Sustainable Building for Affordable Housing

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Summary

New Zealand's housing stock is well known for being cold, damp, difficult to heat, and greedy of resources. This comes at a significant cost to our community with many people living in homes that are not only unhealthy but also costly to run. Improvements to minimum building standards have not produced homes which are healthy and efficient. In addition, new dwellings are frequently built on the periphery of towns and cities, away from employment, amenities and services. In many settlements and cities, residential areas, particularly new developments, are poorly serviced by public transport services. Those areas are unsustainable environmentally, houses prices are unaffordable and the costs of living for the households that live in them are high.

Unfortunately, the debate about sustainable houses has been largely detached from the debate about affordable houses. Where the intersect between sustainable and affordable housing has been recognized at all, it has generally been driven by a perception that the building costs of sustainable housing will inevitably make those houses unaffordable. This paper addresses that debate with particular reference to Beacon;s testing of its NOW Homes®.

Beacon has developed two NOW Homes® – houses built for an average budget for ordinary families which perform significantly better than the vast majority of New Zealand houses. These homes have been monitored in terms of their resource use, quality of the indoor environment and overall sustainability against key performance indicators and benchmarks set by Beacon. The homes have now demonstrated that development of these homes with current technology and for prices within the reach of ordinary households, significantly higher quality and healthier and more resource efficient housing is able to be developed.

Overall, this paper shows that sustainable building is critical to affordable housing. It shows that the entry level price of new dwellings is driven by increased dwelling sizes which are both resource costly and place significant entry and operating cost burdens on the households that buy and live in them. The paper presents data on new builds and home renovations that show that household living costs can be substantially reduced through increasing the resource performance and comfort of dwellings.

1. Introduction

Since 1996 the increase in dwellings in New Zealand has exceeded the increase in households. Despite this, New Zealand's houses have, until the 2008 international finance crisis, shown an extraordinary increase in price. Between 2002 and the beginning of 2008 real house prices increased by 80 percent (Department of Prime Minister and Cabinet, 2008:3). Associated with this price boom has been a developing crisis in affordable access to dwellings, particularly in the owner-occupier sector of the market, but also, to a lesser extent, in the rental sector. At the same time as an increasing proportion of New Zealand households are struggling to access housing with affordable mortgages or rents, it has been revealed that New Zealand houses are cold, damp, unhealthy and costly. A significant proportion of energy and water consumption in the country occurs in the residential sector (Statistics New Zealand, 2006). Similarly, the residential sector produces significant amounts of waste (Kazor and Koppel, 2007). Our houses are cold, difficult and expensive to heat, and are unhealthy (Isaacs, *et al*., 2003, 2004, 2005; Howden-Chapman, *et al*., 2007). The tendency for New Zealand cities to be both low density and sprawling is associated with high private transport use and private car use accounts for almost 90 percent of New Zealand's total passenger transport energy use (Trodahl and Weaver, 2007).

It was in that context that Beacon has built two resource efficient NOW Homes® in Waitakere, Auckland and Rotorua. These homes have been monitored against benchmarks that Beacon has set around what defines a High Standard of Sustainability™ for homes. These homes have been designed and built with cost effectiveness and affordability as key considerations. Measures taken have been aimed at both making the homes more efficient to operate (therefore with far lower energy, and where applicable, water and waste bills) and healthier to live in. This paper describes Beacon's research, presents the performance data from the Waitakere NOW Home® and comments on one of the importance of dwelling size to building sustainable and affordable homes.

2. Beacon Pathway Ltd: Its Aspirations, Research and the High Standard of Sustainability

Beacon Pathway is the vehicle chosen by a number of like-minded organisations that seek to radically change the design, construction and renovation of New Zealand's homes and neighbourhoods. Our goal is to significantly improve housing sustainability through scientific research, communication, information sharing, and advocacy, opinion forming and networking.

The Foundation for Research, Science and Technology matches funding from Beacon's shareholding partners, a unique mix of industry, local government and research organisations: Building Research, Scion, New Zealand Steel, Waitakere City Council and Fletcher Building.

