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New Directions for Housing Research Due to Climate Change in New Zealand

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Abstract. Research concerned with energy and housing in NZ has focussed on the cost-effectiveness of maintaining warmth. Studies have concentrated on heat loss from houses and the efficiency of heating systems. One of the consequences of this has been Government subsidies for insulation and heat pump installations to reduce energy consumption in winter months. This has led to a significant growth in the heat pump market.

Research is indicating that these devices are not significantly decreasing the demand for electricity in the winter. Of greater concern is that there is an increase in demand for electricity for cooling purposes which introduces a new and significant electrical load in the summer. This paper will outline the research currently being undertaken on the long-term impact of both climate change and energy depletion and the consequences for Building Code standards and 'sustainability' rating tools for housing.

In New Zealand there has been a general shift in peak electrical demand from winter towards summer which has increased the risk of inadequate supplies in summer months. Climate change will not only alter the seasonal demand for electricity it will also impact on seasonal supply. About 50% of the water used for hydro electricity generation comes from glacial melt-water during the summer. The glaciers are now retreating due to climate change and it has been estimated that most glaciers will have melted by about 2040. NZ will not only experience 'peak oil' and 'peak gas' but also 'peak hydro'. This will significantly increase the cost of electricity and the risk of interrupted supplies.

The paper concludes that consideration should be given to subsidising long-lasting improvements to the fabric of houses rather than subsidising short-lived equipment such as heat pumps. Rating tools for the 'sustainability' of new and refurbished housing should also address

this problem and actively discourage equipment that results, not only in increased electricity consumption, but also does not allow the human body the ability to adapt over time to the predicted increased average temperatures in New Zealand.

Introduction

Housing research in the area of environmental sustainability in New Zealand has focussed on the efficient provision of warmth within houses. This has resulted in Building Codes, sustainability rating tools and Government grants that favour the installation of heat pumps.

One important aspect of climate change is the predicted increase in average temperatures across New Zealand. This will reduce the heat loss from houses and has the benefit of reducing electricity demand and problems associated with healthy housing in the winter. However, it increases the risk of overheating and use of electricity by heat pumps for cooling during the summer months.

Surveys (Buckett, 2007) carried out on heat pumps in housing have shown not only a dramatic increase in ownership but also an increasing trend to use of them for summer cooling rather than winter heating. The extent and duration of the use of heat pumps could further increase due to the phenomenon of 'take back'. For example, once one room is cooled, the other rooms are perceived as hotter with a result that additional heat pumps are installed.

The installed capacity of the heat pumps is rising at approximately 200MW per year; a significant new demand on the national grid (French Isaacs Camilleri, 2008). For example, the magnitude of this electrical load can be compared with New Zealand's total installed geothermal generation capacity of 700MW (New Zealand Energy Quarterly 2010). When combined with the predicted increase in electric vehicles (Smith 2009) as well as the increased demand on air-conditioning in the commercial building sector, this new demand could threaten not only the capacity of the grid system but the ability to provide an adequate seasonal electrical supply.

Not only is the demand for electricity increasing but climate change will also significantly affect supply. About one half of the water for hydro-electric generation is produced by melt-water from snow and glaciers. Climate change is causing both less snow and glacial retreat thereby reducing the storage capacity of water and the possibility of glaciers disappearing by the middle of this century (World Glacier Monitoring Service).

The combination of both an increase in demand for electricity during the summer, due to heat pumps, and also a decrease in electricity supply, due to the demise of melt-water, significantly increases the risk of an interrupted supply of electricity in summer months. Under these circumstances, heat pumps are rendered useless, and poorly designed houses will overheat.

With a mechanical cooling system as the principle means of cooling a house, there is little incentive to design or retrofit passive means of cooling such as external shading devices, fenestration that allows good cross-ventilation or thermal mass. A house designed to rely only on heat pumps to keep it cool is not easily or economically adapted to be passively cooled.

The paper will argue that the energy efficiency benefits of heat pumps for winter heating will be outweighed by the use for summer cooling and that Government grants for heat pumps may be counterproductive in the longer term. If grants are available they may be better implemented in

promoting enduring means of passive cooling in houses rather than short-lived mechanical devices.

