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Abstract

New Zealand’s residential dwellings account for about one-third of all electricity consumed and are a source of 20% of the country’s carbon dioxide emissions. Despite a recent increase in policies and strategies associated with or linked to housing, New Zealand, as a nation, is failing to meet its goals and is well below international standards for energy efficiency, health and sustainability. Meeting the requirements of the first commitment period of the Kyoto Protocol and beyond presents big challenges for New Zealand’s construction and energy supply industries.

To this end, opportunities exist for the implementation of building solutions with low energy requirements and low carbon emissions which would enable New Zealand to meet national goals for triple bottom line outcomes required of energy, health and sustainable development strategies. However, to embrace the government’s drive towards sustainable development, attitudes need to change, both in industry and the community, to enable the successful transition of ‘green’ building from the fringe to the mainstream.

The path to a sustainable built environment is underway. A cross-sector consortium is developing the NOW Home, the first part of a housing ‘vision’ that will result in the construction of new domestic dwellings and retrofitting of existing building stock to a high standard of sustainable design and thermal comfort. This will help New Zealand meet national and international goals, and achieve equitable social, environmental and economic outcomes.

This paper examines the progress this initiative is making to deliver sustainable housing to current and future communities, and the part it plays in the larger picture of a low-carbon built environment

Keywords: climate change, sustainability, low-carbon, mitigation, adaptation, NOW Home

1. CLIMATE CHANGE AND THE BUILT ENVIRONMENT

1.1 Introduction

The need for low-carbon housing solutions, both internationally and in New Zealand, is of pressing urgency as it constitutes an important future component of the building and construction industry's efforts to mitigate climate change. The construction and occupation of houses are 'activities' which have major impacts on the environment via the use of inappropriate materials, ecosystem destruction, production of gaseous and solid by-products and excessive use of resources, such as energy and water.

New Zealand is facing a carbon-constrained future brought about by human-induced climate change. The construction industry faces both challenges and opportunities in helping to bring about a low-carbon society. A carbon-constrained future does not necessarily mean that new technologies are needed. Many of those needed exist already. Progress in the implementation of sustainable building features has been made at the cutting edge in the international industry but there has not, in general, been a larger-scale transfer of sustainable technologies into the building stocks of developed countries.

The technical feasibility of constructing or retrofitting buildings with low energy requirements suggests that existing technology is capable of reducing direct and indirect carbon dioxide emissions to 80%-90% of existing levels (Lowe 2003). Levels of such magnitude have been documented internationally, at least in demonstration houses/developments (Lowe 2003), and there is no technical reason why significant reductions cannot also be achieved in New Zealand given the local technological 'know how' and readily available material resources that already exist.

1.2 Defining the carbon constraints associated with buildings

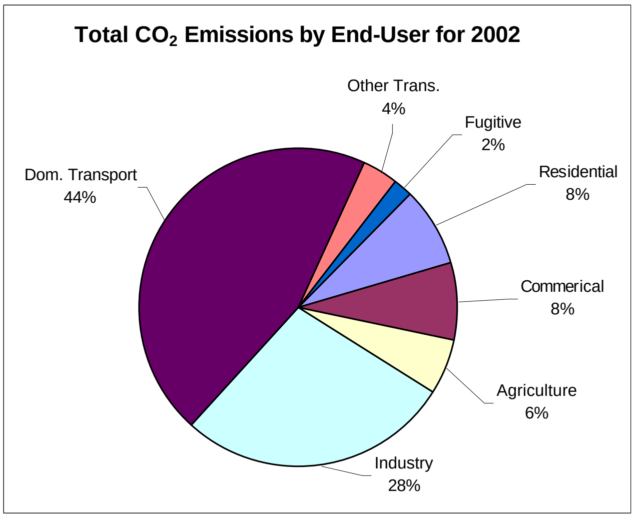

Figure 1: Total CO_2 emissions in New Zealand by end-user for 2002 (from O'Connell and Pollard 2003)

Globally, buildings consume at least 40% of the world's energy and account for one-third of carbon dioxide (CO_2) emissions from the burning of fossil fuels (Roodman and

Lessen 1995). The primary contribution of the building stock to climate change is through the emission of greenhouse gases (GHGs) via operational energy, (primarily the day-to-day usage of space heating and water heating appliances) and embodied energy (carbon generated by energy sources required to produce raw materials and fittings for buildings).

