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Climate Change Impacts On Building Performance

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CLIMATE CHANGE IMPACTS ON BUILDING PERFORMANCE

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ABSTRACT

Climate change is expected to have an impact on many aspects of building performance. As the replacement rate of buildings in New Zealand (and many other countries) is low, and the lifetime of buildings long, much of the existing and future building stock will be affected by any long-term (30-70 years) changes in climate. There is a need to identify what impacts climate change may have on buildings, how serious they are, and what action (if any) could be taken to ensure that future building performance is not compromised.

Climate change scenarios for New Zealand defined the scale of climate changes considered for building performance. For each climate variable, relevant aspects of building performance were examined to determine if there is likely to be a significant impact. Where significant impacts were indicated they were studied in detail and, where possible, the scale of the impacts quantified. A risk-profiling tool was formulated to cover the risk/severity of the most significant climate change impacts, which include flooding (inland and coastal), tropical cyclones and overheating. This tool is for use on houses and office buildings.

Mitigation strategies were developed for each climate change risk. For some types of risks (eg. increased flooding) it will be impossible to detect until after the risk has changed significantly, but the most effective strategy for minimising risk is to take early preventative action. For other risks (eg. overheating) it will be easy to detect problems when they occur, and after-the-fact mitigation measures are effective. Thus, different responses are appropriate for each climate change impact. For those serious risks where delaying action has serious consequences, it may be appropriate to consider changes in building or zoning regulations to anticipate the future impacts of climate change.

In this paper, the results of this research are summarised, and the implications for future building performance, design, standards, and regulation discussed.

KEYWORDS:

Climate change, Global warming, Buildings, New Zealand.

INTRODUCTION

The world's climate is changing. The 1990's were the hottest decade since the 1860's, and the 1900's the warmest century of the millennium (WMO, 1999). Extreme weather phenomenon and anomalies are also apparent, from temperature departures of around +5°C in many parts of Europe, to a super-cyclonic storm in India (WMO, 1999), to the melting of the ice-pack at the North Pole (Guardian Unlimited, 2000). International research has concluded that there is a discernible human influence on the climate (IPCC, 1996).

Perhaps for the first time in human history, mankind has a good idea of how the climate may change in the future. The likely impacts have been, and continue to be, explored by scientists in a wide range of disciplines (Watson, Zinyowera, and Moss, 1996). It is clear that there may be many negative impacts on ecosystems and human systems caused by climate change and global warming. The implicit assumption that climate is static, bounded by known extremes and changes only slowly with

time, is no longer tenable. Argument still persists about whether recent changes in climate are influenced by anthropogenic greenhouse gas emissions, but regardless of the cause, the effects are real and must be managed.

Building codes and practices around the world attempt to protect people and property from the normal range of climate variation. Once this normal range of variation is exceeded, then problems may be expected, ranging from uncomfortable internal environments to the wholesale destruction of large numbers of buildings. At some point, codes and practices must change to suit the new climate. However, changing codes and practices requires a good foundation of evidence and research to evaluate the likely implications, practicalities, costs and benefits — a requirement that is difficult to meet given the uncertainty of current climate change scenarios, and their long time scale.

BACKGROUND TO THE RESEARCH

The BRANZ climate change research programme was created to fill a gap in the New Zealand climate change science base. Many assessments of the risks and impacts of climate change had been undertaken on selected New Zealand activities, for example, the forestry and agriculture sectors, but there was only limited knowledge of the impacts of climate change on the construction sector.

The goals of the research were:

- to identify, and if possible, quantify the impacts of climate change on houses and office buildings
- to develop an assessment tool to rate a building's vulnerability to the impacts of climate change
- to develop adaptation and mitigation strategies for new and existing buildings

CLIMATE CHANGE SCENARIOS FOR NEW ZEALAND

A very brief summary of climate change scenarios for New Zealand is given in Table 1 for the years 2030 and 2070. Detailed climate change scenarios developed by the National Institute for Water and Atmospheric Research (NIWA) are given in Camilleri (2000a).