It will also be argued that human physiology can adapt to the predicted warmer climate in New Zealand without recourse to mechanical cooling. Improved passive design, or retrofitting, to houses combined with human adaptation will result in more resilient buildings, lower energy demands and lower household energy costs.

The focus on heating demand in houses

Historically, the issue of energy and housing in NZ has been concerned with the costs effectiveness of maintaining warmth and this is reflected in the New Zealand Building Code (H1) that regulates minimum insulation standards for housing in order to reduce heat loss through the fabric of the house and thereby reduce national energy demand (NZS 4218).

Heat loss is also the focus of voluntary rating tools that are in the process of being introduced (Easton, 2010). The survey carried out indicated that improved insulation to the building envelope and the installation of a heat pumps were the two most popular intended renovations. Interestingly, there was a significantly greater motivation for improved comfort standards rather than energy savings, with almost twice as many people in the survey considering comfort to be important than energy savings.

Research in this field, for example (Burgess et al, 2010a, Page & et al, 2010b), has focussed on heat loss from houses and the efficiency of heating systems. Not only is the thermal performance of the building fabric an issue but so also is the efficiency of the heating system and a high priority has been given to reducing the use of electric resistant heaters. The heat pump has been the preferred alternative to the resistant heater due to its intrinsic greater efficiency. The potential reduction in electricity consumption due to a combination of improved insulation standards and heat pumps is such that these remedial measures are now subsidised by the Government (EECA, 2010).

The shift to a cooling demand

The focus of research, building codes and rating tools on heat loss and consequent energy consumption by houses has eclipsed the consequences that the remedial measures may have as the climate change continues to increase average temperatures. At a simplistic level, warmer average temperatures result in reduced heat loss and consequent energy savings. For example, research in the UK (Lomas, 2010) has indicated that for every 1°C average warming, the national energy consumption by housing will decrease by about 6%.

In NZ the average increase in temperatures will also have the benefit of reducing space heating demand and other consequential benefits such as healthier homes due to the reduced risk of surface condensation and mould (Byrd 1985). However, it has the disadvantage of introducing a cooling load that has been introduced by default through the mass installation of heat pumps. This new cooling load has the potential to be far greater than any reduction in the heating load.

The potential problem of the overheating of houses has previously been identified (O'Connell & Hargreaves 2004) in their analysis of the impact of climate change on the NZ building stock. However, this analysis was made before any significant realisation of the full extent that the heat pump market could have on NZ homes and the subsequent effect on national energy

consumption. The report identified a need to consider passive means of cooling by such means as solar protection, thermal mass and natural ventilation.

Climate change, in particular predicted increases in average temperatures, will have an impact on comfort within houses. In zone 1 (NZS 4218) the 'cooling degree-days' have been increasing at a steady 0.5 degree days per year over the last half century (NIWA, 2008). Heating degree days have been reducing slightly faster. Zone 1 is heading towards a net cooling load with consequent increases in electrical demand in summer months if mechanical means of cooling are implemented.

A combination of strategic marketing by the heat pump industry combined with Government grants has resulted in a very significant increase in sales of heat pumps (French Isaacs Camilleri, 2008). The emphasis on the promotion of this product has been on efficient heating and its success has resulted in the installed capacity of the equipment growing at the rate of approximately 200 MW per year. Over a 5 to 6 year period the installed capacity of heat pumps will be equivalent the total output capacity of all the hydro power stations along the Waikato River.

The increased use of heat pumps

The intention of displacing resistant heating by heat pumps appears not as successful as intended. Research has indicated (French Isaacs Camilleri, 2008) that these devices are tending to displace non-electric heating, rather than the electric heating as intended, thereby potentially increasing the demand for electricity in the winter. Not only is this counterproductive for winter time energy use but it was also found that many households, almost 2/3rds of the sample surveyed, are using their heat pumps for cooling as well as heating thereby introducing a new demand for electricity in the summer that did not previously exist.

