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**Title: Changing Architecture for a Changing Climate; Unsustainable Trends in New Zealand**

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**Abstract**:

To be sustainable, buildings should usefully last for many generations. This requires building designers to have some knowledge of the future climate and the resources available to maintain the operations, in particular the energy consumption, of buildings. The New Zealand climate is predicted to get hotter and an energy gap to emerge as fossil fuels deplete and seasonal hydroelectricity production declines due to the retreat of glaciers. The historical peak demand of electricity for buildings has been for winter heating. This is now shifting to a summer cooling demand.

Building design should be responding by designing with climate rather than against it. Appropriate consideration of solar shading, thermal mass and natural ventilation systems can provide comfort conditions within buildings with the minimum use of energy. However, the trend in New Zealand has been for commercial buildings to be designed without consideration to excessive solar heat gains resulting in lightweight, highly glazed built forms that are dependent on air-conditioning. This is typical of almost all the buildings that have been accredited as 'green' buildings using voluntary rating tools.

This paper will review those aspects of climate change and fuel depletion that will have an impact on buildings both in the short and longer term. In particular the predicted average temperature increases and the impact this will have on energy demand for air-conditioning. The conflict between a building's image, which affects its rental rating, and environmental performance, which affects its sustainability rating, will be discussed.

The paper will argue that both building design and environmental standards should change to allow adaptation by occupants to a hotter climate and that dependence on mechanical cooling systems should be avoided due to an insecure supply of energy in the longer term.

**Trends in the relationship of energy and buildings**

It is only in the last 100 years that mankind has harnessed enough energy from, primarily, fossil fuels to be able to construct buildings that can ignore the climate around them and exclude the natural environment from within them. Energy has allowed architects to design buildings that can ignore natural ventilation, daylight and the sun’s energy by replacing it with an artificial environment that is air-conditioned, humidified and artificially lit.

This ability to use mechanical means to control the environment has allowed architects to freely experiment with the form, fabric and materials of a building in the knowledge that, however poorly the building envelope performs, the internal environment of a building can always be remedied by using more energy for cooling, heating or lighting.

This has led to an architecture that is characterised by large areas of glass incorporated in the external facade and air-conditioning internally. While this building type has a significant amount of natural light around the perimeter, it relies on artificial ventilation, heating and cooling systems in order to maintain a habitable environment internally. By burning energy in some remote power station, the building can operate both day and night and remain reasonably comfortable so long as this umbilical link to the supply of energy can be maintained.

This style of highly-glazed, lightweight, air-conditioned, poorly insulated building with no consideration to the position of the sun or prevailing winds has kept building scientists employed for decades. The problems that this style of building caused have been analysed, modelled and publicised. Problems such as ‘sick building syndrome’, overheating, glare and excessive energy consumption are well documented. However, the powerful brand image that this building type portrays drives its continued production.

Such is the dependence of these buildings on energy that, if the supply should fail, they become uninhabitable. This was witnessed, for example, in the power failures to the Eastern Seaboard of the USA in August 2003 when New Yorkers had to evacuate most of the buildings in the city because they had non-opening windows and air-conditioning systems in which the air for breathing ran out in under an hour and internal temperatures surged within minutes (Roaf, 2007).

We are now in an era where there is a general understanding that fossil fuels are depleting and our dependence on an adequate supply of energy cannot be assured (Energy Watch Group 2007 & 2008). In this context, it is surprising that these building types continue and even promote themselves as ‘environmentally sustainable’. For example, in New Zealand most ‘green’ office buildings are highly glazed, thermally lightweight and air-conditioned. An interrupted supply of electricity would render them uninhabitable.

While these ‘accredited’ buildings have a very small impact on New Zealand’s energy consumption, their prominence and publicity has disproportionate consequences on architectural practice and education. They become icons to ‘sustainability’ and yet they are so dependent on resources that are not necessarily sustainable. They are designed with little resilience to fuel depletion or global warming.

**The impact of climate change on energy supply and demand**

New Zealand has enjoyed the benefit of low electricity prices due to natural resources such as the Maui gas field and a large proportion of hydro-electric power in the national power mix. With the imminent arrival of international ‘peak oil’ and the depletion of New Zealand’s gas reserves, energy prices of fossil fuels will increase. This is likely to put further pressure on electricity production as demand shifts from fossil fuels to cheaper fuels.

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.

The big fear is that an unusually severe drought would trigger power rationing and the vulnerability of the power sector to dry years is becoming increasingly apparent with the decline of the Maui gas reserves. Since gas and hydro currently (Ministry of Economic Development, 2010) produce about 76% of New Zealand’s electricity, this makes the country very vulnerable to an energy gap that could result in energy rationing and consequent brown/blackouts.

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 such 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. For example, the variation in electricity production during the course of a year in the 1990s was around 20%.

In January 2010 the World Glacier Monitoring Service (WGMS) stated (Jowit, 2010a) “Glaciers across the globe are continuing to melt so fast that they many well disappear by the middle of this century”. The WGMS records data for nearly 100 of the world's approximately 160,000 glaciers, including 30 "reference" glaciers, with data going back to at least 1980. New Zealand’s glaciers have an estimated volume of about $53Km^3$ and have been gradually decreasing in volume over the last century by about one quarter to one third (Hay, 2008).