Table 1. Summary of climate change scenarios for New Zealand

Climate Variable	Year 2030	Year 2070
Temperature	+0.3 to +0.9°C	+0.6 to +2.7°C
Sea level	4-24 cm	10-60 cm
Extreme rainfall	No change to a doubling of the AEP ¹	No change to fourfold AEP ¹
Annual rainfall	-5% to +10% by region	-15% to +30%
UV	decrease by 6-7%	decrease by 10%
Solar radiation	Unknown	Unknown
Windspeed and direction	Unknown	Unknown
El Nino southern oscillation	Unknown	Unknown
Tropical cyclones	Unknown	Unknown

IMPACTS ON BUILDINGS

Even the quantifiable climate changes listed above could be expected to influence almost every aspect of construction practice and building performance. The challenge in assessing the impact of climate change on buildings is to decide which impacts are significant enough to justify changing building practice, or the protection of buildings.

¹ AEP is the Annual Exceedence Probability, and is the probability that a threshold (eg flood height) will be exceeded in any one year.

For each climate factor in Table 1, an analysis of the sensitivity of the related building performance was undertaken. The following potential impacts on buildings were identified and assessed:

- decreased winter space heating
- decreased water heating energy
- increased overheating and air-conditioning load
- greenhouse gas (GHG) emissions of houses
- increased costs due to carbon or GHG charges
- changes in electricity costs
- increased inland flooding
- increased coastal flooding, erosion, and rising water tables
- degradation of polymers
- changes in wind
- increased tropical cyclones
- increased insurance costs
- changes in timber properties

As the number of potential impacts on buildings is large, this paper examines only a selected few to briefly illustrate the most significant impacts, and provide examples of the four possible outcomes of the assessment process:

- 1) An impact is quantified, and shown to be significant
- 2) An impact is quantified, and shown to be insignificant
- 3) An impact is not quantified, but shown to be insignificant
- 4) An impact is not quantified, but cannot be shown to be insignificant

Decreased winter space heating for houses with increased temperatures is an impact of type (1) (quantified/significant), as the data available from the climate change scenario is good, and simulation methods are available to quantify the impact.

To quantify the reductions in heating energy, heating simulations of houses were performed using the ALF method (Bassett, Bishop and Van de Werff, 1990). The anticipated percentage reductions in space heating for several locations in New Zealand are given in Table 2. The range for each location (representing a major climate region) and year reflects the possible range of temperature changes given in Table 1. The percentage reductions in heating energy were found to be similar regardless of insulation level, orientation, thermal mass level, heating schedule or thermostat temperature.

Table 2. Space heating energy reductions with climate change

Location	Latitude	2030	2070
Auckland	36° 51' S	12-70%	69-79%
Wellington	41° 16' S	25-33%	29-86%
Christchurch	43° 32' S	4-14%	9-62%
Invercargill	36° 25' S	12-19%	15-51%

Decreased water heating energy is an impact of type (2) (quantified/insignificant) as although it can be quantified, the energy consequences are relatively minor.

Reductions in the required hot water heating energy of about 3% per 1°C increase in temperature are expected as a result of the warmer air temperature on the cold water supply temperature (Camilleri, 2000a). Temperature increases given in Table 1 would result in water heating energy decreases of 0.8-2.8% by 2030, and of 1.8-8% by 2070, which are insignificant except for the most extreme temperature increase.

Changes in wind speeds are an impact of type (3) (not quantified/insignificant) as the climate change scenario is non-existent, but methods are available to show that the impact on buildings is likely to be undetectable.

Extreme wind causes damage to houses, especially to roofs and windows, and damage to services such as power and telephone lines. New Zealand timber framed houses already have their structural design dictated by wind zones (NZS 3604:1999). The risk is that with climate change, the wind zones and wind exposure could change, possibly exposing houses to stronger winds more frequently than is acceptable according to the current Building Code requirements.