Carbon dioxide is the most important GHG in relation to the building and construction industry. Figure 1 indicates that residential and commercial building CO_2 emissions account for ca.17% of the nation's CO_2 emissions. It is more difficult to quantify industrial CO_2 emissions (from production of steel, concrete, etc). However, these are estimated to be 8% (MED 2003).

Achieving the lowest obtainable target GHG stabilisation level (450 ppm CO_2) set by the Intergovernmental Panel on Climate Change (IPCC) would not result in stabilisation of the atmosphere until well into the 22nd century, requiring as a result that all new buildings in industrialised countries achieve close to zero carbon emissions within half a century (Lowe 2000). Achieving this end will represent no mean feat for the building industry and dwelling occupiers.

To reduce the impacts of climate change, there is a need to reduce global CO_2 emissions by at least 60% by 2050 and 80% by 2100 (Lowe 2000, BSHF 2002). From a United Kingdom perspective it has been argued that all new buildings in industrialised countries will need to achieve close to zero carbon emissions within 50 years (Lowe 2000) to meet the 80% reduction target (building stock average). New Zealand will also need to play its part on the world stage to achieve such levels and in many ways is favourably placed given that a significant proportion of its energy needs come from renewable sources (primarily hydro).

1.3 The impacts of climate change on buildings

Climate change has the potential to exacerbate the demand for and depletion of resources within our urban settlements. Climate change also impacts on all aspects of a community. For buildings it impacts on material choice, design, operation and other less tangible but nevertheless important aspects, such as health and safety and personal wealth.

Climate change impacts can be classed as either direct (physical) or indirect (non-physical). Lowe (2003) has defined the following classes of impact that climate change is expected to have on buildings:

- primary - temperatures, wind speeds, water tables, flooding, driving rain and other extreme climatic events
- secondary - range change of flora and fauna, migration of vector-borne infectious species and diseases
- tertiary - social, behavioural and institutional.

Current projections indicate New Zealand buildings will potentially suffer significant impacts this century (Camilleri 2001), the direct and indirect costs of which may be very high.

2. INITIATIVES FOR CONSTRAINING CARBON EMISSIONS

The primary means for reducing carbon emissions in the built environment are facilitated via government (Sections 2.1 - 2.6) and industry (Section 2.7) initiatives. The government's confirmed (2002) policy package on climate change deals directly or implicitly with mitigation of GHG emissions and stabilising the effects of climate change.

2.1 National Energy Efficiency and Conservation Strategy (NEECS)

The NEECS Building and Appliances action plan has a number of key work streams focused on the built environment. These include:

- information and education: 'components' (e.g. glazing optimisation, solar water heating) and 'whole building' (e.g. Home Energy Ratings Schemes (HERS) in Canterbury, and information gathering via the Household Energy End-use Programme (HEEP))
- standards: Components and design (e.g. better/best practice design standards/guides, amendments to NZBC Clause H1 – energy efficiency)
- implementation support: a raft of measures to improve the 70% of housing stock built before the first minimal insulation requirements, including residential grants and retrofitting
- research: e.g. the Health and Energy in Residential Buildings Research Project (a study to determine health impacts of poor energy efficiency).

2.2 New Zealand Transport Strategy (NZTS)

The role of transport in the built environment is significant and interwoven with many of the issues surrounding the construction of better buildings and communities. The government has made a clear commitment to reduce the impact of transport on climate change (NZTS 2002). No specific plan of action can be identified, as yet, that specifically targets the construction transport sector.

2.3 New Zealand Waste Strategy (NZWS)

A lot of construction and demolition wastes can be used or recycled, but the incentives to do so are low. The three core aims of the NZWS are to lower waste cost to society; reduce environmental damage from generation and disposal; and increase economic benefits from more optimal use of waste. A key target for the building industry is to achieve a 50% reduction in construction and demolition waste going to landfill by 2008.

