



## **Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part I)**

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**Abstract:** *This session brings together policy-makers, government officials, researchers and others to present perspectives on how innovation in building regulation and control, such as performance-based approaches, are currently being used to advance sustainability concepts in buildings, whether we are doing enough, and where and how we might see further innovation in the coming years. In this grouping of session papers, representatives of the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and the International Council for Research and Innovation in Building and Construction (CIB) Task Group 79 discuss a range of policies implemented in their countries and/or the focus of research and development in their respective countries. Related papers can be found in the corresponding set of session papers (Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part I)).*

**Keywords:** *building regulatory systems, building control, performance-based, sustainability, climate change, resiliency*



## Resilience of Australian Buildings to Extreme Weather Events

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Matthew MCDONALD, Group Manager, Strategic Policy, Australian Building Codes Board, Canberra, ACT, Australia ([Matthew.McDonald@abcb.gov.au](mailto:Matthew.McDonald@abcb.gov.au)) – *Resilience of Australian Buildings to Extreme Weather Events*

**Abstract:** *The policy direction for the work the Australian Building Codes Board (ABCB) undertakes in the area of sustainability is usually derived from Government. These directions place policy expectations and boundaries upon the ABCB that impact on the way it is able to deal with the challenges relating to sustainability. The ABCB has traditionally dealt with some elements of sustainability, such as resilience to extreme weather events, under the building code core objectives of health, safety and amenity. Additional elements, such as energy efficiency, have been added over time which has resulted in the addition of sustainability to the core objectives of the code but not all risks and similarly not all buildings are addressed. The vast majority of existing buildings were constructed before the current sustainability requirements came into force. This means that many occupants of existing buildings are vulnerable to higher relative risk.*

**Key words:** *Australia, sustainability, climate change, natural hazards, resilience, regulation, building.*

### Background

Effective resilience to extreme weather events (or extreme climate related natural hazards) involves a number of strategies across all levels of government, business and communities. These strategies include consideration of settlements and infrastructure, emergency planning and response, insurance, and human health. For the purpose of this paper, consideration is limited to buildings, structures, and plumbing systems, which come under the domain of the Australian Building Codes Board (ABCB) and the National Construction Code (NCC).

To provide an understanding of what ‘resilience’ means for the purpose of this paper, the following definition contained in the Intergovernmental Panel on Climate Change (IPCC) 2012 report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* is useful.

“Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.”

Not to be confused with property protection as an outright objective, a critical future challenge facing the ABCB is ensuring that the NCC contains appropriate standards for buildings and plumbing systems to be sufficiently resilient in the face of natural hazards affected by extreme weather events, which may change over time. This is not, however, a new concept for the ABCB.



The ABCB's mission, references sustainability in the design, construction and performance of buildings. In turn this is reflected in the NCC requirements for new buildings and plumbing systems to be designed and constructed to withstand extreme climate related natural hazard events, including wind and cyclones, rainfall, snow, bushfire and flood, as appropriate to their location.

The ABCB has traditionally relied on historic climate and weather data when setting standards for the resilience of buildings, structures and plumbing systems facing extreme natural hazards and extreme weather events. In addition, the ABCB has promptly investigated natural disasters to determine whether the current NCC provisions are appropriate and has developed new provisions where required.

Changes to the NCC are subject to compliance with Council of Australian Government (COAG) best practice regulatory principles; this includes a cost benefit analysis, regulation impact assessment (RIS) and consideration of available data and research. However, more recently the ABCB has sought to utilise scientifically based climate projections such as in its review of wind standards for construction in cyclone affected areas.

There are a number of policy expectations and boundaries placed upon the ABCB that impact on the way the ABCB is able to deal with future challenges concerning extreme weather events. At a national level these include, the policies of different governments, societal expectations, cost benefit analysis and the availability of data.

One of the main objectives of the ABCB is to ensure that the NCC requirements are as far as practicable nationally consistent. This does not mean, however, that 'one size fits all' because different locations can have geographic, climatic or other differences, but the overall risk levels to the community should be reasonably similar.

Governments require the ABCB to undertake a regulation impact analysis for every significant change to the NCC, which includes an assessment of net benefits and costs, and justification for the most appropriate option. The analysis must be cleared by the Government's Office of Best Practice Regulation, which also determines the applicable discount rate. The analysis ultimately informs the decision making process of the Board but it is not the only consideration and the Board has the ability to choose an option that may not provide a clear net cost saving to the community but delivers life safety.

#### **Climate related natural hazards currently addressed by NCC**

Buildings are currently designed and constructed in accordance with the NCC to withstand climate related hazards such as cyclones and extreme winds, intense rain, bushfire, snow and flood, as appropriate to their location.

These hazards impose loads and risks to buildings determined mainly by historic records and post event analysis, from which design events with annual probabilities of exceedance are specified.

Building standards have undergone constant review, particularly after major hazard events and via research, to ensure adequate levels of safety and health are maintained for the community. Where the building standards proved to be inadequate, as identified in the wake of Cyclone Althea in 1971 and Cyclone Tracy in 1974, they were subsequently upgraded (refer Figure 1 for example of damage caused by Cyclone Tracy impacting on Darwin).



**Figure 1: Example of damage - Cyclone Tracy**

These improved standards for high wind design were later demonstrated to be satisfactory as evidenced by the small number of building failures resulting from Cyclones Vance, which affected northern WA in 1999, and Cyclones Larry and Yasi which affected northern Qld in 2006 and 2011 respectively. However, the largest problem identified by recent cyclone investigations relates to pre-1980 buildings that were designed in the main to lesser standards and which have often been weakened by material degradation and inadequate maintenance (refer Figure 2 for example of damage to older housing caused by Cyclone Yasi).



**Figure 2: Example of damage to older house - Cyclone Yasi**

The ABCB has undertaken a recent study into the impact of climate change on the NCC. The Report found that by and large, buildings designed and constructed in accordance with the current NCC are likely to be reasonably adequate for climate related hazards anticipated in 50 years- time, associated with a low emissions scenario. If the climate changes in accordance



with high emissions scenarios however, the current BCA is likely to be deficient in some areas.

Whatever the emission scenario, potential climate change impacts at both a regional and national level require constant monitoring and review to ensure the NCC's established level of safety is proportional to the likely hazard intensity and resultant risk of damage.

The fact the NCC currently addresses a number of natural hazards through what have been adjudged to be proportional minimum performance requirements, results in both significant social and financial benefits for the Australian economy.

For example, a report by Risk Frontiers, Macquarie University in December 2007 for the ABCB entitled 'Financial benefits arising from improved wind loading construction standards in Tropical-Cyclone prone areas of Australia', found that '...the improved building standards have been enormously successful with our calculations suggesting that they have been responsible for reducing annual average cyclone-related losses by nearly two thirds'. The report estimates that this equates to a present value benefit of future loss reductions equalling AUD14.2 billion. It is anticipated that additional significant financial benefits will also accumulate from the other natural hazards addressed by the NCC.

The impact of climate changes on wind and cyclones appears minimal at this stage. An investigation commissioned by the ABCB reviewed recent studies of climate change effects on tropical cyclones. The studies indicate that in the Australian region, the total number of cyclones has diminished. However, there is evidence that the number of more severe events has increased. Simulations of future climate, with projected increases in CO<sub>2</sub> concentrations, also predict fewer cyclones, but further increases in more severe tropical cyclones. One of the more significant scenarios is the possibility of a greater risk of a severe cyclone affecting South-East Queensland.

### **Hazards not addressed by NCC**

The NCC currently does not cover hail, storm tide or have specific requirements relating to heat stress. However, for heat stress, the NCC energy efficiency requirements would moderate the impacts of extreme heat within buildings that have been built to contemporary energy efficiency standards, resulting in reduced risk of heat stress for building occupants.

Some of the largest insurance property losses result from hail damage (e.g. the 1999 Sydney hailstorm). However, any proposed changes would need to pass regulation impact analysis. It is unlikely it would be cost effective to require all external building materials to resist hail impact, taking into account the localised nature of such storms, the cost of upgrading or restricting certain building materials, and the low risk to life safety.