Currently, there is no reliable assessment on the possible changes in windspeeds with climate change. In the absence of a climate change wind scenario, a sensitivity study to changes in wind speed was carried out. This considered the problem of detecting a change in the frequency of extreme winds. It was found that any likely change in the frequency of extreme windspeed would be statistically undetectable over a 50-year time period, even if the current design windspeeds were known precisely. If the estimated error in current design wind speeds is considered, then there is no practical way of detecting an increase in design wind speeds based on meteorological data, or a wind data proxy such as building damage statistics. From this it was concluded that even if climate change led to large increases in the AEP for damaging winds, these changes would be undetectable over a 50-100 year (or longer) time span. Therefore there is no need to change design wind speeds.

Tropical cyclones are an impact of type (4) (not quantified/not insignificant) as the climate change scenario is very uncertain, and the possibility of marked adverse impacts cannot be discounted.

Climate change science currently has several conflicting assessments of changes in tropical cyclones, ranging from no change to slight increases in frequency and intensity. When cyclones do strike New Zealand, the result is substantial damage. Insurance claims from cyclones from 1978-1988 amounted to about \$55 million dollars, with more than \$50 million in 1988 from Cyclone Bola alone (Insurance Council, 1997). Any increase in the number of tropical cyclones would dramatically increase weather-related damage, including structural damage from wind, increased flooding, and increased landslips. The potential for damage to houses from any increase in tropical cyclones is so large that, despite the uncertainties, this potential impact must be taken very seriously.

CLIMATE CHANGE SUSTAINABILITY INDEX

The Climate Change Sustainability Index (CCSI) is a tool created to aid the assessment of the impact of climate change on a building (Camilleri, 2000b). It is designed to rate the impacts of the most significant impacts of climate change (impact types (1) and (4)) so that potentially vulnerable buildings can be identified, and if possible remedial action identified. The assessment methodology is built around industry standard tools, and readily available information.

The complete CCSI consists of two separate numerical ratings: one for impacts on a house (which includes summer overheating; coastal and inland flooding; tropical cyclone risk), and another for greenhouse gas emissions for space and hot water heating (not discussed in this paper).

The rating for each impact is on a scale of -2 to +5, with 0 being the reference level for normal building performance, and an 'X' rating being available for an extreme risk. This rating scale was adopted from the Green Building Assessment Tool (GBAT) (Larsson, 1998).

The CCSI rating is designed to be easy to apply using limited data. For some impacts a comprehensive method is used if data is available, and a simplified method is used if no data is available. The CCSI for inland flooding is provided as an example.

Inland Flooding — CCSI

The CCSI rating for inland flooding has both a comprehensive and simplified method.

The comprehensive rating is performed on the basis of known flooding risks. The reference level is an Annual Exceedence Probability (AEP) of 2% after the flooding risk has increased four-fold, that is the current AEP is 0.5%, or higher. The 'X' rating denotes extreme risk, and a house with this rating is likely to be flooded more than once each decade with changes in the flooding return period. The '5' rating only applies for houses with no flooding risk. No house on a floodplain, near a river, or in an urban area draining a large area would qualify. The flood risk here may be low, but is not zero.

Table 3. Comprehensive CCSI credits for inland flooding, based on AEP

AEP	CCSI Credits
= 0%	5
> 0%	4
≥ 0.05%	3
≥ 0.1%	2
≥ 0.25%	1
≥ 0.5%	0
≥ 1%	-1
≥ 2%	-2
≥ 5%	X

The simplified rating is based on the site geography and local knowledge of flooding occurrence. For many parts of New Zealand prone to flooding, the actual risk of flooding is not known because of factors including a lack of monitoring, changes in the catchment or relatively recent development.