A similar result was obtained by other research (Doody & Becker 2010) on a sample of houses across New Zealand. It was found that heat pumps were used predominantly outside the winter heating season. Approximately 70% of respondents used heat pumps outside the winter period. Equally revealing was that, for those who did not already own a heat pump, nearly 80% of them were considering installing a heat pump.

The combination of this potential increase in ownership of this equipment along with the predominant use of heat pumps in the summer has introduced a dramatic new electrical load on the New Zealand electricity grid that comes during the higher risk period when hydro lakes and rivers are at their lowest. Research at BRANZ has estimated this increase in electrical load in summer months over the next three decades (Page, 2009). While there are many assumptions in calculating future electricity loads, the model indicated a tenfold increase in the Auckland area, due largely to population growth, and approximately a threefold increase in other cities.

However, this increased electrical demand for the 'base case' did not take account of climate change or the impact of 'take back'. It was estimated that if climate change caused average increased temperatures of 1°C then the electricity consumption would increase by 30%. The model also assumed one heat pump in an open-plan living area. When adjusted to allow for bedroom cooling as well (take back), the energy consumption increased by between 180 to 250%. Since the effect of climate change and take back are accumulative, the potential increase in energy for summer cooling could be 200 to 300% more than the base case. This is illustrated in Figure 1.

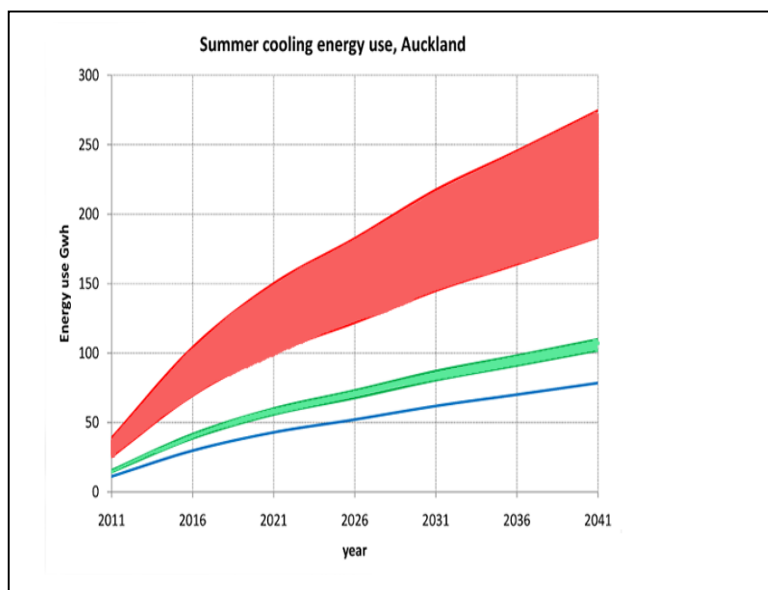
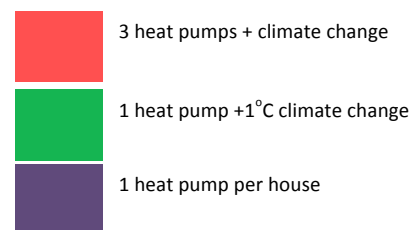


Figure 1.

Predicted electrical energy required for cooling use in Auckland houses.

Data derived from Page (2009)



The effect of ‘take-back’ in New Zealand homes is discussed in more detail in research concerned with drivers of demand for heat carried out at Otago University (Howden-Chapman et al, 2009). Apart from the increased use of heat pumps in the summer and extent of use throughout a house, there is also likely be an increased duration of use. There is increasing evidence for all measures of energy efficiency intervention in housing that the predicted savings are generally greater than actual savings (Lomas 2010). For example, increased insulation standards of buildings in UK has resulted in an increase in energy consumption, rather than a decrease, as occupants tend to heat more rooms in their house, to a higher temperature and for a longer duration.

The same can be applied to cooling. Once one room is cooled, the other rooms are perceived as hotter with a result that additional heat pumps are installed. The market growth in home entertainment systems has also resulted in increased energy use not only due to the equipment but also longer periods of time spent indoors requiring either additional heating or cooling or both.