In order to provide a framework for Beacon to measure the influence it is having on the sustainability of houses at a national level, and to provide a useful benchmark against which individual households can evaluate their home's performance, Beacon has developed benchmarks for a High Standard of Sustainability™ (HSS) in homes (Easton, 2006). These benchmarks have focused on five key aspects of dwelling sustainability:

- Energy Use
- Water Use
- Indoor Environment Quality
- Waste
- Materials

Underpinning these five technical aspects of dwelling sustainability are the issues of affordability and future flexibility. When considering the individual household benchmarks at which the HSS performance indicators should be set, affordability was a significant consideration (Easton, 2006). The benchmarks have therefore been set at levels where many of the features used to bring about their achievement are:

- low cost (eg simple measures such as fitting of draught stoppers and use of low-flow shower heads)
- have a payback period of less than the expected life of the product
- In the case of new development, can be undertaken at no or minimal extra cost (eg passive solar design).

The benchmarks developed represent a preliminary "line in the sand" for Beacon and are expected to be updated and refined over time, and as the research into the state of New Zealand's home performance continues. While detailed comparative work is still being undertaken, new homes built to achieve the Beacon HSS appear to be roughly comparable with a "good" rating (56-69 points) under the BRANZ Green Homes Scheme (New Zealand's only current sustainable home rating scheme), or a Level 4 compliance with the UK Code for Sustainable Homes. This compares with, for example, the average new New Zealand home, which would score around 10-15 points under the BRANZ Green Homes Scheme and not achieve a rating on the UK Code for Sustainable Homes. In other words while the Beacon HSS benchmarks are significantly higher than the minimum requirements of the NZ Building Code, they are set to be within what is a considered to be able to be a reasonable target for all new homes to achieve by 2012.

3. Beacon's NOW Homes®

Beacon has developed two NOW Homes® – in Waitakere, Auckland and Rotorua. The Waitakere NOW Home® was completed in August 2005 and the Rotorua NOW Home® in September 2006. Both homes were designed and built to budgets and constraints typical of "ordinary" New Zealand housing rather than aimed at the top 5% of the market more typical of other "ecohomes". Passive solar design, resource efficiency, minimisation of hazardous materials and future flexibility were all key considerations in designing and building the homes.

3.1 Waitakere NOW Home®

The budget for the Waitakere NOW Home® was set based on a comparison of housing cost within the surrounding suburb (Bayne and Kane, 2004) and the house was built for $213,000 + gst**.** The home contains many features which would have then be considered to be outside the design parameters of an "affordable house" – such as double glazing and a solar hot water system, however these extra cost features were able to be incorporated through careful design and elimination of wasted space such as corridors and unnecessary features**.** The home is a relatively modest size new home in New Zealand being 146m^2 including the garage. Average floor area for new houses in 2008 is currently estimated to be 205 m^2 (Statistics New Zealand, 2008).

The Waitakere NOW Home® uses timber weatherboards, fixed to a timber frame on a heavily-insulated concrete slab. The roof is concrete tile, and the ceilings and walls are heavily insulated. The entire building is double glazed.

The building is sited to maximise the benefits of passive solar heating, using the highly insulated envelope to trap and retain the sun's warmth – mainly via the polished (no carpets) concrete slab. Passive ventilation is incorporated in the design to facilitate air changes without creating draughts – important for a healthy indoor environment.

A solar water heater is installed on the roof, and a water tank collects rainwater from the roof. The tank water is used for many non-potable water needs within the house. Where possible light fittings are high-efficiency compact fluorescent types.

The majority of the appliances belong to the tenants, however the range, fridge, dishwasher and washing machine are new efficient items supplied as chattels.

The Waitakere NOW Home® was been occupied over the period September 2005 – March 2008 by a family of four (two adults, two children). At the start of the tenancy the two children were of pre school age and one of the children suffered from asthma.

Figure 1: Waitakere NOW Home Floor Plan

3.2 Rotorua NOW Home®

The Rotorua NOW Home® has been built on the same principles of design and material selection as the Waitakere house, with the benefit of subsequently available knowledge, as well as meeting Housing New Zealand Corporation (HNZC) requirements for social housing. The house is owned by HNZC, and forms part of their rental housing portfolio. The cost was $180,000 +gst.

The Rotorua NOW Home® uses preprimed timber plywood and prepainted steel for cladding, fixed to a timber frame on a heavily-insulated concrete slab. The roof is prepainted steel, and the ceilings and walls are heavily insulated. The entire building is double glazed.