2.4 Adaptation to climate change

The government's adaptation strategy is under development. Initial material to be released will include guidance material on coastal hazards and details of community case studies. Investigation into the adaptation of buildings to climate change, the synergy between adaptation and mitigation strategies, and understanding the importance of adaptation with regard to the building and construction industry is described elsewhere (O'Connell 2003, 2004).

BRANZ has a three-year project (2003 – 2006) underway investigating ‘an integrated response to climate change mitigation and adaptation for the built environment’ which is intended to complement material being prepared by the New Zealand Climate Change Office (NZCCO).

2.5 Kyoto Protocol ratification and national practicalities

Since New Zealand’s ratification of the Protocol in December 2002, attention has turned to practical aspects such as Negotiated Greenhouse Agreements (NGA) and Projects to Reduce Emissions (PRE). For example, of significance to the building industry is the PRE process which may provide potential openings for energy-intensive industries (cement, steel, aluminium, etc) to establish developments such as wind turbine farms to offset their carbon emissions.

An emissions charge per tonne of CO_2 equivalent will be introduced from 2007/8 for the General Energy Users group which includes dwelling occupiers (DPMC 2002). This ‘carbon tax’ will act as an additional driver to bring about industry change. However, for such a tax to work effectively, it would almost certainly need to be supplemented by a regulatory framework (Lowe 2000).

Internationally, the Clean Development Mechanism (CDM – a Kyoto flexible mechanism) is designed to create tradeable certified emission reductions (CER) that can help developed countries (e.g. New Zealand) meet their Kyoto GHG emission reduction targets while assisting a developing country to meet its sustainability objectives.

For example, a New Zealand building and construction company could supply a product or technology (e.g. a low-carbon house) to a south east Asian nation (where good trade links already exist). The New Zealand government would get its investment back in the form of CER; and the host country would have sustainable housing that reduces demand on non-renewable energy sources.

2.6 Amendment to building regulations

The New Zealand Building Code (NZBC) currently enforces minimum standards, promotes a ‘lowest-cost’ mentality in both homeowners and the industry and generally does not promote or facilitate sustainable housing (Benge 2002).

There has been a drive for inclusion of sustainable development principles in the Building Act Review process. The current draft of the Bill proposes revisions to the Building Act that include:

- ensuring that, ‘*Buildings are constructed and used in ways that promote sustainable development*’
- requiring the chief executive of the regulatory agency to take into account: ‘*the costs of a building (including maintenance) over the whole of its life*’
- ‘*the need to facilitate the efficient use of energy and energy conservation and the use of renewable sources of energy in buildings*’
- ‘*the need to facilitate the efficient use of water and water conservation in buildings*’.

The report of the government Select Committee on the Bill was due to be promulgated to Parliament by May 2004 but is now delayed until June/July. Even if the revisions become embedded in law, it is unlikely that changes will be made to the NZBC until 2008 at the earliest; and any positive outcomes of the code's revision and implementation may not be discernable until about 2010.

2.7 Industry - built environment policy

A 'National Policy on the Built Environment' was drafted by the New Zealand Institute of Architects in 2000, endorsed by the Construction Industry Council (CIC) and submitted to the government in 2002. This policy includes:

- an integrated coordinated approach to achieving environmental, social and economic underpinnings of sustainability
- strategic, government-led, direction for urban change and development
- a framework within which the building professions, academia and other organisations can effectively focus their efforts
- leverage for high-quality design and research into the built environment, driven by industry consortia and organisations such as the Design Taskforce.

A formal built environment policy has yet to emerge. However, the importance of achieving good urban design is a key action identified through the 'sustainable cities' stream of the government's Sustainable Development Programme of Action (DPMC 2003). This action, the Urban Design Protocol (UDP), is seen as a way of promoting discussion and achieving agreement at a national level about ways to improve the urban design of our cities and towns.

The finalised UDP (a draft is due by July 2004 for formal comment) will seek commitment from all levels of government, professional groups and other key stakeholders.