Storm tide is potentially a very high risk in low lying coastal communities, especially those subject to the risk of cyclones. However, it would be very costly and restrictive to design and construct buildings to resist storm surge because of the significant water forces involved.



Restricting development in high hazard areas via planning controls may provide a more realistic solution.

Recognising the inter-operability of building and planning controls for natural hazard mitigation is crucial, not only to ensure the correct geographic locations are identified for the application of building standards, but also because the best way to reduce risk to life and property is to determine where buildings should or shouldn't be built in the first place.

It is also important to note that the vast majority of buildings that are highly exposed to natural hazard events already exist. The NCC does not apply retrospectively unless required by State and Territory laws (such as in the case of swimming pool fences). This means it will take a long period of time for the existing stock to be replaced or incrementally improved as owners undertake renovations that require the building to meet the current requirements of the NCC.

### **Impact of climate changes on extreme weather events**

The weight of scientific analysis tells us that our climate is changing and this may impact on extreme weather events such as storms, floods and heat waves. Data is also confirming that temperatures are rising and that the impact on rainfall appears more variable around the country (refer Figure 3 showing changes in average temperature for Australia from 1910-2010). However, the impact of these changes on extreme natural hazard events is not always apparent.

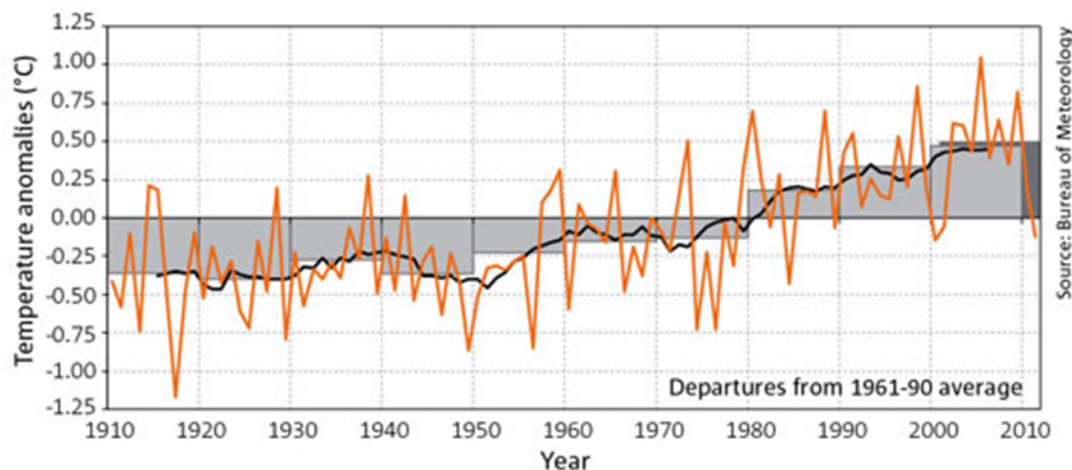


Figure 3: Changes in average temperature for Australia

In addition to the climate change implications for weather affected natural hazards impacting on buildings, other significant impacts on potential risk to life and building damage include the increasing density of settlements and the increasing dwelling size and value. In other words, a greater number of buildings of increasing value are being exposed to extreme weather events. Examples include increased density of settlements on the coastlines and river systems of Australia which are exposing a greater number of people and buildings to cyclones

and other extreme winds, flooding and storm surge (refer Figure 4 showing increase in development on the Gold Coast from 1950's to present).



Figure 4: Contrast of Main Beach, Gold Coast Queensland, in the 1950's and in more recent times (Source Gold Coast Tourism Bureau)

Even if the risk of extreme weather events does not increase, the greater density and value of settlements exposed to these risks will mean that losses of life and property will inevitably also increase.

### **Conclusion**

The ABCB is committed to comprehensively reviewing and considering the impacts of extreme weather events in relation to all relevant new regulatory initiatives but the ABCB is not a climate expert. The ABCB must rely on climate/weather experts to provide advice, research and evidence to establish whether and to what extent climate changes are impacting on extreme natural hazards and should be taken into account in determining the coverage and appropriate risk levels in the NCC. This must occur in conjunction with policy makers having regard to the science and providing strategic direction for the ABCB in undertaking its work.

The ABCB has robust processes in place to ensure the NCC adequately addresses future extreme weather events, and that codes are continually refined and improved. All changes to the NCC must be evidence based with the problem clearly articulated and the response proportional to the issue being addressed.

The largest concern is in relation to existing buildings constructed prior to today's contemporary building standards. These buildings are likely to be vulnerable to current climate hazard events, so would be even more vulnerable when faced with the prospect of more severe future events.

The challenges will also stretch the capacity of the ABCB to maintain national consistency and minimum performance standards across jurisdictions for new building and plumbing work, whilst ensuring the NCC continues to meet its objectives of minimum performance standards for safety and health, amenity and sustainability.



Finally, the ABCB needs to continually engage with its stakeholders to ensure there are ample opportunities for input and to ensure that all potential impacts of proposed changes are fully identified and analysed before final decisions are made.



## Life-time Environmental Sustainability of Buildings under the Singapore Building Control Act

*Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee*

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**Abstract:** *With a land area of 723.2 km<sup>2</sup> housing a population of 5.4 million, Singapore is one of the most densely populated countries across the world. Given our scarce resources and limited land, it is imperative to ensure developments go hand-in-hand with efforts to preserve our environment in tandem with rapid urbanisation and increased population. As the authority for the building sector, Building & Construction Authority (BCA) plays a leading role in steering the building sector towards sustainable development. In 2005, BCA has spearheaded and launched the BCA Green Mark Scheme,<sup>1</sup> with the objective to promote the adoption of green building design and technologies that improve energy efficiency and reduce the impact of buildings on the environment. While there has been considerable headway in promoting the development of green and sustainable buildings in Singapore, there is a need to ensure that appropriate regulations are in place to provide the relevant impetus on the desired reduction in energy consumption and carbon emissions. The paper will discuss on the legislative frameworks in place under the Singapore Building Control Act and how these frameworks would help advance the sustainability concepts in buildings from design to operation.*

**Keywords:** *Sustainable Development, GreenMark Legislation, Building Control, New Buildings, Existing Buildings, Periodic Energy Audit, Energy Consumption Data*

### Introduction

In Singapore, the building sector is the third largest contributor to Singapore's carbon emissions after the manufacturing and transport sectors, contributing 16% of the total carbon emission. To reduce carbon emission levels of buildings, there is a need to optimise the energy usage of buildings while minimising the use of carbon intensive materials and waste generation. In essence, buildings would have to be designed, constructed and maintained to be energy-efficient and environmental friendly, beyond merely fulfilling the functionality. To start with, the public sector being a large consumer of resources in building development and ownership, has initiated a range of measures to drive resource efficiency since 2006 under the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiatives. Under this PSTLES framework, all public sector agencies are required to submit an annual

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<sup>1</sup> The BCA Green Mark Scheme is a green building rating system to evaluate the environmental impact and performance of buildings launched in Jan 2005. Today, BCA's Green Mark scheme has become the national yardstick to rate the environmental performance of buildings and the qualifying standard for determining the eligibility and grant quantum under various green building related incentives. Its assessment framework is also adopted as the compliance method under the current regulatory requirement on environmental sustainability of new and existing buildings.

environmental scorecard to update their environmental performance for each of their buildings. On the aspects of new building construction, the public sector agencies are to take the exemplary lead to ensure that their new buildings with more than 5000 square metres air- conditioned spaces are designed and constructed to attain the Green Mark Platinum rating. As for the existing buildings with more than 10,000 square metres air-conditioned spaces, the public sector agencies will have to make progress in improving the building performance by way of energy efficient retrofitting when appropriate, to attain the Green Mark Gold<sup>Plus</sup> rating by 2020. These initiatives help create a demand for energy efficient buildings and related services, providing opportunities to influence and to bring about a broader change in the private sector. To further intensify our efforts in view of the rising global concern for environmental issues, Other than fiscal measures and government policies to encourage green building alternatives, regulatory controls were also put in place to help push for a wider adoption of green building technologies and practices in the building industry.