A solar water heater is installed on the roof, and a 5000 litre underground water tank collects rainwater from the roof. The tank water is used for toilet flushing and to supply the washing machine within the house. All light fittings are high-efficiency compact fluorescent types. Unlike the Waitakere Home, appliances were not supplied with the home, with the exception of the stove as HNZC policy is to not include whiteware.

Due to Rotorua's colder climate, the space heating requirement was four times that of the Waitakere NOW Home® and a low emission pellet burner was installed to provide supplementary heating. The house was designed to provide for wheelchair access, and a second bathroom included was specifically designed for accessibility. The home has been tenanted since September 2006 by HNZC tenants.

4. Performance of the Waitakere NOW Home®

Monitoring of the Waitakere NOW Home® includes the collection of end use information for both the electricity and water use. Temperature and humidity are measured in each room as well as CO_2 in the living room. The water temperatures, solar radiation and water flows for the solar water heater were also measured (French et al, 2006).

Post occupancy evaluation surveys were also undertaken to capture the occupants' experiences compared with the previous house they lived in, to gain an understanding of the occupants' behavior and influence on the house performance as well as the influence of the house on the occupants.

4.1 Energy use within the Waitakere NOW Home®

In its first year of occupancy the Waitakere NOW Home® used 7400 kwh/year of electricity, with supplementary space heating required on only two days. When compared to the occupants' previous dwelling, this was 45% less electricity than they used in their previous home (French et al, 2006). This equated to a financial saving of approximately $900 in annual operating costs. This was primarily achieved due to the home needing heating for only 2 days of the year and the substantial impact on hot water heating costs from the solar hot water system. In the average New Zealand home heating and hot water account for approximately 2/3 of energy use**.** Electricity use would have been even lower in the Waitakere NOW Home if the occupants had not taken advantage of the substantial cost reduction to expand their appliance use (large screen television, multiple computers) and to establish a home office in the dwelling. The home office alone contributed 850kwh/yr of energy use.

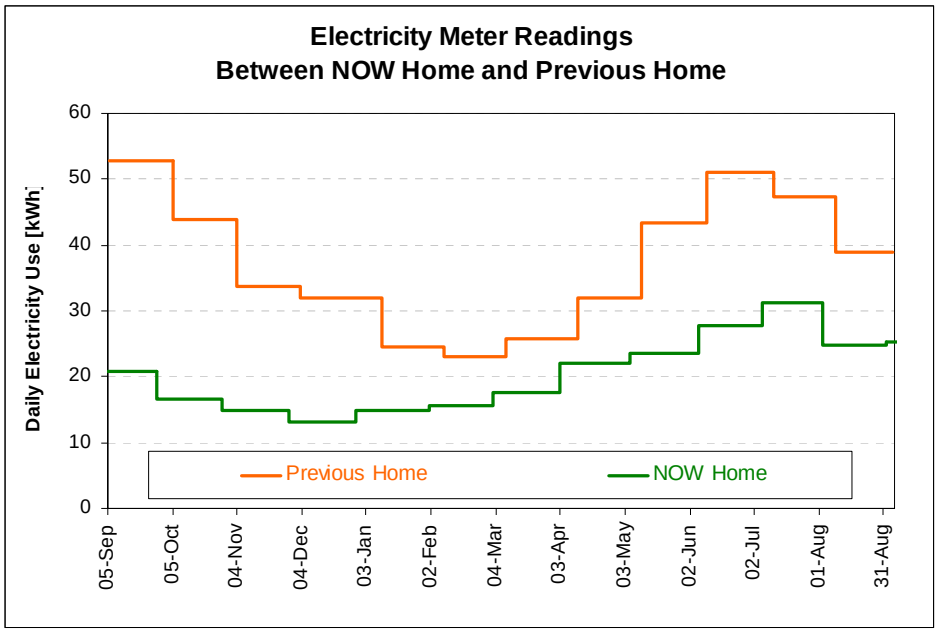

Figure 2 Comparison of electricity use by the occupants of the Waitakere NOW Home® compared to their previous home (after French et al, 2006)

4.2 Water use within the Waitakere NOW Home®

The presence of a rainwater tank as supplementary supply for the Waitakere NOW Home meant that reticulated water use (which is directly billed to the consumer in Auckland) was 100 litres per person per day, dropping to 85 litres per person per day in the second year (Pollard et al, 2008). This meant that the household consumed between 40 and 50% less than the Waitakere City average – with associated decreases in water bills.