The addictiveness of cooling

Previous research (Nicol, Rudge & Kovats, 2005) has identified that thermal comfort conditions are not related to absolute temperatures but to prevailing external temperatures. Comfort inside a building is related to outside temperatures. It also demonstrated that occupants of air-conditioned buildings have less tolerance towards adapting to warmer temperatures. Once they have adapted to constant and cooler temperatures they have less tolerance to fluctuating or warmer temperatures. This has significant consequences for energy demand since occupants rely on the air-conditioning system to maintain a narrow band of comfort rather than adapting by either behavioural or physiological means.

More recent research (Candido et al 2010) has taken this issue further and suggested that cooling is “addictive”. The work showed that people’s ‘thermal history’ dictates their preference for temperatures and building types. Buildings without air-conditioning are actively disliked by

those accustomed to air-conditioning. This can be taken further as air-conditioning in cars, that are used frequently, will also have an impact on the addiction to a static thermal environment.

Other research (Tuohy et al 2010) has shown the extent to which energy consumption by air-conditioning can be reduced if cooling set points allow for both adaptation and outdoor air temperatures. By allowing adaptation, energy consumption in office environments was predicted to halve. The converse is that unless allowance is made for thermal adaptation, the potential to reduce energy consumption in buildings will be lost.

The implication of this on domestic heat pumps is that an air-conditioned work environment will create an expectation of a static temperature in the home environment. The choice to purchase a heat pump, its temperature settings, duration of use and coverage within a house are part of a larger shift towards cooling in our enclosed environments of a car, workplace or home.

Assumptions in heat pump efficiency

The research (Page, 2009) also made the assumption that the coefficient of the performance (COP) of heat pumps would increase to a value of between 4.2 and 5 by the year 2041 from an average COP of 3 at present. Heat pump performance is very sensitive to system design and installation and a recent field trial (Energy Savings Trust, 2010) in the UK showed that, although manufacturers were claiming a COP of about 3, the average measured (excluding estimated) performance for the field trial was less than 2. If these results were replicated in New Zealand it would increase the predicted energy consumption by almost one-third. The implication of this is that the energy used for cooling New Zealand homes, taking account of climate change, take-back and system performance, could exceed the energy demand for heating in the future.

Future competition for electricity

In New Zealand there has been a general shift in peak electrical demand from winter to summer. With about 60% of the country's electrical supply from hydro, this increases the risk of inadequate electrical supplies and brown outs in summer months.

This shift will be further accentuated by the predicted exponential increase in electric cars in the next two decades. The electric vehicle industry (Smith, 2009) view the night-time production of electricity from wind power as an obvious alternative energy source to oil-derived fuels and, since transport currently consumes almost half the total energy supply in New Zealand, electric vehicles will have the potential to consume not only all the electricity produced by wind power but also a significant amount produced by hydro. If this were the case, it would leave little residual energy for buildings.

Not only is there a trend in the use of heat pumps in housing but also the design of new commercial buildings is resulting in increased demand and dependence on air-conditioning. There is an emerging pattern amongst 'green' rated buildings to have a high proportion of glazing that is inadequately protected from the sun and fenestration that is sealed thereby negating the use of natural ventilation (Byrd 2010).

Climate change is also likely to result in competition for water. The predicted decrease in rainfall across most of the crop producing areas of NZ (NIWA 2008) is likely to increase the demand for agricultural irrigation and thereby reduce the amount of water available for hydro generation.(New Zealand Business Council for Sustainable Development, 2008)

The impact of climate change on electricity production

Apart from ‘peak oil’ and ‘peak gas’, New Zealand also faces ‘peak hydro’. The hydro industry has long formed the backbone of New Zealand’s successful power sector. It has provided a relatively constant 60% of total electricity production since the 1930s and enabled the country to enjoy some of the lowest power tariffs in the world.

One of the biggest problems with New Zealand’s existing hydro schemes is the lack of water storage capacity. New Zealand’s hydro schemes do not benefit from large reservoir capacity and most have just several months’ worth of storage (Waterpower, 2006). They are therefore more vulnerable to annual or even seasonal fluctuations in precipitation and snow melt.