### **Progressive Legislative Frameworks to drive Environmental Sustainability**

Since the energy crisis in the 1970s, BCA has been actively involved in energy conservation in buildings. A set of energy standards was developed and incorporated in the Singapore Building Control Act and Regulations then, with subsequent revisions to keep abreast with advancement in technology and global trends. Reducing the carbon emission levels of buildings through various energy efficiency measures has always been an integral part of Singapore's energy policy. Under the Sustainable Development Blueprint formulated by the Inter-Ministerial Committee on Sustainable Development (IMCSD), the target set for Singapore's built environment is to have *"At least 80% of the buildings in Singapore to achieve the BCA Green Mark Certified rating by 2030"*. To achieve this, BCA has rolled out its Green Building Masterplan, a roadmap that sets out specific initiatives including regulatory measures to achieve a sustainable built environment in Singapore by 2030. To advance sustainable development, the Singapore Building Control Act was revised over time to put in place appropriate legislative controls where market forces would not be sufficient to achieve the optimal level of sustainability in buildings. These legislative frameworks would provide the necessary impetus on the desired reduction in energy consumption and carbon emissions by taking the whole life cycle of buildings into consideration. The legislative frameworks implemented are as follows:

- (1) Mandating a Minimum Environmental Sustainability Standard for Building Development
- (2) Setting Mandatory Higher Green Mark standards for Government Land Sales Sites
- (3) Establishing National Energy Benchmarks through Annual Mandatory Submission of Building Information and Energy Consumption Data
- (4) Prescribing Mandatory Minimum Environmental Sustainability Standard for Existing Buildings Undergoing Installation and Replacement of Cooling Systems
- (5) Closing the Loop by Requiring Mandatory Periodic Audit of Energy Efficiency of Building Cooling System for All Buildings



## **Mandating a Minimum Environmental Sustainability Standard for Building Development**

To step up our efforts in driving environmental sustainability in buildings, BCA has taken the decisive steps to introduce a mandatory minimum standard of environmental sustainability known as the Building Control (Environmental Sustainability) Regulations in Apr 2008. This regulation requires developers and owners of new building projects as well as existing building projects involving major retrofitting (with Gross Floor Areas of 2000 m<sup>2</sup> or more) to meet the compliance standard which was modelled after the basic Green Mark certified standard. Compliance with the standard is required before building plan can be approved. Site audit will be conducted by BCA where needed to ensure that the design intent for environmental sustainability submitted is implemented before issuance of the Temporary Occupation Permit (TOP).

The minimum environmental sustainability standard covers performance based requirements that necessitate the use of cost-effective energy saving technologies, design strategies, construction methods and operational monitoring. Under this requirement, their design practitioners appointed by the developers or owners would have to ensure that the building design meet at least 28% energy efficiency improvement from 2005 codes along with other salient aspects of environmental sustainability such as water efficiency, indoor environmental quality, environmental management and the use of green building technologies. As building cooling systems can account for more than 50% of the total electricity consumed in a typically air-conditioned building, having more energy efficient ones would help reap a significant portion of the energy savings during building operations. Coupled with the fact that these systems have a long lifespan lasting 15 to 20 years before replacement, it becomes crucial to ensure that new air-conditioning systems installed are of higher energy efficiency in the first instance and subsequently operated in an efficient manner. For this, the standard stipulate the use of better energy efficient air-conditioning systems<sup>2</sup> to be installed, which would benefit the building owners with more energy savings in the long run.

Recognising the barriers to achieving optimal energy performance during building operations is the lack of adequate metering and energy monitoring equipment, the standard also incorporates provision to require buildings to be equipped with suitable means for the monitoring of energy efficiency of the air-conditioning systems, so as to facilitate energy improvement opportunities. With these devices, building owners would be able to track and pro-actively improve the energy performance of their buildings during operation. On a whole, it is evident that the minimum environmental sustainability standard successfully provided a baseline to drive and integrate green building design and technologies into the mainstream design practices over the years. Integrating the mandatory requirement with the building plan process has also effectively created a greater pool of industry practitioners including builders motivated in green building design and practices. The adoption of the BCA

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<sup>2</sup> The minimum environmental sustainability standard spells out the prescribed air-conditioning system efficiency which are higher than the current code requirement (i.e. SS 530 & SS553) for compliance. For example, air-conditioning system efficiency should be better than 0.7 kW/ton for basic Green Mark project.



Green Mark standard into the legislative framework has also created a common language or platform on sustainability issues among practitioners, providing a consistent approach and drive in accelerating the development of green buildings locally.

### **Setting Mandatory Higher Green Mark standards for Government Land Sales Sites**

With increased capacity and knowledge on the benefits of sustainable development among industry practitioners, BCA has mandated higher Green Mark standards under the Government Land Sales Programme in May 2010, to further enhance the environmental sustainability of our built environment. This requirement applies to key development areas which include Jurong Lake District, Kallang Riverside, Paya Lebar Central and Marina Bay/Downtown Core. This would help achieve a significant impact in energy efficiency improvement of at least 38% over the 2005 codes. The development of these areas in an environmental sustainable manner, could also be showcased locally and internationally as exemplary for sustainable development. Under this requirement, developers who are interested in bidding the lands in these districts are required to ensure their new building developments are certified to meet the Green Mark Platinum or Gold<sup>Plus</sup> standards as stipulated in the land sale tender conditions. If the developer fails to submit evidence of achieving the intended Green Mark rating, the clearance for Temporary Occupation Permit (TOP) can be held back under the Building Control Act. The minimum environmental sustainability standard spells out the prescribed air-conditioning system efficiency which are higher than the current code requirement (i.e. SS 530 & SS553) for compliance. For example, air-conditioning system efficiency should be better than 0.7 kW/ton for basic Green Mark project.

### **Establishing National Energy Benchmarks through Annual Mandatory Submission of Building Information and Energy Consumption Data**

From 1 July 2013, building owners are required to submit their building information and energy consumption data annually to BCA. In the initial phase, only building owners with hotels, office buildings, retail buildings and mixed developments are required to submit data. The requirement will be further extended to other building types in phases. The intent of this requirement is to establish and facilitate a national energy benchmarking system. The data collected will be shared to enable building owners to benchmark and compare their building performance against other similar building type. This will help motivate them to take proactive actions to improve their building's energy profile and to manage their building's energy cost. With availability of data, BCA will also be able to monitor energy consumption patterns and evaluate the effectiveness of various initiatives that have been adopted to improve energy efficiency in buildings. Currently, the requirement does not directly require public disclosure of the energy performance of individual buildings. Energy consumption data will be obtained from the utility suppliers without the need for building owners to submit the data individually and separately to BCA.

### **Prescribing Mandatory Minimum Environmental Sustainability Standard for Existing Buildings Undergoing Installation or Replacement of Cooling Systems**



As existing buildings constitute more than 90% of our total building stock, there is scope to improve their energy efficiency standard to contribute to Singapore's carbon abatement. It is pertinent to ensure that these buildings are equipped with better building cooling systems when retrofitted and continue to operate efficiently throughout their life-cycle. To improve the energy efficiency standard of existing building, BCA has imposed a minimum environmental sustainability standard based on the basic BCA Green Mark standard for existing buildings with effective from Jul 2013. Building owners will need to ensure that their existing buildings meet this standard when they install or replace their building cooling system. In the initial phase, the requirement to meet the minimum standard will apply to hotels, retail buildings and office buildings with gross floor area (GFA) of 15,000m<sup>2</sup> or more and in the process of installing/replacing a central air conditioning system. There is also pre-requisite to require the building cooling system installed to meet certain specified design system efficiency (DSE). The standard also prescribes the installation of permanent measurement and verification instrumentation for the monitoring of the energy efficiency of central air-conditioning system.