More than half the water entering hydroelectric lakes comes from glacial water (Fitzharris, 1989). However, global warming will have an impact on this. Predictions of a $3^oC$ (NIWA 2008) temperature rise and 15% increase in precipitation indicate a significant decrease in snow accumulation resulting in increased flows of 40% in the winter and a 13% decrease in the summer.

With increased temperatures, the peak demand for electricity will shift towards summer rather than winter. There will also be an increased demand for water for irrigation during the summer. This will reduce the ability of the hydroelectric power sector to provide an unfluctuating supply and could result in significant reduction in the hydroelectricity supply in the future.

The predicted increase in electricity production from wind power will play an important role in replacing the decreased production due to fossil fuels and hydro in the future. However, wind power is intermittent, cannot be relied upon to match with peak demands and is expensive to store. This has recently been illustrated in the UK (Jowit, 2010b) where a fall of 7.5% in power obtained from wind, hydro and other renewable sources in the first 3 month of 2010 was blamed on a dry winter with low wind speeds.

There will also be competition by other users for the electricity produced by wind power. 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 nearly all electricity produced by wind power. If this were the case, it would leave little residual energy for buildings.

There is also likely to be a significant increase in demand of electricity in both winter and summer due to the increased use of heat pumps in residential buildings. Government subsidies for heat pump installations **(‘**Warm Up New Zealand: Heat Smart programme’) have led to a significant growth in the heat pump market. Research has indicated (French, 2008) that these devices are displacing non-electric heating, thereby increasing the demand for electricity in the winter. Furthermore many households, almost 2/3rds of the sample surveyed, are using their heat pumps for cooling as well as heating.

Higher average temperatures in New Zealand will have the combined effect of increasing demand on electricity while decreasing the output of hydro power throughout the summer months. ‘Peak oil’ and its consequences are likely to increase the demand on electricity throughout the year if there is to be a shift towards the use of electric vehicles. While wind power will help offset the loss in energy supply, there remains a potential gap between supply and demand in the near future.

**Trends in energy consumption in ‘green’ buildings**

With a potential energy gap, new buildings play an important role in reducing electricity demand and there is a clear priority for ‘green’ buildings to address this issue.

While all building designs must achieve the minimum Building Code standards in New Zealand, there is a growing trend to achieving alternative voluntary standards set by ‘rating tools’ which attempt to measure the ‘sustainability’ of a building. This trend follows other countries, most notably the UK and US, where rating tools, BREEAM and LEED respectively, have been in operation for over a decade.

These ‘rating tools’ measure ‘energy’ as one of the criteria for achieving accreditation. In New Zealand, energy consumption is given a maximum of 25% of the total score though many high profile ‘green’ buildings do not even achieve half of this score. For example, for those case studies of air conditioned office buildings on the New Zealand Green Building Council web site (NZGBC 2010) the average score for ‘energy’ is only 50% of the available.

This means that the ‘rating tool’ allows building designs to be accredited when ‘energy’ is valued at approximately 12.5% (50% of 25%) of the total rating tool value. A new building can potentially achieve a 4 or 5 star NZ Green Building Rating while only just achieving the minimum required code standards for the thermal performance of the building envelope. This means it is possible to achieve “best practice” or “New Zealand Excellence” rating while the building envelope is almost breaking the law (Building Act).

This brings into question whether rating tools are being used for improved environmental design or whether they are being used for brand image. This issue was addresses in research (Gabe 20101) on the first 450 LEED accredited buildings. There is growing evidence from the body of research into both the design and actual performance of LEED certified buildings that the prime motivation behind the use of rating tools is for commercial marketing and promotion rather than for any environmental concerns.

In architecture, this is where there is a significant conflict between style and performance. Low energy efficiency standards for the building envelope and a low value given to ‘energy’ in rating tools allow the opportunity to use large areas of glazing. Many high profile ‘Green’ buildings in NZ have taken this opportunity and have been designed with a large proportion of glazing for purposes of image. For example, the Green Building cases studies (NZGBC 2010) of new office developments average in excess of 80% of glass on those facades that directly serve office spaces and, in some cases approach 100%.

High proportions of glazing lead to an overall poor energy performance of a building since glass does not perform well and readily allows useful energy out or unwanted energy in. This results in excessive heat losses when there is an overall heat demand and excessive solar heat gains, particularly if the glazing is not adequately shaded. While a high proportion of glazing admits daylight, the proportion of glazing has little effect if the glass is below the working plane (Pedrini, 2003) and if the room is deeper than about 7m. The conflicting energy demands of lighting, heating and cooling need to be balanced.