3. CHALLENGES IN CONSTRUCTING LOW-CARBON BUILDINGS

Approximately 900,000 houses were built in New Zealand before 1977 when building standards did not require insulation. Of these, approximately 600,000 are either not insulated or inadequately insulated, and central heating systems are rare. Older housing tends to be damp and cold - conditions that have been strongly linked to health problems for the occupants (PHAC 2003). Many older houses in New Zealand have been poorly insulated and average temperatures are often well below World Health Organisation (WHO) recommended minimums of 16°C (for health) and 18°C (for comfort) (BRANZ 2003).

3.1 Key barriers and obstacles

The level of knowledge of climate change issues within the building and construction industry is not high (Saville-Smith 2000). Additionally, the Kyoto Protocol is still perceived by many in business as a fiscal liability. Therefore, ways need to be found to achieve sustainable structural change (in the industry) appropriate to New Zealand's level of technological, ecological, financial and political capacity (Reisinger 2003).

Sustainability issues have long been viewed as of no concern to the construction industry, that construction is simply progress. BRANZ has recently sought to correct this view by starting to raise awareness of key sustainability issues - sustainable design, energy use, water use, and waste. In a recent nationwide seminar series (called *The Green Payback*, March/April 2004), it was demonstrated to the industry that cash savings can be made, and a market advantage can be gained by considering issues that concern clients/customers and which confront economies worldwide.

Development of low-carbon housing (and buildings in general) faces many other hurdles (some substantial) to progress, including:

- consumer attitude – e.g. GHGs are an inevitable by-product of high living standards (Reisinger 2003)
- lifestyle choice – demand for larger houses (consequent increase in resource intensity and embodied GHGs)
- reducing energy and other resource demand and delivering a building performance that can meet government climate change policy targets
- silo thinking and lack of integration by industry specialists (resulting in poorly designed, sited and constructed buildings)
- skill base in the building industry has declined (Hunn et al 2002)vested interests in retaining, and lack of willingness to change, 'business as usual' industry practices, i.e. Kyoto solutions perceived to stifle capital growth
- barriers to renewable energy sources (though this is improving)
- availability of increasingly cheaper and more energy efficient appliances (using *more* energy *more* efficiently), therefore raising carbon emissions.

Examples of prototype and production low-carbon buildings do exist, primarily in Europe and North America. Some also exist in New Zealand. These buildings represent current, or close to current, international best practice, though some are not necessarily cost-effective in these regions and are likely not to be under existing New Zealand market conditions.

Progress can be made but will require a will by the government, the industry and consumers working together to collectively come together to change current mindset and practices.

4. OPPORTUNITIES AND BENEFITS

Low-energy buildings are technologically feasible. It has been estimated that by making a combination of relatively modest 'fabric' changes (insulation, solar heating, etc) and reducing carbon intensity of energy supply to households, a reduction of up to 75% in carbon emissions could be achieved using available technology (Lowe 2000). However, the construction industry in the developed world has, until now, been unable to deliver anywhere near such levels of performance.

4.1 Low-carbon buildings in practice – moving from fringe to mainstream construction

Lowe (2000) has documented best-case low-carbon studies for categories of buildings (both domestic and non-domestic):

- prototype (effectively new stock) – where energy usage is three to 10 times lower compared with the stock average (e.g., the Passiv Haus in Darmstadt, Germany)
- retrofitted buildings – where a 50% reduction in energy usage compared with class average has been achieved (e.g. Kranichstein, Germany and Southwell, UK)
- achieving of negative net carbon emissions – exceptional cases such as the Rocky Mountain Institute's Colorado headquarters.

The financial benefits of sustainable buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operational and maintenance costs, improved health through thoughtful selection of non- or less toxic materials, improved ventilation and savings from increased productivity and health (Goldstein and Rosenblum 2003, Kats et al 2003).

Although the environmental and human health benefits of green building have been widely recognised, these authors confirm that minimal increases in upfront costs of about 2% to support green design would, on average, result in life cycle savings of 20% of total construction costs – more than 10 times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of $1 million in today's dollars over the building's lifetime.