To comply with the minimum environmental sustainability measures stipulated in the Regulations, the building shall achieve a minimum Green Mark score of 50 points and meet the pre-requisite requirements. Before commencement of the replacement or retrofitting works, the building owner shall appoint a Professional Engineer (Mechanical) to assess the design of the retrofitting works, prepare the Green Mark design score; provide the documentation of the design score that meets the minimum environmental sustainability standard and such other documents required in the Regulations before the commencement of the retrofitting works. The retrofitting work must be commenced and completed not later than the period granted. Upon completion of the installation or replacement works, the Professional Engineer shall assess and prepare the as-built Green Mark score that meets the minimum environmental sustainability standard, and provide to the building owner the documentation of the as-built score, completion certificate and such other documents for submittal to BCA within the period prescribed in the Regulations.

With the requirement to meet the minimum Green Mark standards for buildings undergoing installation/replacement of their cooling systems, building owners can take the opportunity to relook at their existing building cooling systems and make improvements to them and also to other parts of the buildings to achieve greater energy savings. By meeting the minimum standard, building owners can expect to achieve a minimum 25% improvement in energy efficiency as compared to 2005 codes and will stand to benefit from lower energy bills during operation.

### **Closing the Loop by Requiring Mandatory Periodic Audit of Energy Efficiency of Building Cooling System for All Buildings**

While buildings may be designed and installed with energy efficient cooling systems, operating these systems at an optimum performance level would be of paramount importance to ensure that the intended energy savings will be realised. By carrying out periodic energy





audit of cooling systems would help ensure that the systems continue to operate as efficiently as per initial design throughout their life span, allowing building owners to continuously reap the energy saving benefits as intended. With effective from 1 Jan 2014, building owners are required, upon notice from the Commissioner of Building Control, to engage the services of a Professional Engineer (Mechanical) or an Energy Auditor registered with BCA to carry out an energy audit on the building cooling system and to make the energy audit report within stipulated timeframe for approval. For existing buildings which have undergone retrofitting, owners will have to conduct their first energy audit of the building cooling system together with the submission of the as-built Green Mark score upon completion of the retrofitting works; and subsequently, to conduct energy audits in 3 yearly intervals from their last audit. As for new buildings with centralised chilled-water cooling system which are required to comply with the enhanced Green Mark standards for new buildings implemented on 1 December 2010, building owners will have to conduct their first audit within one year from the date of the first temporary occupation permit or certificate of statutory completion; and subsequently, to conduct energy audit of the system in 3 yearly intervals from the last audit. If the cooling system does not meet the applicable prescribed energy efficiency standard, building owners would have to take measures in relation to the cooling system to ensure that it meets the applicable prescribed standard.

## **Conclusion**

Singapore is one of a very few countries to close the loop by ensuring that a building that is designed and constructed as a green building would continue to operate efficiently through its life cycle. Under this legislation in Singapore, a building is required to be retrofitted to meet a minimum environmental sustainability standard, when it undergoes installation/replacement of its cooling system. This innovative measure will raise the overall building's energy efficiency from the beginning. Coupled with the three-yearly energy audit of the cooling system (which constitutes usually 50% to 60% of a total building's energy consumption), a building can remain energy efficient throughout life cycle. At the end of its life cycle, the process would repeat itself, as a building would again be retrofitted to high energy efficiency standards to comply with the minimum environmental sustainability standards.

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## Sustainability Labelling for Building Standards

*Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee*

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**Abstract:** *In Scotland building regulations set standards for the health, safety and welfare of persons in and around buildings, furthering the conservation of fuel and power and furthering the achievement of sustainable development. These standards are supported by guidance contained in a set Technical Handbooks, and apply to new buildings and to buildings being converted, altered or extended. In May 2011 sustainability labelling was introduced to Scottish building regulations. Applicable to all new buildings, the principles build upon the degree of sustainability already embedded within the building regulations. The labelling system in Section 7 of the Technical Handbooks rewards new buildings that meet the 2010 building standards with a Bronze level label. Further optional upper levels are defined by Silver, Gold and Platinum. These have been created through identifying cost-effective benchmarks verifiable through the building standards system. Section 7 has been fully developed for dwellings and school buildings. However for all other non-domestic only carbon dioxide (CO<sub>2</sub>) emissions can be assessed. Section 7 also includes an indicator that identifies whether buildings incorporate a low or zero carbon generating technology (LZCGT). The criteria for each sustainability level seeks to balance the social, economic and environmental aspects associated within the scope of sustainability, addressing issues such as resource use through carbon dioxide emissions, energy efficiency and water use, enhanced biodiversity, improved occupant wellbeing, and flexibility and adaptability in design.*

### Introduction

Sustainability is a broad and complex term that means different things to different people. Addressing issues such as climate change, pollution, the wasteful use of finite resources, population well-being, habitat destruction and species loss, as well as the harnessing of renewable energy. However the fundamental aim of sustainability is to live within the capacity of the planet and secure a future for forthcoming generations. More often than not it is simply a worthy lesson in common sense. The definition for sustainable development is neatly reinforced in the Bruntland commission's report.

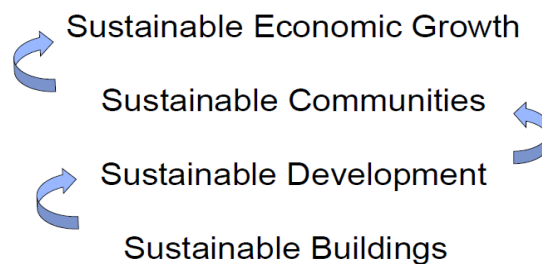
*“meeting the needs of the present without compromising the ability of future generations to meet their own needs”*

Brundtland Commission of U.N 1983

It is therefore prudent that the process of sustainable development and the quality of 'sustainability' within the built environment should account for:

- social, economic and environmental factors;
- the potential for long-term maintenance of human wellbeing in and around buildings;
- the wellbeing of the natural environment and the responsible use of natural resources;
- the capability for the built environment to be maintained.

Sustainable buildings have a positive impact on occupant well-being, whilst minimising the use of finite resources including land and water, as well as fossil fuels which are a major contributor to carbon dioxide (CO<sub>2</sub>) emissions and Climate Change. For a building to be considered sustainable, it must demonstrate that a wide range of factors are considered in its design and construction. The building standards in Scotland focus specifically on buildings and their immediate curtilage, therefore a bottom-up approach was devised for developing a framework for measuring and assessing sustainable buildings.

