in New Zealand accounted for about 13% of the total energy consumed [3] in the country with an average of 12,150 kW h/year/dwelling.

New Zealand has a cool temperate climate, lying between 34 and 46° south. The South Island is significantly cooler than the North Island with Dunedin having some 2580 heating degree days (base of 18 °C) compared to Auckland in the north which has 1150 heating degree days (base 18 °C). About 80% of housing stock in New Zealand was built before energy efficiency regulations with regard to insulation came into effect in 1977–1978 [4].

Public housing in New Zealand was built to a high standard according to the prevailing regulations but with no insulation. New Zealand houses have larger floor areas than the average among OECD countries [5]. Also newer houses are larger than older ones [6] and are moving to lower occupancy levels [7]. Houses that have a larger building envelope area and/or poor levels of insulation require more energy to achieve minimum levels of thermal comfort. To compensate perhaps for the larger house sizes, people in New Zealand tend not to heat the entire house. Consequently houses in New Zealand are relatively poor in terms of thermal comfort [8,9]. In terms of the future, new

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housing is not going to change the situation significantly due to low building turnover rates and it is likely that approximately 70% of the 2030 housing stock already exists [10].

1.1. International studies

Many international studies reveal that there are health impacts associated with cold housing [11,12]. Houses that are cold are also likely to be damp leading to mould and fungal growth; together these are known to cause respiratory problems for the occupants [13]. Damp and mould is an endemic problem in many homes in New Zealand, compounded by low levels of heating and often poor ventilation [14]. Low indoor temperatures moist air and then cyclic heating followed by cooling further increases the risk of condensation [15]. This situation is known to lead to high levels of seasonal mortality and respiratory diseases such as asthma [16,17].

The financial inability to heat the home to an adequate temperature results in thermal discomfort and health risks, a condition which has been defined in the UK as fuel poverty [18,19]. A study on ''Poverty and Comfort'' by the Building Research Association of New Zealand (BRANZ) suggested that ''*energy is a significant cost item for low income households*'' and that ''*our houses are not achieving conditions which promote or even support good health*'' [20]. A more recent study suggested that between 10% and 14% of the population of New Zealand is currently living under fuel poverty conditions, with the percentage in the lower south island much higher [21]. Wilkinson et al have shown that in the UK there was a gradient of risk with the age of the houses; the older the houses the greater the risk of death in winter [22].

Thus far the existing research is not controversial; cold homes are unhealthy. What is happening in recent times is that all governments, including the New Zealand government, are under pressure to address the anthropogenic global warming problem by tackling energy consumption on the demand side. One relatively easy way to reduce fossil fuel usage is thought to be by improving residential housing insulation levels, as this measure can both reduce energy consumption and improve health by increasing indoor temperatures. But if homes are not already adequately heated, the outcomes are usually at the expense of each other, that is, higher temperatures mean more energy consumption or reduced energy savings.

Because the turnover of housing stock is quite low this demand side problem is often tackled by retrofitting existing housing with various energy efficient upgrade packages. The importance of retrofitting was recently pointed out at a Sustainable Buildings workshop held in 2006, organized jointly by the OECD and the IEA, the report resulting from the workshop suggested that: ''*since existing buildings account for a large proportion of the total stock, upgrading the energy efficiency of existing buildings has become an urgent task*'', and that a ''*Cost-benefit analysis tools, quantifying environmental gains are expected to assist decisions of owners for appropriate renovation*'' [23]. Internationally several energy efficient retrofitting programs have been designed and implemented aiming to both alleviate fuel poverty and to provide higher levels of comfort, while simultaneously reducing energy use and CO_2 emissions.

The environmental health of the planet is now receiving a high priority and so achieving energy reductions and consequent CO_2 emission reductions are often paramount, especially in selling the upgrade project. According to the New Zealand Ministry of Social Development in 2003 [24]: ''*The Energy Efficiency Retrofit Programme has provided the largest reduction in HNZC's environmental footprint over the last two years. Based on EECA estimates, HNZC retrofits completed to date will save tenants (collectively) approximately $1.0m per year*'' and ''*reduce CO_2 emitted into the atmosphere by approximately 60,000 tonnes*''.

The efficacy of the upgrade programs, however, has been found to be somewhat controversial as they can be expensive and can often produce ambiguous outcomes (see below). This has been particularly true in terms of levels of energy reduction, where for instance, Milne and Boardman found in the UK that ''*In most cases of domestic energy efficiency retrofits, there are varying degrees of differences between the predicted energy savings, based on the calculated heat loss reduction, and the actual energy savings achieved in practice*'' [25]. In general the findings of several studies have suggested that lower levels of energy reduction than expected occur due to a trade-off between taking the savings as thermal comfort rather than decreasing their energy consumption [26,25].

Other authors suggest that the simplicity of the model assumptions used to estimate the assumed benefits might not be accurate due to not having taken into account all the variables, with high levels of errors used for the model calculations. In addition the well documented 'rebound effect' [27,28] needs to be taken into account whereby, according to Hass et al: ''... *Increases in energy efficiency will lead to cheaper prices for service provided and to a substantial increase in service and energy demand. This increase will outweigh the conservation effect to a large extent and, hence, make conservation programs useless*''. In their study of retrofitting residential homes in Austria, Hass et al concluded that ''*Standards with respect to building codes are very important tools to increase the thermal quality of new buildings'' and ''due to prevailing low energy prices, a triggering tool, which may be rebates or loans, has to be implemented to increasing the efficiency of the building stock*'' [29]. Another study, this time in the UK, by Bell and Lowe, found that a 40% greater fuel consumption was recorded above the predicted level in centrally heated dwellings because of the householders preference towards the continued use of existing (and inefficient) individual gas fire appliances in tandem with a new (efficient) gas central heating system [30]. Many people recognise that retrofit programs might provide benefits other than reducing energy consumption, especially if designed for low income householders. In a cost-benefit study, Clinch and Healy suggested that improving energy efficiency in housing will not necessarily result in reduction in energy use [19].

There is, however, some evidence, particularly for smaller upgrade projects, that residential housing energy retrofit programs are successful in reducing energy consumption. One study in the UK (York) monitored four houses that had