4.3 Indoor Environment Quality within the Waitakere NOW Home®

Temperature and humidity data collected across the first year of occupancy identified that the temperatures within the home were maintained within healthy and comfortable parameters for the vast majority of the time occupied (Pollard et al, 2008**)**. In terms of user behavior, a portable heater was only required to be used by the tenants twice during what was a colder than average winter. The tenants brought with them dehumidifiers, heaters and electric blankets from their previous home, but didn't need to unpack them. Particularly pleasing for both the family and the researchers involved was that the child with asthma had substantial improvements in his health, with reduced need for asthma medication, and the whole family experienced reduced ill health in the home.

4.4 Experience of the occupants of the Waitakere NOW Home®

Interviews with the tenants and post occupancy evaluation identified that they considered the Waitakere NOW Home® to be "their best home ever". Overall the occupants' experience of the house was extremely positive, with the features consistently impacting most positively on their experience of the house being the layout and open plan design, sun and natural light, warmth and temperature, the concrete floor and reduced energy costs. The occupants regularly and consistently referred to significant health and wellbeing benefits from living in the house, including decreased levels of ill health, increased children's confidence, a more active social life, enhanced interfamily relationships, a low noise environment and generally feeling "happier" (Trotman, 2008).

5.0 Size and Sustainability

One of the features of the Beacon's NOW Homes® has been the constraint on house size. This is consistent with sustainable building specifications elsewhere (Prahl, 2000; Roberts, 2003).

The Beacon NOW Home® specifications require a maximum dwelling size of 180m^2 for a three bedroom house. At 146m^2 including the garage the Waitakere NOW Home® is both typical and atypical in relation to size. It is a typical New Zealand house in that it is a three-bedroom house and the 2006 census shows 46.3 percent of New Zealand's occupied housing to have three bedrooms. It is atypical, however, because despite falling household sizes and occupancy rates, New Zealand houses are getting bigger. In 1996 only

22.3 percent of the occupied stock had four or more bedrooms. By 2006, that proportion had increased to 27.6 percent. Moreover, the dwellings with eight of more rooms has increased from 15 percent of private occupied dwellings in 1996 to over a fifth (22.4%) of dwellings in 2006. The result is that 24.1 percent of households with one, two or three household members lived in dwellings with seven or more rooms in 2006. In 1996, only 18.4 percent of smaller households lived in larger dwellings.

The census understates this 'sizing-up' trend simply because the stock increase over an inter-censual period is relatively small. It is most evident in the new stock added each year to New Zealand's existing stock. The real size difference between the Waitakere NOW Home® and others built around the same period is evident when its floor size is compared with current floor sizes for new homes. In 1973, the average dwelling size was a little under 110 sq metres compared to 197 sq metres for the ten months to January 2008. For houses, the average floor size in 2008 was 205 sq metres. In the year ending March 2007, 25,740 residential building consents were approved with an average floor size of 194 sq metres. In 1973, an individual had an average of 32.5 sq metres living space in a new home in 1973, by 2008 that average had increased to 73 sq metres.

Mar Yr	Number of Dwellings		Average Floor Area	
	Houses	Flats	Houses (m²)	Flats (m²)
1976	20,932	11,257	121	83
1980	11,687	3,510	133	93
1985	15,664	6,118	133	99
1990	21,365	1,486	136	88
1995	21,619	2,062	171	116
2000	21,386	4,472	177	105
2005	23,355	6,690	206	94
2008	22,422	2,811	205	137

Table 1: Average Floor Area 1976-2008 - Statistics NZ Building Permits Series

The Household End-Use Energy Project (HEEP) has recently analysed the impact of house size on energy costs and has found that around 16.6 percent of the variance in winter energy expenditure is accounted for by a dwelling's floor area. The average winter energy expenditure in dwellings of 100 sq metres or less was about around $107 per month. The average monthly winter fuel expenditure was around $183 for a dwelling with a floor area in excess of 200 sq metres.