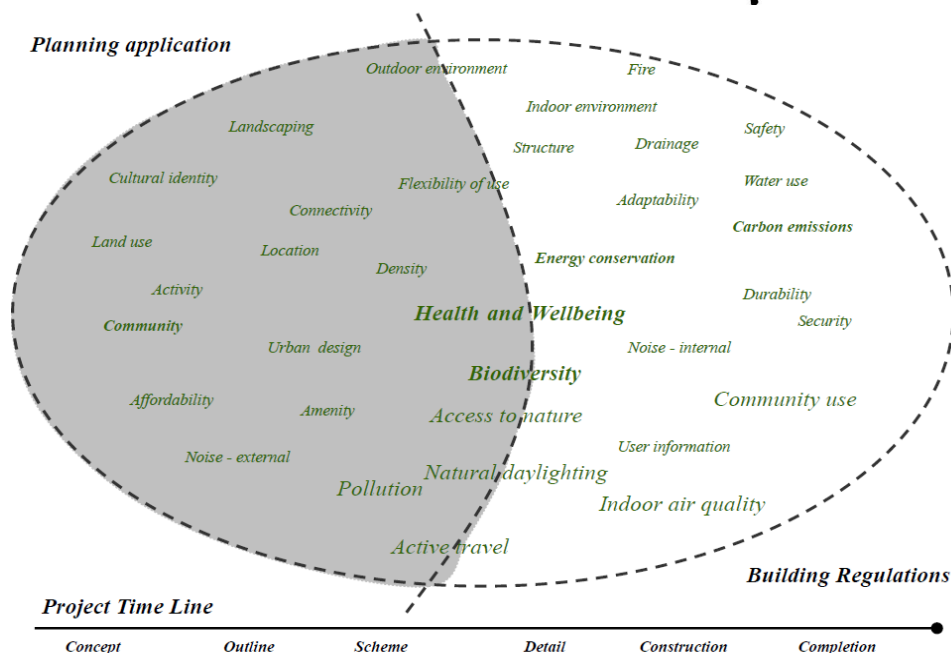


*Figure 1 - Sustainable model for Scottish Government*

### **Defining sustainability for building standards**

When the Scottish Government's Building Standards Division sought to define sustainability for the built environment it was established that the approach to sustainable development should be holistic encompassing a large number of topics (see fig 2). However to avoid these topics becoming meaningless they need to be broken into defined parts. Some of the issues to be addressed in defining sustainability in the built environment were considered to be easily quantifiable such as, structure, noise and land use, and some less so, such as cultural activity and amenity but all issues matter to some degree when trying to balance sustainability. Each of the topics can be broadly addressed in each of the following statutory processes:

- 1st statutory application: Planning Permission - addresses issues relevant to land use, location and amenity
- 2nd statutory application: Building Warrant (permit) – addresses technical detail on the construction and layout of individual buildings



**Figure 2 – Topic Cluster**

From the above cluster, sustainability for building standards was able to be distilled from the topics into 3 key areas:

- Resource use – including energy, water, fuel and land use looking at how finite resources are accessed
- Well-being – improving quality of life and being able to deliver lasting benefits to building occupants and users
- Flexibility – maximising the efficiency of building by encouraging buildings to be able to be used for multiple purposes

### **Drivers and influences and how these helped shape proposals**

The key purposes of the Building (Scotland) Act is to:

- (i) Secure the health, safety, welfare and convenience of persons in or around buildings:
- (ii) Further the conservation of fuel & power and
- (iii) Further the achievement of sustainable development.

The Act was the first clear driver that enabled sustainability to be addressed through building standards. Prior to 2011, this had been addressed by progressively embedding sustainability aspects within building standards. A further driver was the Sullivan report. The report was the output produced by an expert panel appointed by Scottish Ministers to advise on a low carbon buildings standards strategy for Scotland. It made recommendations across a wide range of topics, including on the delivery of very low carbon buildings through building regulations, in support of climate change objectives. A further legislative driver was the Climate Change



(Scotland) Act 2009, this set a framework allowing Scotland further responsibility for their Green House Gas emissions by setting legally binding targets to reduce emissions and mitigate climate change. The fourth and probably most important driver/influence is market demand, this set aspirational design levels beyond minimum regulations and standards and allows applicants to gain formal recognition for achieving so. For example environmental assessment methodologies such as, Passiv-haus, BREEAM and LEED are very useful tools which demonstrate the complexities in addressing sustainability through the built environment.

### **Sustainability for building standards**

The introduction of sustainability labelling enabled Building Standards to measure, encourage, and recognise sustainability in the construction process. Voluntary upper levels were developed in conjunction with industry, by identifying cost-effective benchmarks verifiable via the building standards system. This allowed those with environmental ambitions to demonstrate their 'green' credentials by encouraging:

- lower carbon buildings;
- efficient use of resources such as energy and water; and;
- progressive sustainable design

Although energy efficiency and CO<sub>2</sub> emissions forms a key part of any sustainability agenda, it was established for a building to achieve an enhanced levels of sustainability , it must be demonstrated that a balanced range of measures have been considered in design and achieved in construction.

### **How does it work? Levels of sustainability**

In 2011 sustainability labelling was included in the Technical Handbooks, this awarded new buildings that met the 2010 building standards with a Bronze level label. Further optional upper levels of sustainability were defined by Silver, Gold and Platinum labels (see fig 3). The labelling system also includes an indicator for buildings which incorporates a low or zero carbon generating technology (LZCGT) identified with an 'Active' marking. The initial level of sustainability labelling (the 'bronze' level) which all buildings will achieve demonstrates that a building complies with the minimum building standards applicable at the time of application. The rationale for this is to differentiate between buildings constructed prior to 2010 and acknowledge the considerable improvements recently made to standards. These include improvements to energy standards, adoption of some of the lifetime homes principles and improved security standards.





**Figure 3 - Sustainability levels**

The ‘silver’ and ‘gold’ levels are voluntary defined by criteria relating to the design and construction process. The Silver level has been developed to recognise best practice in the industry, and encourage those who may not typically wish to build beyond minimum regulations. The gold level has been set as a more challenging and demanding target to promote and reward those seeking to produce exemplar buildings. A Platinum level has been identified for future scope and development.

The Sustainability labelling system was fully developed for domestic buildings and a CO<sub>2</sub> Aspect introduced to all non-domestic buildings. For October 2013 sustainability labelling for school buildings was developed on the principles explored for domestic buildings with the intention of this being a pathfinder to expand sustainability to other non-domestic buildings. Issues defined within building standards legislative control were identified. These can be assessed by verifiers during the building standards process. ‘Aspect’ is the term used for a subject area of sustainability (see fig 4). Level is the term used as a grouping, where all of the 8 individual aspects of sustainability have achieved the criteria set out in the guidance. To obtain a label the level of sustainability must be specified during the design stage, the building will have to be constructed in accordance with the drawings and specification. On completion a sustainability label is created using customised software and the label affixed to a building and a copy sent to a register. Sustainability labelling for building standards differs from other existing voluntary codes (e.g. BREEAM) which allow for the trading off of topics against each other. The labelling system has fixed requirements all of which must be achieved in order to achieve each level. Each aspect addresses issues which are directly allied to the building standards system and relate to the technical, environmental and functional performance issues of design and construction as well as supporting this with information useful in the efficient operation of a building. The validation of the system is part of the normal building warrant process therefore to achieve an upper level of sustainability an additional assessment fee is not required. The eight aspects for both domestic and non-domestic school buildings are summarised in the table below.

| <b>Domestic</b>          | <b>Non-Domestic (school buildings)</b> |  |
|--------------------------|--|--|
| Carbon dioxide emissions | Carbon dioxide emissions               |  |
| Energy for space heating | Energy efficiency                      |  |
| Energy for water heating | Water efficiency                       |  |

|                              |                              |  |
|------------------------------|------------------------------|--|
| Water use efficiency         | Biodiversity                 |  |
| Optimising performance       | Optimising performance       |  |
| Flexibility and adaptability | Flexibility and adaptability |  |
| Wellbeing and security       | Wellbeing                    |  |
| Material use and waste       | Material use and waste       |  |

**Figure 3 - Sustainability Aspects**

### Who is it for?

Sustainability labelling can be utilised by developers or planners who may wish to demonstrate their environmental commitment by referring to the sustainability labels. The system can also be used by Local Authorities or developers to gain recognition for building to higher standards and potentially to obtain market advantage. Organisations' funding bodies may choose to make constructing to higher level of sustainability a condition of statutory approval or funding. The topics included have been developed to complement and support other initiatives that promote sustainability. The introduction of the labelling systems also increases the likelihood that sustainability is considered as a first principle during the design process.

### Benefits

In Scotland Building Standards are recognised as effective, and valued by industry and the public alike. By continuing to embed sustainability within regulations rather than referring to other environmental standards is considered valuable, and the continuity this brings is welcomed. This has been well received by industry for its clarity and ambition. Sustainability labelling does not need to be an additional burden on development as the initial level of award (bronze and bronze active) recognises that a development has already achieved a measure of sustainability by simply complying with current building regulations. One of the advantages of the system is that it removes the need for the involvement of external assessors such as those used in the delivery of environmental assessment methodologies such as BREEAM. The process is delivered through the existing Building Standards system, verified by each Local Authority as part of a statutory application required by law and intended to deliver a consistent national sustainability standard.