More significantly, NZ’s glaciers are also retreating. The glacier’s melt water produces about 50% of the water for hydro power (Fitzharris, 1989). While the glaciers retreat this may increase melt water for a short period. However, it has been estimated by the World Glacier Monitoring Service (World Glacier Monitoring Service, 2009) that most glaciers will have melted by about 2040. This will reduce the ability of the hydroelectric power sector to provide an unfluctuating supply of electricity and could result in significant seasonal reduction in future supplies (Hay & Elliott 2008).

Other renewable resources for generating electricity supply could be exploited to compensate for this loss. For example, wind power could increase from the current 3% up to around 15% of New Zealand’s electricity needs (Electricity Authority, 2010). The country’s move towards more renewable energy within the supply mix was set out in the New Zealand Energy Strategy to 2050 (New Zealand Government, 2007). The scope for additional renewable energy sources from wind, geothermal and solar were discussed and an estimated maximum of 90% electricity from renewables set on the basis that it was uneconomical to achieve a higher percentage due to the nature of these intermittent and weather dependent resources.

Interrupted electricity supplies

Climate change in NZ brings with it a double problem. On the one hand, increased temperatures will result in people wanting to use heat pumps more frequently in order to cool down. On the other hand there will be less electricity produced to run heat pumps which will have an impact on electricity pricing and the possibility of further increased costs by tariffs imposed at times of peak electrical demand which may occur at times of peak temperatures in the future.

Blackouts and brownouts due to inadequate water supply for hydro power stations have been experienced in NZ previously. The future increased demand for electricity by residential heat pumps, air-conditioning in commercial buildings and electric vehicles combined with reduced supply of electricity due to reductions in average rainfall and reduced melt water will significantly increase the risk of supply not matching demand and could result in long periods of seasonal electricity rationing.

Under these circumstances, heat pumps are rendered useless and other methods of adaptation to a hotter climate will be required. The remaining options are to improve the fabric of buildings and to allow for human physiological adaptation to increased temperatures.

Discussion

While the intention of subsidising heat pumps is to reduce energy demand, it is likely to have done the opposite. The subsidy has helped promote the heat pump industry that has in turn marketed the product aggressively. As a result there has been a rapid increase in the purchase of the equipment and, for those who have not purchased, it remains a high priority. It appears that it may not be significantly displacing electric resistant heating in the winter and is certainly creating a new demand for electricity in the summer that could potentially exceed the winter energy demand.

As average temperatures increase due to climate change, the energy consumption due to cooling is likely to increase exponentially. Cooling is addictive in a hot climate and what may start as cooling in one room rapidly leads to whole-house cooling. Once adapted to cooling, the human body will lose its tolerance to the external heat and occupants tend to remain cocooned. Apart from extending the length of the cooling period, a further consequence of this is the increased use of home entertainment systems that are becoming a predominant aspect of domestic energy consumption.

An argument for promoting heat pumps is the concept of 'healthy homes'. The relationship between health and home is principally concerned with house temperature and humidity. Cold surface temperatures, due to inadequate heating and poor insulation, combined with high humidities, due to high occupancy levels and lifestyle, result in surface condensation and mould growth. Airborne mould spores are a major cause of respiration problems.

Heat pumps reduce this effect by dehumidifying a house and increasing temperatures. However, there is a risk that heat pumps may not fulfil this potential. Healthy homes issues are frequently related with socio-economic groups that are vulnerable to significant increases in electricity prices which will influence the affordability of running a heat pump. Furthermore, one of the benefits of increasing average temperatures due to climate change is that houses will generally be warmer. In a warmer climate, passive means of heating in the winter and cooling in the summer are not only more affordable but also result in improved internal air quality.

The efficient use of heat pumps also impacts on house design. To be energy efficient, a house that is cooled should be well insulated and have minimum air infiltration in both the summer and the winter. Ironically, the cost-effectiveness of double glazing increases with the use of a cooling system in the summer. With a cooling system installed, there is little incentive to subsequently install passive means of cooling such as external shading devices or fenestration that allows good cross-ventilation. A house designed to rely on heat pumps is not easily or economically adapted to a passively cooled house.