Table 4. Simplified CCSI credits for inland flooding, based on site geography or flooding occurrence

Criteria	CCSI Credits
Never flooded, not on floodplain, not near river, lake, or urban drainage area	5
Never flooded, but in urban drainage area	4
Never flooded, but near river	3
Never flooded, but on floodplain	2
Never flooded, but nearby areas flooded	1
Never flooded, but adjacent properties flooded	0
Flooded once	-1
Flooded twice	-2
Flooded more than twice	X

ADAPTATION AND MITIGATION STRATEGIES

The CCSI has been extended to include adaptation and mitigation strategies aimed at reducing the potential impact of climate change (Camilleri, 2001). Together, they form the informational basis of a decision support tool to aid in planning and adaptation for climate change.

Once the CCSI rating is performed, a decision can be made as to whether or not adaptation for climate change is necessary. CCSI ratings of 0 or 1 or lower (depending on the impact) would justify adaptation in terms of building performance. Once the adaptation is deemed necessary, a range of

basic options are presented, depending on the impact, its severity, the type of building, cost, practicality etc. Other issues are also important, such as the timing of adaptation (adapt now or in the future) and the economic value and life of the building.

By creating a set of adaptation and mitigation strategies, the core problems of adaptation to climate change are highlighted. The adaptations range from easy and cheap, to costly and difficult.

Inland Flooding — Adaptation

Continuing with the example of inland flooding for housing, there are number of options for reducing the risk and impact of flooding, including:

- don't build on a flood prone site
- exceed minimum above-ground floor levels
- consider multi-storey construction
- use flood-resistant materials
- install essential, vulnerable equipment as high above ground level as possible.

Taking steps to mitigate flooding risk is most effective before construction of a new house. The marginal cost of higher foundations or flood-resistant materials is likely to be low at this stage. For existing houses, adaptation and mitigation to flooding risk are likely to be more difficult and expensive. Some measures to consider for existing houses include:

- raise or move house
- build a second storey and use first storey as non-living space
- replace cladding, flooring, and linings with flood resistant materials
- move services (hot water, electricity distribution board) to above flood levels
- build levy or floodwall around the house.

Unfortunately, adaptation can be expensive and difficult, and may force changes in land use practices, such as restrictions in coastal zones. As the impacts are not likely to occur for many decades, and the benefits of adaptation will be invisible until flooding occurs, it may be difficult to get support from the community. This may mean that the cheapest and most effective adaptations, which are land use restriction and minimum floor levels, may not be used, forcing either costlier options later, or the full consequences of increased flooding damage. Delaying action may be very costly in this situation.

IMPLICATIONS FOR THE FUTURE

The research has shown that climate change will have different impacts on different buildings depending on the building type, scale, use, construction and location. The different climate impacts call for different actions and responses, as discussed in the section on adaptation and mitigation strategies, which focussed on changes in design and construction practice. There is also scope for revising existing standards, and changing or creating building controls to maintain current levels of building performance with likely changes in the climate due to climate change.

The New Zealand Building Code (NZBC) is a performance-based code, implemented through 'Approved Documents' which may include one or more 'Verification Methods' and / or 'Acceptable Solutions' as ways of demonstrating compliance. Acceptable Solutions are examples of materials, components and construction methods, while a Verification Method may be based on calculation, or laboratory in-situ testing.

The New Zealand building control system regulates only those matters essential for ensuring that buildings perform in a way which safeguards people from injury, illness and loss of amenity, protects

other property from damage and facilitates efficient use of energy. It does not deal with aesthetics, comfort or the owner's specific economic interests.

Thus only those impacts of climate change which can be shown to fall specifically within the ambit of the NZBC can be considered for regulatory control. In this section, some options for each of the climate change impacts on buildings are discussed.

Overheating

Control or prevention of overheating in houses and commercial buildings is not included in the NZBC. It appears unlikely that it will become part of the NZBC, as overheating is currently not seen as either a health or safety issue. This attitude could change if overheating occurred in large numbers of buildings for significant periods of time. Even if overheating were included in the NZBC, it is technically complex and difficult to assess, as there are so many interactions between building components, form, climate and behaviour. Simplified measures, such as placing restrictions on window areas or prescribing shading or window treatment, might well be rejected by the design and construction sectors as being too restrictive and prescriptive.

Best practice guides could provide a good informational base to influence the design of buildings, rather than regulatory requirements.