The system was developed to offer convenience and simplicity as well as adding little or no additional cost to the design and verification process other than for those who opt to achieve the higher levels. The structure was designed to enable each of the 8 individual aspects of sustainability to be clearly identified, easily measured, and even referred to individually where required. With energy standards continuing to improve and the introduction of the Climate Change (Scotland) Act 2009, there are signs that Local Authorities are less inclined to create their own carbon reduction targets applicable to individual buildings. A single national standard for sustainable buildings points towards a more measured approach. Some Planning departments have referenced the Building Standards sustainability standards when preparing policies on carbon reductions within Local Development Plans. The more recent

development of introducing sustainability for all aspects of new non-domestic school buildings would provide a system that could be used consistently throughout Scotland aligning with calls from funding bodies. Without Scottish Government intervention, sustainability labelling will only be the preserve of those who are prepared to pay extra for an assessment. This also supports many of the Scottish Government's Strategic Outcomes. The range of topics addressed in sustainability labelling was developed following considerable discussion and collaboration with other Scottish Government departments and associated agencies. In many instances organisations were able to refer to aspects of the sustainability system in support of their Policy delivery. For example Scottish Water have provided funding to install the water efficiency measures defined in new social housing. Also, measures that formed part of the voluntary upper levels of sustainability for water efficiency have now been incorporated into building regulations. Additionally the Scottish Government Division responsible for social housing have made available funding for newly constructed social housing to meet the first voluntary upper levels for CO<sub>2</sub> emissions and energy efficiency standards. Included as part of the sustainability criteria for new school buildings is the provision of a user guide to enhance biodiversity and promote ecology. This has received broad support from Scottish National Heritage (the national body responsible for promoting and caring for the natural heritage) and widely promoted by the Scottish Government across the existing school estates. The system was also developed to give planning authorities a consistent route to achieve their obligations under Section 72, of The Climate Change (Scotland) Act 2009 in relation to the use of low and zero carbon generating technologies. Scottish Government is now in discussion with the Building Research Establishment to incorporate sustainability labelling within BREEAM for Scotland, this will allow those seeking to address issues of sustainability not verifiable through building regulations the opportunity to do so.

### **Summary of key benefits**

- Obtaining recognition in achieving the level of sustainability achieved by meeting the current building regulations, without additional assessment costs.
- Providing home buyers and building owners, directly, with information on the level achieved.
- Setting standards to allow industry to achieve aspirational upper levels of sustainability, which would be officially recognised.
- Providing a simpler approach to achieving sustainability compared to other more complex and tradable assessment processes.
- Creating a 'level playing field' for all of industry, not disadvantaging either smaller or larger businesses.
- Reducing carbon dioxide emissions and energy demand from new buildings, when constructed to the silver and gold levels.
- Supporting the Government's agenda to tackle climate change and promoting sustainable development in Scotland.



- Reducing use of finite natural resources and promoting development and adoption of systems that incorporate renewable energy sources.

## Building Standards

## Sustainability

At completion, the building achieved the specified level of sustainability in the aspects below:



- Platinum
- Gold Partly Achieved
- Silver Achieved
- Silver Active Achieved by use of the following technology: solar thermal panels
- Bronze Sections 1-6, 2010 Standards

**Building / Development:**

**Building Warrant Reference:**

**Date:**

15 June 2011

### Building Standards Division's Technical Handbooks

Contain detailed guidance on the measures to achieve the levels within each aspect of sustainability. See Building Standards pages on [www.scotland.gov.uk](http://www.scotland.gov.uk)

This statement of sustainability for a new building must be fixed within the building in accordance with standard 7.1.



## Building Regulatory Control in Facing the Challenge of Climate Change: a case of Hong Kong

*Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee*

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Chi-kwong CHAN,<sup>1</sup> Edwin H W CHAN<sup>2</sup> and Queena K. QIAN. Building and Real Estate Department, Hong Kong Polytechnic University, Hung Hom, Kowloon, HKSAR ([cckwong01@netvigator.com](mailto:cckwong01@netvigator.com), [bsedchan@polyu.edu.hk](mailto:bsedchan@polyu.edu.hk)) – *Building Regulatory Control in Facing the Challenge of Climate Change: a case of Hong Kong*

**Abstract:** *Facing the challenge of climate change, global actions are required to reduce energy consumptions in various economic sectors. Buildings consume a significant amount of electricity generated from fossil fuels, and governments worldwide are seeking solution to reduce energy consumption in buildings. Buildings worldwide not only exhibit poor energy performance, but also pose adverse impacts to the built environment. This paper review the regulatory control for buildings in Hong Kong in the face of climate change and the findings are commented with suggestions for further study.*

**Keywords:** *Buildings Ordinance, Building Energy Efficiency, Overall Thermal Transfer Value, building environmental assessment*

### Introduction

The residential and commercial buildings sector in many countries consumes 25 – 50% of the total energy of the countries and contributes a significant amount of GHG emissions (OECD, 2003). Like many cities, the building sector In Hong Kong consumes most of the total energy and contributes a significant proportion of GHG emissions, and thus implementation of appropriate regulatory control of energy conservation in buildings is a significant concern of local governments. This paper provides an overview of the regulatory control on buildings in Hong Kong Special Administrative Region (HKSAR) in response to the mitigation of climate change. Since early 1990s, green building practice has been emerging to address the issues of the negative impacts posed by the building construction to the built environment. Green buildings pursue efficient use of land, energy, water and natural resources, improvement of indoor and outdoor built environment. However, the interpretation of green buildings can be various, and sometimes the terms green buildings and sustainable buildings are used vice versa (Adshead, 2011). These buildings involve evaluation of a majority of interactions between buildings and their environments. Moreover, one of the key characteristics of green buildings is to use energy more efficiently than conventional buildings, otherwise it is not persuasive that green buildings are actually green (Howe and Gerrard, 2012). The publication of Building Research Establishment Environmental Assessment Method (BREEAM) of Hong Kong in 1990, attempts to establish comprehensive approach to assess a wide range of environmental performance of buildings emerged (Cole, 1998).

### Buildings Energy Efficiency in Hong Kong

Implemented on 16 February 2005, the Kyoto Protocol defined binding obligations on developed countries for the reduction of GHG emissions by an average of 5.2% (UNFCCC, 2013). China ratified the Kyoto Protocol as a developing country (Non-Annex I Party) on 29 May 1998 (China Daily, 2000). Under the Protocol, China has no binding reduction target of GHG emissions to be achieved. Although Hong Kong, being a special administrative region of China, is not a party to the Kyoto Protocol, the Central Government of China decided according to Article 153 of Basic Law of Hong Kong, that the Kyoto Protocol shall be applied to Hong Kong with effect from 5 May 2003 (EPD, 2007), even though there is no binding GHG emissions reduction target to be achieved by Hong Kong. However, as a member of the Asia-Pacific Economic Co-operation (APEC), The Government committed on 8 September 2007 in the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development held in Sydney to achieve a reduction in energy intensity of at least 25% from 2005 level by 2030 (China View, 2007; EPD, 2008). The energy intensity is referred to as amount of energy end-use consumed in producing a unit of gross domestic product (EMSD, 2013). In September 2010, The Government issued *The Hong Kong's Climate Change Strategy and Agenda Consultation Document 2010* in which, The Government aimed at reducing the energy intensity of the territory by 50% - 60% by 2020 as compared to 2005 (HKSAR, 2010).