Balancing the energy demand of heating, cooling and lighting is usefully illustrated by the ‘LT Method’ of predicting environmental performance, developed at Cambridge University (Baker, 1994). For well insulated buildings in temperate climates it is difficult to justify a proportion of glazing of more than 50% irrespective of orientation or internal lighting level. It could be argued, in particular for Zone 1 in New Zealand that, with a changing climate, a temperate model is inappropriate. To overcome this, the LT Method was adapted by the University of Queensland (Hyde, 1998) for a sub-tropical climate. This model indicated that an even lower proportion of glazing was optimal. Indicating that as the climate warms there is an even greater requirement to reduce the proportion of glazing in a building’s envelope.

**The impact of interrupted energy supplies on buildings**

The majority of New Zealand’s ‘green’ rated buildings are not only highly glazed but are also fully air-conditioned with unopenable windows. Although openable windows are undesirable while air conditioning is in operation, it also means that these buildings cannot work as either naturally ventilated or mixed mode buildings at other times. This makes them vulnerable to electricity supply failures.

The depletion of fossil fuels and seasonal hydro electricity will significantly increase the risk of maintaining a constant and adequate electricity supply to buildings. The predicted higher average temperatures and reduced rainfall will accentuate the seasonal differences in electricity supply. This, combined with the likely exponential growth in the electric vehicle market and increased use of heat pumps in housing, may well result in interrupted supplies of electricity in summer months.

Buildings that are air-conditioned, excessively glazed and unable to be naturally ventilated rapidly overheat in summer conditions to the extent that they become uninhabitable. Under these conditions they need to be evacuated and limit, if not halt, production.

The rental value of commercial property in CBDs is rated (generally A to D) according to its desirability. An essential characteristic for A and B rated buildings is air-conditioning. While electricity is abundant and cheap, these building types are desirable. However, this could all change when electricity prices increase and supplies become interrupted as a frequent and lasting problem.

Green buildings are frequently promoted on the basis of increasing productivity. This is not a straight forward characteristic to quantify and is generally measured by a questionnaire asking occupants if they consider that they are more productive in their new building (Leaman, 2010). If there are to be regular energy shortages, rationing or blackouts in the future, then production will dramatically decline in air-conditioned buildings. Over a prolonged period the market is likely to shift to buildings that can remain in operation; naturally ventilated buildings. It is plausible that A and B rated buildings could change to D ratings in the future.

**Adapting comfort standards**

In a changing climate with predicted increases in temperature, 'green' buildings in New Zealand are still being designed with a dependence on air-conditioning. There appears to be an assumption that there will be an adequate supply of energy for the whole lifetime of the building that can maintain current comfort standards. This may be the case for buildings that can be certain of a secure an enduring supply of renewable energy. However, for the overwhelming majority of buildings, there is no unconditional security of an uninterrupted energy supply.

The drive for air-conditioning is partly motivated by the corporate clients whose key drivers are dictated by brand image and 'real estate strategy' of achieving Grade A or B rated space (Pellett, 2010). It is an area where rating tools are also fostering the use of air-conditioning and could provide improved guidance by balancing some of the conflicting requirements and standards of 'Indoor Environmental Quality' (IEQ) with 'Energy'.

Historical comfort standards are emerging as a significant impediment to reducing energy demand in buildings (Roaf, 2009). Standards for noise levels within offices, incorporated in

IEQ for rating tools, promote sealed buildings that negate natural ventilation. Lighting standards are based on an outdated method of measuring our perception of light that has resulted in the over specification of both daylight and artificial light (Cuttle). Above all, temperature standards offer little flexibility for accepting the fluctuating and less predictable variations that occur in a naturally ventilated building.

With increased long-term average temperatures due to climate change, a decision has to be made whether buildings will become artificially cooled retreats or whether we learn to accept higher temperatures and adapt to buildings with warmer and fluctuating internal temperatures that may exceed current standards (Roaf et al, 2010). The former requires an ever increasing supply of energy to cool buildings while the latter allows for the potential of zero energy buildings.

## Conclusions

Readily available and cheap energy supplies have historically allowed architecture to rely on its mechanical plant, rather than fabric, to heat, cool and light buildings. This has resulted in highly glazed buildings that consume a disproportionate amount of energy. However, this building type has had a universal appeal to organisations that see this style as increasing their brand image.

In the last few years many organisations have also come to realise that 'sustainability' is also an important brand image. Rating tools for 'green' buildings have become a marketing tool in this respect. However, this can result in a conflict between the style of a building and its environmental performance. Highly glazed, lightweight, air-conditioned buildings are good for image in a CBD but they are high energy consumers and will perform progressively more poorly as climate change pervades.

Peak oil and peak gas are now imminent and climate change could also result in 'peak hydro' in New Zealand making the country very vulnerable to an energy gap that could result in energy rationing and consequent brown/blackouts.

Not only will the energy costs of these building types increase but so also will their inability to remain adequately productive. The claim that 'green' buildings are more productive will not be tenable in the event of recurring interrupted supplies of electricity. In the event of an electricity supply failure, highly glazed, air-conditioned buildings will become uninhabitable.

While the main drive behind the design of these buildings in brand image, 'green' rating tools are inadvertently also promoting this building type. If the mission of 'green' rating tools is to accelerate the transformation of the global built environment towards sustainability, then it needs to reconsider the criteria to take account of energy depletion, climate change and the consequent need for adaptation by building occupants.

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