Climate change is a significant contributor to reduced melt-water and subsequently hydro electricity production in the summer. With increased competition for electricity, as other fuels deplete, there is a significant risk of electricity rationing in New Zealand. Buildings designed for air conditioning or heat pumps rely on an uninterrupted supply of electricity. Without it they become uncomfortable and even uninhabitable. In contrast, passively cooled buildings are resilient to these changes.

In view of this, it is suggested that subsidies are better aimed at passive measures of reducing energy consumption that are likely to last for many decades and have no operating costs rather than subsidies to equipment that may only last one decade and has high operating costs.

Subsidies and 'green' rating tools that either overtly or incidentally promote heat pumps may be counterproductive in the long-term.

Heat pumps provide an efficient way of electrically heating a house and offer the potential of energy savings in winter months. Further research is required on the increased use of the equipment due to climate change and the effect of take back during summer months. The research referred to above indicates the potential for heat pumps to increase summer energy demands by 200 to 300% and even more if system performance is not significantly improved. Energy that need not be consumed at all if houses are to be reasonably designed or retrofitted with passive means of cooling.

Conclusions

The current subsidy of heat pumps for domestic use is contributing to a shift in electrical demand from winter to summer. This, together with a predicted increase in electrical vehicles due to the impact of 'peak oil', will have a detrimental impact on electrical supplies in the future when there could be a high risk of a gap emerging between demand and supply.

While heat pumps have the potential to reduce electricity consumption for space heating, this requirement will gradually reduce with climate change. Heat pumps introduce a new electrical demand that may not be met in the future.

Consideration should be given to subsidising long-lasting improvements to building fabric, such as insulation, shading and thermal mass rather than subsidising short-lived equipment such as heat pumps with the ability to cool. Air-conditioning delays the ability of humans to adapt to a warmer climate. Adaptation will become inevitable as electricity production in NZ is likely to decline due to peak gas and hydro.

Rating tools for new and refurbished buildings should address this problem and actively discourage equipment that results in increased electricity consumption and reduces the ability of occupants to adapt to increased temperatures.

Building codes should be amended to require passive means of cooling and set targets to minimize solar heat gains rather than rely on heat pumps to reduce peak temperatures in buildings.

Reference list

- Buckett, N 2007, *National Impacts of the Widespread Adoption of Heat Pumps in New Zealand*, Report No. 169, BRANZ.
- Burgess, JC, Buckett, NR, Camilleri, MJT, Burrough, LJ & Pollard, AR 2010a, 'Papakowhai Retrofit Project-Improving the Thermal Envelope and Space Heating', in *SB10 Conference*, Wellington, New Zealand.
- Burgess, JC, Buckett, NR, Camilleri, MJT, Burrough, LJ, Pollard, AR & Hancock, PJ 2010b, 'Sustainable Renovations of 1970s New Zealand Homes', in *SB10 Conference*, Wellington, New Zealand.
- Byrd, RH 1985, 'Condensation in Terrace Housing: Causes and Cures', *Building Services Engineering Research and Technology*, vol. 6, no. 3, p. 109.
- Byrd, RH 2010, 'Architectural Science vs. Green Buildings: Issues for New Zealand', in *44th ANZAScA Conference 2010*, Unitec Institute of Technology, New Zealand.
- Candido, C, de Dear, R, Lamberts, R & Bittencourt, L 2010, 'Cooling Exposure in Hot Humid Climates: Are Occupants Addicted?', *Architectural Science Review*, vol. 53, no. 1, pp. 59-64.
- Doody, B & Becker, J 2010, 'Building People into Plans: Insights into Heating and Cooling New Zealand Homes', in *SB10 Conference*, Wellington, New Zealand.
- Easton, L & Saville Smith, K 2010, 'Homesmart Renovations-Testing Tools to Promote Sustainable Renovation', in *SB10 Conference*, Wellington, New Zealand.
- EECA 2010, *Warm up New Zealand: Heat Smart Programme*. Available from: <<http://www.energywise.govt.nz/funding-available/insulation-and-clean-heating>>. [Aug. 2010].
- Electricity Authority 2010, *Electricity in New Zealand*. Available from: <www.ea.govt.nz>. [Nov. 2010].
- Energy Savings Trust 2010, *Getting Warmer: A Field Trial of Heat Pumps*, Energy Savings Trust Publication, London. Available from: www.energysavingstrust.org.uk.
- Fitzharris, J & Hay, J 1989, 'Glaciers: Can They Weather the Storm of Climate Change?', in *15th New Zealand Geography Conference*, ed. R Welch, New Zealand Geographical Society, pp. 284-291.
- French, L, Isaacs, N & Camilleri, M 2008, 'Residential Heat Pumps in New Zealand', in *29th AIVC Conference*, Kyoto, Japan.
- Hay, J & Elliott, T 2008, 'New Zealand's Glaciers', in *Darkening Peaks: Glacier Retreat, Science, and Society*, eds. BS Orlove, E Wiegandt & BH Luckman, University of California Press.