The transition from sustainable or 'green' building as a fringe activity to a mainstream activity is, by and large, proving hard to 'sell' and diffuse into the housing market as the new building standard (Lowe 2000, Vale and Vale 2003). However, there is no reason in theory, then, why such buildings cannot now be constructed in New Zealand.

4.1.1 Domestic sector

It has been recently demonstrated that sustainable housing projects can be affordable and financially viable while at the same time provide significant improvements in comfort and health to the occupants (Goldstein and Rosenblum 2003). Case studies indicate that it is possible to design, construct and operate sustainable, affordable housing at close to, and in some cases below, conventional development costs (Goldstein and Rosenblum et al 2003).

Though not yet commonplace in the domestic sector, successful outcomes are being realised in New Zealand, such as the Earthsong Eco-Neighbourhood in the Auckland region and the Aranui Community Renewal Program in Christchurch. In the latter, consensus on the form and detail of this new state housing development was reached by technical experts, regulators and the community before construction (Hargreaves 2003).

4.1.2 Commercial sector

The integration of sustainable or 'green' building practices into the construction of commercial buildings has been demonstrated to be a solid financial investment (Kats et al 2003). Research also demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. Although it is not straightforward to evaluate all benefits specifically (aside from energy, water and waste savings), the benefits to aspects such as health and productivity are significant and not zero (Kats et al 2003, Howden-Chapman et al 2004).

The 'greening' (retrofitting or new construction) of commercial or non-domestic buildings is at an early stage in New Zealand. Very few examples exist but they include retrofitted and new buildings on the Waitakere Hospital site, the new South Christchurch Library and Service Centre and Environment Canterbury's Emergency Operations Centre for Civil Defence (Hargreaves 2003).

4.2 Adaptation co-benefits

The inclusion of adaptive measures can also help serve carbon-reducing (mitigation) measures for buildings. These could include:

- where buildings are identified as being at risk from marine inundation, coastal or inland flooding, raise structures or in extreme cases, consider relocation
- adopt natural cooling design strategies for predicted increase in summer overheating, such as optimum orientation and external shading
- awareness campaigns to reduce cooling and/or heating demand, such as the NZCCO's '4 Million Careful Owners' campaign (http://www.4million.org.nz)
- promotion and use of co-generation technology for domestic applications (e.g. the WhisperGen developed in Christchurch) to reduce dependency on the main grid
- reduction of the 'heat island' effect and demand for active cooling (air-conditioning) in urban areas through introduction of green roofs (and walls – maintained by recycled rain/grey water), highly solar-reflective surfaces and extensive planting of trees
- altering current urban development patterns (i.e. urban sprawl) to alternatives such as high-density and mixed uses in urban areas resulting in reduced embodied infrastructure emissions, and construction and commuting transport emissions
- using regulation (e.g. via proposed amendment to Building Act and NZBC) to improve operating energy performance of new and existing buildings
- provide training and guidance for the industry on better building envelope design.

Many of the measures listed above will assist meeting the targets and objectives of the government's mitigation and proposed adaptation climate change strategies. Adaptation strategies undertaken early in the cycle, i.e. at building planning and design stage, will future-proof the building and be more effective in the longer term (Graves and Phillipson, in Lowe 2001).

The capital cost of taking adaptive measures will be slightly higher initially but will be much lower than having to retrofit at a later stage (Graves and Phillipson, in Lowe

2001). It has also been argued that adaptation measures hold more immediate appeal to the public and that the adaptation potential of a synergistic approach should be strongly emphasised (Lowe 2003).

4.3 Environmental and health co-benefits

4.3.1 Improvement of air quality

The emission of GHGs and air contaminants is often closely connected, especially from combustion sources. With the Ministry for the Environment's intent to implement air quality standards, there will be ramifications for the building and construction industry in terms of non-compliance with resource consent conditions and the geographic location of industrial plants. Considerable effort will also need to be put into convincing householders of the benefits of switching to making long-term choices both in terms of thermal comfort (to or above WHO recommended levels) and achieving financial pay-back on their investment in sustainable technology/design in a dwelling.