For office buildings, a reduction in overheating of around 1°C can be achieved by reducing internal loads (lighting and/or equipment) by around 10 W/m² (Energy Group, 2000), compared to the NZBC requirement of 18 W/m² (NZS 4243:1996). This is technically feasible and cost-effective now for lighting loads. It would ensure that the future overheating performance of office buildings for modest temperature increases will not be any worse than today.

Flooding

Protection from flooding for housing, communal residential (e.g. hotel) and communal non-residential (e.g. church) buildings is included in the NZBC. The current performance requirement under NZBC **Clause E1: Surface Water** is that the AEP for over-the-floor flooding must not exceed 2% (Building Regulations 1991). However the assessment of the flood risk assessment, as set out in the Verification Method (E1/VM1 1), need only take account of the historical characteristics of the total catchment as well as the particular building site (BIA 1995). It does not need to consider any potential future climate changes.

The assessment of flooding under climate change, is that flooding AEPs could increase by up to two to four times, which indicates that some buildings built under today's Building Code will have a future flooding risk that is considered currently unacceptable.

Should the Verification Method be revised, to require a lower current risk of flooding to act as a 'buffer' for any future climate change? As it will be very costly to adapt houses in the future for an increased flooding risk, it seems sensible to use reasonable, inexpensive, no regrets options such as tighter land use controls and higher minimum floor levels.

There are no limits on flooding risk for commercial buildings in the NZBC. The management of the flooding risk is left either to local or regional government under their zoning regulations, or to building owners to incorporate active (e.g. pumps) or passive (e.g. flood design) responses.

Local and regional government has a strong influence over zoning and district plans, and could adjust the flood risk zones to anticipate future risks. However, there is the possibility that such changes could be appealed by property owners through legal channels.

Tropical Cyclones

The risk of increased tropical cyclone activity is uncertain with climate change, but the impacts include damage from wind, inland flooding, and coastal flooding. As all these three risks are concurrent, and widespread, the potential for disaster is high.

Without any scientific certainty about the future risks, it is difficult to factor this risk into decision making. At the very least, the inland and coastal flooding risks should be reviewed as for the known increased flooding risk from increased rainfall, and perhaps some extra margin given for the likely coincident coastal and inland flooding with cyclones.

CONCLUSION

It is clear that even without the current uncertainties in climate change science and the potential impacts of climate change on buildings, establishing suitable mechanisms to deal with these issues is also problematic.

As a result of climate change, the future performance of buildings may be significantly different than current performance for:

- coastal and inland flooding
- overheating (as defined by occupant expectations)
- wind damage and flooding associated with tropical cyclones.

The CCSI gives an assessment of the vulnerability of buildings to these climate change risks. The adaptation and mitigation strategies outline some ways that buildings can be changed so that current building performance standards are maintained. The appropriate response depends on the particular impact, but can range from late action by building owners, or early action through building controls or good practice standards.

For flooding and tropical cyclone risks a 'wait and see' approach is likely to increase both the costs of adaptation and mitigation, and the amount of damage caused to buildings. Early action by contrast will generate an effective, and ultimately lowest cost, response.

Climate change risks should be included in future reviews of the appropriate clauses of the NZBC and associated Approved Documents. The scope, time scale, and uncertainties around climate change risks may be outside the current scope for such reviews, as may be the process by which such risks are assessed and managed. The NZBC expects buildings to have a minimum life of 50 years, and it is likely the climate will have changed within that period. Given the increasing certainty of the likely type of climate change to occur in the coming century, regardless of the cause, the need for consideration in the NZBC is becoming clear. It is possible that other land-use legislation may also need to consider issues of changing climate, but this is outside the scope of this paper.

In dealing with climate change, we are dealing with an uncertain science – climate change science and impact assessments are never going to be precisely known, and should form only one part of a risk management process. If the scope of the risk management excludes or heavily discounts risks of this nature, then buildings are likely to suffer potentially costly and dangerous consequences in the future.

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