- Howden-Chapman, P, Viggers, H, Chapman, R, O'Dea, D, Free, S & O'Sullivan, K 2009, 'Warm Homes: Drivers of the Demand for Heating in the Residential Sector in New Zealand', *Energy Policy*, vol. 37, no. 9, pp. 3387-3399.
- Lomas, K 2010, 'Carbon Reduction in Existing Buildings: A Transdisciplinary Approach', *Building Research & Information*, vol. 38, no. 1.
- New Zealand Business Council for Sustainable Development 2008, *A Best Use Solution for New Zealand's Water Problems*. Available from:
http://www.nzbcسد.org.nz/water/nzbcسد_water.pdf. [May 2011].
- New Zealand Energy Quarterly 2010, *March Quarter 2010*. Available from:
www.med.govt.nz/energy/nzeq/. [Aug. 2010].
- New Zealand Government 2007, *New Zealand Energy Strategy to 2050; Towards a Sustainable Low Emissions Energy System*. Available from:
<http://www.med.govt.nz/templates/MultipageDocumentTOC24480.aspx> [May 2011].
- Nicol, F, Rudge, J & Kovats, S 2005, 'Safe and Warm: Effect of Climate Change on Thermal Comfort and Health', in *Adapting Buildings and Cities for Climate Change*, ed. S Roaf, Elsevier, Amsterdam.
- NIWA 2008, *Climate Change Projections for New Zealand*. Available from:
<http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios>>. [Jul. 2010].
- O'Connell, M & Hargreaves, R 2004, *Climate Change Adaptation; Guidance on Adapting New Zealand's Built Environment for the Impacts of Climate Change*, Report No.130, BRANZ.
- Page, I 2009, *Regional Heat Pump Energy Loads*, Report No E528, BRANZ.
- Page, I & Ryan, V 2010, 'It Takes All Types-a Typology of New Zealand Housing Stock', in *SB10 Conference*, Wellington, New Zealand.
- Smith, B 2009, 'Electric Vehicles and Generation Development', in *The Impact of Electric Vehicles on the NZ Electricity System*, NZ Electricity Commission. Available from:
<http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/GPAs/presentations-29Feb08/electricvehicles.pdf>.
- Tait, A, Liley, B, Sansom, j & Henderson, R 2005, 'Finding New Zealand's Renewable Energy Resources', *Water & Atmosphere*, vol. 13, no. 4. Available from:
<http://edit.niwa.co.nz/news-and-publications/publications/all/wa/13-4/renewable>.
- Tuohy, P, Roaf, S, Nicol, F, Humphreys, M & Boerstra, A 2010, 'Twenty First Century Standards for Thermal Comfort: Fostering Low Carbon Building Design and Operation', *Architectural Science Review*, vol. 53, no. 1, pp. 78-86.

Waterpower 2006, 'International Water Power and Dam Construction (2006)', [Editorial],

Hydro in the Mix in New Zealand. Available from:

<http://www.waterpowermagazine.com/story.asp?sectionCode=166&storyCode>

=2039414

World Glacier Monitoring Service 2009, *Glacier Mass Balance Data 2008 & 2009*. Available

from: <www.wgms.ch/mbb/sum09.html>. [Jul. 2010].