4.3.2 Health

The number of days with uncomfortable outdoor temperatures (> 25 ºC) in some urban centres is expected to increase markedly (Camilleri 2000). Improved building envelope design (and less reliance on air conditioning) will prevent summer overheating and largely eliminate the prevalent damp and cold conditions associated with many New Zealand houses. As a result, there will be a decrease in respiratory conditions, particularly in vulnerable groups, and a marked improvement in indoor air quality. Ambient air quality will also improve as the contribution from domestic sources is decreased, especially in cities and towns where wintertime urban air-shed contamination is an issue.

5. THE NOW HOME PROJECT

New Zealanders prefer living in airy, well-lit homes that offer privacy and security as well as good access to the outdoors. Home owners want their homes to be warm and cosy in winter but cool and open in summer. They also like homes that reflect some 'Kiwi' heritage, but also value being a bit different from everybody else. Because New Zealanders have historically 'made do', they also aspire to a house that is affordable.

By and large the building industry is aware of these aspirations and do, within the limitations of clients' budgets, deliver homes that are as close as possible to the ideal. However, taking advantage of some simple design principles is often not done at the critical point in the building process. As a result, this costs twice – once when building the house, and again when the occupants are living in it (see Figure 2).

Data available from studies such as the Household Energy End-use Project (BRANZ 2003) and findings from Wellington School of Medicine linking health and housing (Howden-Chapman et al 2004) underline the fact that New Zealand homes are often colder than recommended temperatures. Further, many homes are excessively damp, leading to respiratory ailments, especially among children and the elderly; and many homes use more energy than they should, both in construction and in operation.

In recognising home – owner aspirations and the evidence described above, a consortium comprising BRANZ, Fletcher Building, Forest Research, and Waitakere City Council is working to establish and demonstrate what can be achieved in a sustainable house. Technical experts from each organisation have spent much of the last year refining design specifications for a home that meets the aspirations above, incurs a build cost comparable with ‘mainstream’ homes and lower running costs.