### **Intensive Energy Consumption and GHG Emissions**

The energy types available to Hong Kong are mainly oil and coal product, town gas and liquefied petroleum gas (LPG), and electricity (EMSD, 2013). While the consumption of oil and coal products was decreasing, and the usage of town gas and LPG was at a steady rate, the electricity consumption in Hong Kong was increasing rapidly. Statistical records revealed that electricity consumptions were 48% in 2000 and 54% in 2010 of the total energy consumption of the territory. The rate of increase was amount to 1.5% per year as compared to that at 2000, and 1% per year as compared to that at 2005. The saving of consumption of oil and coal products was offset by the increases in the consumptions of electricity. Moreover, there is no sign of decrease in electricity consumption (EMSD, 2013). The key sectors of electricity consumption in Hong Kong are residential, commercial, industrial, and transport sectors (EMSD, 2013). The first and second sectors are generally referred to as building sector which is the biggest electricity consumer among the other two sectors. Electricity consumption in building sector is mainly for the space conditioning, lighting, refrigeration, cooking, water heating, office equipment, laundry and industrial process. And the building sector consumed more than 90% of total electricity consumptions of the territory since 2007, and 92% in 2011. As at 2010, the rates of increase in electricity consumption are 26% and 10% as compared to 2000 and 2005 respectively. As far as GHG emissions are concerned, the total GHG emissions in Hong Kong grew from 35,300 kilotons in 1990 to 41,500 kilotons in 2010. Figure 1 illustrates the increasing trend of GHG emissions in Hong Kong for the period between 2000 and 2010. With reference to the distribution of different energy types and the amount of electricity consumption in building sector, the contribution of GHG emissions by

the building sector can be amounted to 60% (HKSAR 2010). Therefore the building sector in Hong Kong provides a challenge to large scale reduction of GHG emissions.

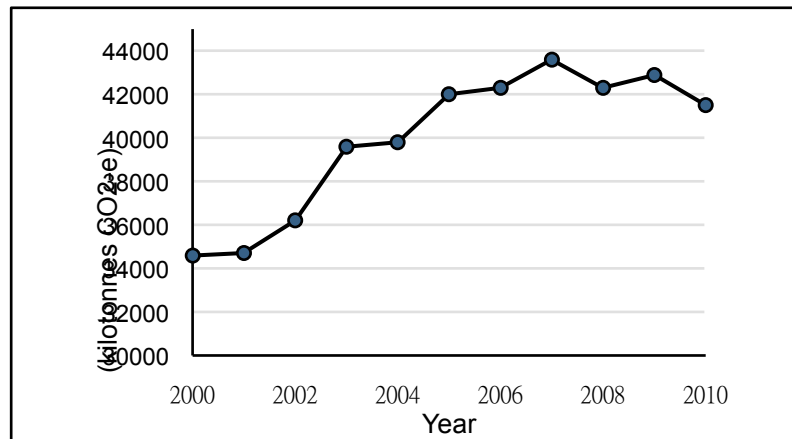


Figure 1 – GHG emissions (in terms of Carbon) in Hong Kong [Data retrieved from (EMSD, 2013a)]

### General Framework for Building Controls in Hong Kong

The earliest legislations related to building construction were probably the ‘Ordinance for the Preservation of Order and Cleanliness within the Colony of Hong Kong’ enacted in 1844, ‘Buildings and Nuisances Ordinance’ enacted in 1845, and ‘Public Health Ordinance’ in 1887. These legislations set out requirements for the construction of buildings and the associated basic sanitary facilities as overcrowding and insanitary living environment were prevailing in those years. Since 1889, Buildings Ordinance was firstly promulgated to improve the structural stability and sanitary condition of buildings. Although major amendments of the Ordinance were then made in 1935 and 1955, the control of buildings was closely linked to matters relating to structural safety, fire safety and sanitation of buildings (McInnis, 2000). The current regulatory control of the planning, design and construction of buildings comprise four major instruments enforced by the Building Authority. These instruments are:

- The main legislation
- Subsidiary regulations
- Code of Practice
- Practice Notes

### Regulatory Control of Energy Conservation in Buildings

Following the first oil crisis in 1973, The Government issued in 1979 guidelines for the design of electrical installation in government buildings as a first step towards energy conservation in buildings (EMSD, 2004). In 1995, the Government enacted Building (Energy Efficiency) Regulation (B(EE)R) which requires building envelope of commercial buildings and hotels shall be designed with a suitable Overall Thermal Transfer Value (OTTV). Under the B(EE)R, OTTV is defined as the amount, expressed in watts per square metre (W/m<sup>2</sup>), of

heat transferred through that building envelope and calculated having regard to factors such as the area of the building envelope, the material used in its construction, thermal properties of the material, orientation of the building, the area of the openings in the building envelope and the shading effect of projections from the building envelope. In other words, the OTTV represents a measure of thermal transmission through the façade and roof of a building, and implies that the lower the OTTV the better thermal performance of a building (Building Authority, 1995). Under the Buildings Ordinance and B(EE)R, the OTTVs of all new commercial buildings and hotels are subject to approval prior to application for the commencement of the construction of the commercial buildings and hotels (PNAP No. APP67, 2011). In practice, suitable OTTV of commercial buildings and hotels are applied to the tower portion and podium portion of the building, and stipulated in Code of Practice of Overall Thermal Transfer Value in Building 1995 issued by Buildings Department. Table 1 tabulates the suitable OTTV of the requirements.

| Application of OTTV             | Effective from year |                     |                     |
|---------------------------------|---------------------|---------------------|---------------------|
|                                 | 1995                | 2000                | 2011                |
| In the case of a building tower | 35 W/m <sup>2</sup> | 30 W/m <sup>2</sup> | 24 W/m <sup>2</sup> |
| In the case of a podium         | 80 W/m <sup>2</sup> | 70 W/m <sup>2</sup> | 56 W/m <sup>2</sup> |

Table 1 – Overall Thermal Transfer Values for Commercial Buildings and Hotels

In addition to OTTV control, EMSD published the following voluntary building energy codes: the Code of Practice for Energy Efficiency of Lighting Installations in 1998, the Code of Practice for Energy Efficiency of Air Conditioning Installations in 1998, the Code of Practice for Energy Efficiency of Electrical Installations in 1999, and the Code of Practice for Energy Efficiency of Lift and Escalator Installations in 2000.

As the five Code of Practice issued by the Buildings Department and EMSD are principally prescriptive standards, EMSD further issued Performance-based Building Energy Code (PB-BEC) in 2004. By the performance-based approach, the overall energy consumption is allowed to be estimated taking into account of thermal transfer through the building envelope and the energy consumption of electrical equipment including the lighting, air-conditioning, fixed electrical, and lift and escalator systems. In other words, designers are allowed to adopt flexible approach in designing the energy efficiency in buildings (EMSD, 2007). The Government further enacted in September 2012 Building Energy Efficiency Ordinance (BEEO) requiring developers of new building projects and major retrofitting projects to submit declaration notifying compliance the requirements of the relevant building energy codes. Under the BEEO, the coverage of regulatory control has been extended from commercial buildings and hotels to include common areas of residential and industrial buildings, schools and hospital (BEEO, 2010). Under the BEEO, owners of commercial buildings and hotels shall made first declaration to EMSD within 2 months from the date of granting consent for the commencement of the construction of the building works granted by the Building Authority, and the second declaration shall be submitted to EMSD within 4 months from the date of obtaining occupation permit of the building granted by the Building



Authority. The BEEO also mandates commercial buildings to conduct energy audit every 10 years (EMSD, 2013b).

### **Policies and Incentives to Promote Green Building**

In April 2009, the HKSAR government launched the “Buildings Energy Efficiency Funding Scheme (BEEFS)” allocating with HK\$450 million funding in order to provide financial incentive to owners of private buildings to conduct “Energy-cum-carbon Audits Projects” and “Energy Efficiency Improvement Projects” (ECF, 2013). The Energy-cum-carbon Audit Projects aimed at encouraging owners of existing buildings to carry out systematic review of energy consumption and GHG emissions and identify opportunity for improvement of energy efficiency and reduction of GHG in their buildings. Under the Scheme, the common areas of residential, commercial or industrial buildings were covered. Furthermore, the audit should be carried out in accordance with the requirements of “Guidelines to account for and report on GHG Emissions and Removals for Building (Commercial, Residential and Institutional purposes) in Hong Kong; and Guidelines on Energy Audit published by The Government of HKSAR (ECF, 2013). Energy Efficiency Improvement Project intended to encourage owners of existing buildings to upgrade the energy performance of lighting, electrical, air-conditioning and lift and escalator installations of their buildings through the carry out of alteration, addition or improvement works. Under the Scheme, applicants were required to engage qualified persons to certify the scope of the project, justify cost effectiveness, supervise and certify completion of the improvement works. There were requirements that on completion of the project, the fixed electrical equipment or installations had to comply with the standards stipulated in the building energy codes issued by the EMSD (ECF, 2013). However, the BEEFS only covered the communal areas of buildings and was terminated in April 2012. By the end of April 2012, there were 72 applications for Energy-cum-carbon Audit Projects and 984 applications for Energy Efficiency Improvement Projects approved (ECF, 2013).