This pattern of higher energy costs for larger dwellings is somewhat muted by the number of people living within the dwelling. However, the impact of household size on energy costs is most evident in smaller dwellings (Table 2). In HEEP dwellings of 100 sq metres or less the average winter monthly energy cost is about $54 more for a household with four or more members than the average winter monthly energy cost for a one-person household in the same size house. By way of contrast, however, in the HEEP dwellings of 151-200 sq metres with a household with four or more members, the average winter monthly energy cost is only $18 more than for a similar size dwelling occupied by one person.

Floor Area Sq Metres	Household Size					
	1 person		2-3 people		4 or more people	
	Mean $	Median $	Mean $	Median $	Mean $	Median $
100 or less	$85	$75	$97	$95	$139	$130
101-150	$104	$105	$122	$120	$139	$140
151-200	$150	$150	$153	$150	$168	$152
201 or more	No data	No data	$168	$160	$250	$250

Table 2: Estimated Typical Monthly Winter Energy Costs by Dwelling and Household Size – HEEP

These costs do reflect differences in energy use. The average total energy use of HEEP dwellings between 151 and 200 sq metres is 13,400 kWh. That is, 4,000 kWh above the average annual energy use of dwellings 100 sq metres and less, and 2,000 kWh above the average annual energy use of HEEP dwellings between 101 sq metres and 150 sq metres. One-person households in dwellings 151-200 sq metres had twice the median winter monthly energy cost of dwellings 100 sq metres or less. Households with 2 or 3 household members in dwellings in excess of 200 sq metres had median monthly winter energy costs of around 1.7 times those of similar sized households in dwellings 100 sq metres or less.

Clearly, the size of a dwelling impacts significantly on the costs of operating it. Larger dwellings also cost more to acquire than smaller dwellings despite the per metre building cost being somewhat lower in larger dwellings. The recent report of the House Price Unit in the Department for Prime Minister and Cabinet (2008) suggest that the cost of a 145 sq metre new dwelling in 2007 is around $247,636 while a 202 sq metre new dwelling is $292,631. Under current conditions, a household taking up a 20 year mortgage would require a household income of over $118,000 to afford the 202 sq metre dwelling, while the 145 sq metre dwelling would require a household annual income of around $100,000. A smaller, 100 sq metre dwelling at prevailing building cost would only require an annual household income of about $70,000 to make mortgage servicing affordable.

Trends to larger houses are not solely a characteristic of New Zealand. This is an international trend. House size is determined by a complex set of factors including socio-cultural drivers related to the expression of social status and changes in the patterns of household interaction (Reimer, 1943). Trends to home-based employment may also drive up house sizes, although this is not clearly established. Some argue that income policy settings also generate incentives for reduced occupancy and smaller households (Ellen and O'Flaherty, 2007). The relative weight of those factors in New Zealand is not well understood, although there appears to be a strong perception among builders that they can achieve better returns from constructing larger and more expensive dwellings (DPMC, 2008).

6.0 Conclusions

The debate about affordable housing in New Zealand has largely avoided two significant issues – the relationship between house size and house cost and the affordability of house operation and performance. The Beacon NOW Home projects have demonstrated that it is possible to build high quality housing at a price which is comparable with other new housing. The homes demonstrate that good design can reduce the size of dwelling needed to meet the needs of New Zealand families, reduce the impact of the dwelling construction and operation on the environment, and reduce the costs needed to operate the dwelling, leading to a cost effective model for mass housing.

Currently consumers in the new home market are not asking for high performance from their homes, despite the fact that it is relatively easy to design and construct homes which perform significantly better than the norm. Instead they appear to accept increasingly large poorly performing houses, with associated high upfront capital and operating costs. Where affordability is a consideration, the default response appears to be to deliver cheap low quality housing, rather than to design to high quality, but smaller dwelling sizes.

This lack of demand is often cited by the industry as a reason not to provide high performing dwellings, yet there is a significant lack of capacity within the sector to deliver these outcomes. Beacon is working with builders and developers within New Zealand to try and improve the capability and capacity of the sector to build and renovate homes to meet the HSS benchmarks. Without engagement from the consumer with the performance of their home however, there is likely to be limited uptake of these opportunities, and more sustainable homes will remain a small segment of the house market.

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