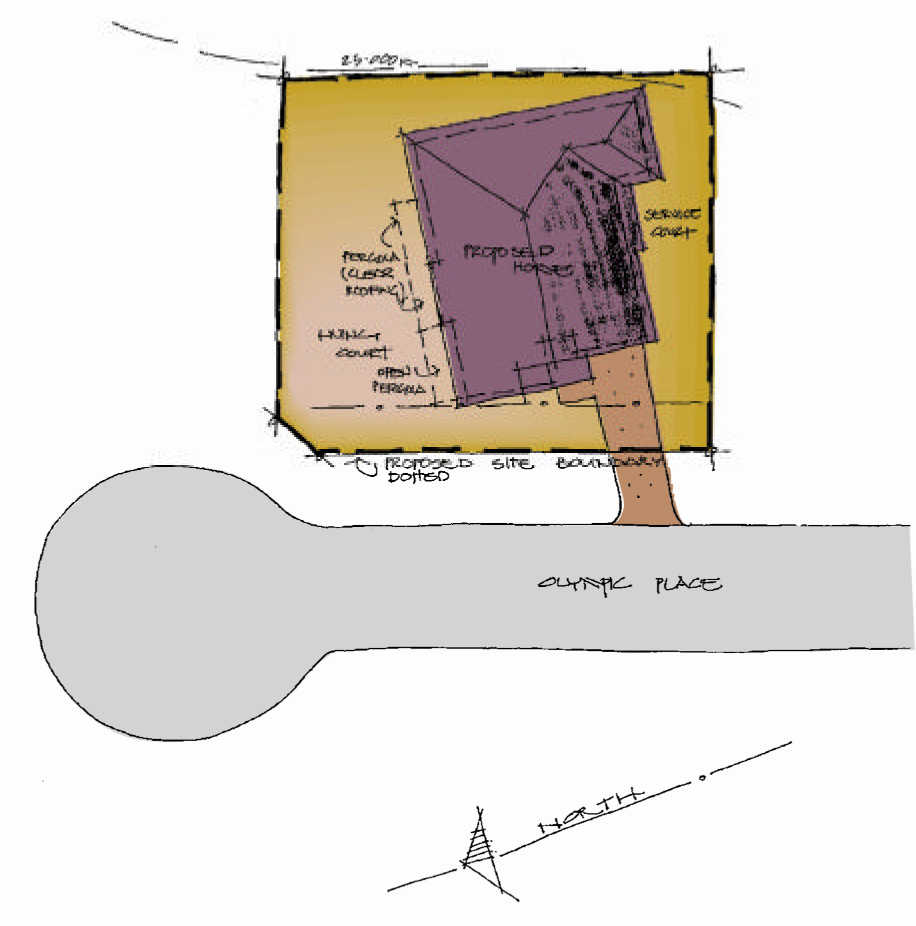

Figure 2: NOW Home, aligned to the sun, not the property lines (image courtesy of Paul Minett)

Working out how to design a ‘mainstream’ home that meets sustainability criteria has shown how much work still needs to be done, despite many technical solutions being available. The issues surrounding the delivery of housing that also meets personal needs of happiness and comfort are not yet fully understood and will be the subject of ongoing work.

5.1 The NOW Home

The first home to be built using the design methodology described above is the NOW Home at Olympic Place in Waitakere City (http://www.nowhome.co.nz). The name is derived from its purpose – to demonstrate what can be done NOW to provide a warm, healthy, attractive home that is affordable to build while substantially less costly to run using tried and true materials, smart design and crucially, understanding where the tradeoffs can be made.

The NOW Home design protocol may well become a benchmark for affordable 'best practice' home construction in New Zealand for the foreseeable future. It will form a practical step towards government strategies for National Energy Efficiency and Conservation (NEECS), zero waste, sustainable energy and other projects, and also make a very good reference point for meeting the sustainability requirements of the building code.

The NOW Home is the first stage of a more involved project. There are some 1.2 million homes in New Zealand, 900,000 of which were built before insulation became mandatory and when water shortages were unusual even in the driest of summers. Those homes are part of the country's heritage, but unless they can be adapted to meet the needs of future generations (e.g. to provide long-term resilience against the impacts of climate change) they will become a liability both to the country and those living in them.

6. CONCLUSIONS

Buildings account for one-third of the planet's CO_2 emissions and as a consequence are a key contributor to human-induced climate change. The policy response requires a reduction in carbon emissions from industrialised countries in the order of 60% by 2050. Achieving such reductions in carbon emissions from the built environment will require that emissions from new buildings be reduced by ca. 80%. The technology exists to undertake this magnitude of reduction, however, it remains to date largely unimplemented.

Improvements to New Zealand's housing stock will have a measurable effect on reducing GHG emissions from the industry and contribute towards New Zealand meeting its Kyoto Protocol and national objectives. However, a number of industrial and societal barriers, lack of awareness of sustainability and environmental issues, and a reluctance to grasp business opportunities that undoubtedly exist, stand in the way of progress towards a low-carbon building future.

Such obstacles are gradually being removed, assisted by the government's commitment to sustainability, development of initiatives such as the Urban Design Protocol, and mechanisms contained in the government's confirmed climate change policy package. These strategic and practical measures will assist the transition of New Zealand buildings, widely recognised to be sub-standard in terms of health and comfort, to perform at the same levels as above-standard building stock of the future. This process will enable New Zealand to meet national and international goals, and achieve equitable social, environmental and economic outcomes.

Most New Zealand houses are anything but 'low-carbon' and very few have sustainable features. They are, in general, poorly insulated, or un-insulated, and many are expected to be thermally uncomfortable to live in. The building industry consortium shareholders for the NOW Home are practically and strategically positioned to increase the momentum toward the mainstream construction of low-carbon dwellings.

New Zealanders have a history of being innovative in the building industry and the consortium's NOW Home is strongly innovative. When backed by strong and focused government strategies, and the uptake of practical approaches at industry and individual level, to combat climate change, the result will be that New Zealand has a first-rate, low-carbon building stock within a sustainable built environment.

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