In 1996, a non-profit organization HK-BEAM Society launched a scheme known as Building Environmental Assessment Method (BEAM) for assessment of environmental performance of office buildings. Following several updates and revisions, the current version of the assessment scheme is renamed as “BEAM Plus” and embraces a wide range of new and existing buildings, including residential, commercial, institutional, and industrial buildings (BEAM, 2013). In 2009, The Government announced that all new government buildings with construction floor area more than 10,000 square meters should aim to obtain at least ‘Gold’ rating under BEAM Plus (HKG Press Release, 2009). Furthermore, since 2011, the Building Authority allows curtain walls to be projected over streets if the curtain walls meet certain standard of the BEAM Plus (PNAP APP-2, 2011). The assessment of BEAM Plus covering energy efficiency aspect and conferred by the HKGBC is also considered as requirement for granting additional floor areas of building projects (PNAP APP-151, 2011). In addition, there are other key Initiates for Building Energy Efficiency including:

- *Wider Use of Water-Cooled Air Conditioning System:* a ‘Pilot Scheme for Wider Use of





Water-Cooled Air Conditioning System' was launched in 2000.

- *Energy Efficiency Registration Scheme for Buildings*: since 1998, the EMSD established an Energy Efficiency Registration Scheme for Buildings in 1998.
- *Energy Audit Program*: from 1994, the EMSD conducted survey of all major government buildings.
- *Establishment of Appliance and Equipment Labeling Scheme* : since 1995 EMSD has administered a voluntary scheme for energy labeling of appliances and equipment used in home and office.

### **Future Development**

Although the regulatory control of the planning, design and construction of buildings in Hong Kong has been amended since 1995 to address the energy conservation in buildings, there are critics about the control system, incentives and the initiatives. As observed by Adshead (2011) that coupling with the issue of energy efficiency in buildings are that buildings: (a) consume a great amount of natural resources in terms of land, natural material, and water resources; (b) generate a great amount of solid waste, and sewerage; and (c) emit large quantities of pollutants (UNEP 2007a, OECD 2003). Adoption of green building practice rather than sole regulating the energy efficiency of building is recognized as a key strategy to tackle the climate change (Adshead, 2011). The Government of HKSAR issued in 2010 consultation document named "The Hong Kong's Climate Change Strategy and Agenda Consultation Document 2010" in which, the following relating to energy use in buildings have been proposed by HKSAR: promoting use of energy meters, sensors and communication links that help property management to control energy consumption in major equipment in commercial buildings; and, expanding the current energy labeling scheme for electrical appliances.

### **Conclusion**

The current regulatory control of the buildings is administrated under the Buildings Ordinance which is originated from the legislations that aim at improving the structural safety, fire safety and sanitary conditions of the built environment. The Government made a major amendment to the Ordinance and enacted a few building energy efficiency related regulations over the years to address energy conservation in buildings. Until the implementation of Building Energy Efficiency Ordinance in 2012, methodology for complying with the requirements stipulated in Building (Energy Efficiency) Regulation includes performance-based approach by which the overall energy consumption may take into account of thermal transfer through the building envelope and the energy consumption of electrical equipment including air-conditioning system. Although various measures or initiatives have been adopted by The Government, most of them are not building works related. Future studies should embrace innovation in the current building control system of Hong Kong to achieve large scale enhancement of the built environment.

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## **Sustainability, resilience and risk in earthquake-prone areas: Lessons for building regulators from the Canterbury earthquakes**

### **Author:**

Mike STANNARD, Chief Engineer, Ministry of Business, Innovation & Employment (MBIE), New Zealand ([Mike.Stannard@mbie.govt.nz](mailto:Mike.Stannard@mbie.govt.nz)) – *Sustainability, resilience and risk in earthquake-prone areas: Lessons for building regulators from the Canterbury earthquakes*

**Abstract:** *The Canterbury earthquake sequence has been an outlier internationally in both scale and complexity of consequences. Using a risk, resilience and sustainability framework, issues are highlighted and lessons drawn for building regulators addressing natural hazards.*

**Key words:** *Canterbury earthquakes, risk, resilience, sustainability*

### **Introduction**

This paper discusses issues and initiatives as a result of the Canterbury earthquake sequence commencing September 2010 using a risk, resilience and sustainability framework. Initiatives are on-going and many remain unresolved. This paper aims to provide some insights to building regulators, particularly to those in areas of earthquake risk.

### **Background**

The Canterbury earthquake sequence began at 4:36am on 4 September 2010 with a damaging  $M_w$ 7.1 earthquake situated in Darfield on the Canterbury Plains, on the east coast of the South Island of New Zealand. The epicentre occurred approximately 30 km from Christchurch, New Zealand's second largest city. New Zealand is a seismically active country being situated on the boundary of the Pacific and Australian tectonic plates and thousands of earthquakes are experienced every year, most being of small consequence.

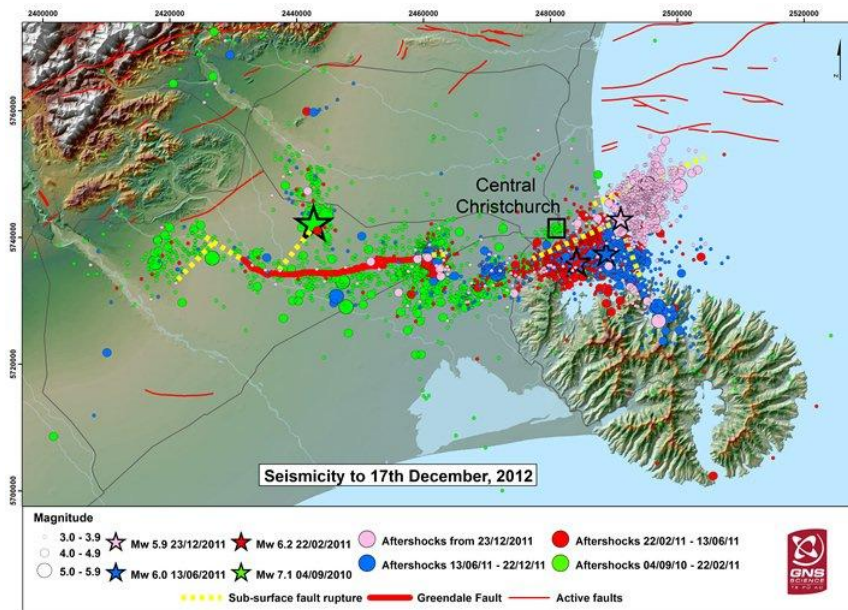


Figure 1 – Canterbury earthquake sequence 2010-2012

This was the most significant earthquake experienced in an urban environment in New Zealand since the Napier earthquake in 1931. The Darfield earthquake, being early in the morning when few people were about, resulted in no loss of life and very few injuries. It did result in significant building damage, mainly to those older buildings constructed in unreinforced masonry. There was also widespread damage to houses on the loose saturated sandy or silty soils of the Canterbury Plains from liquefaction and lateral spreading (Leeves 2012). A significant aftershock caused further damage to the Christchurch CBD on 26 December, 2010 and then on 22 February 2011 the devastating  $M_w$  6.3 Port Hills earthquake resulted in further widespread damage, the collapse of two commercial buildings (CTV and PGC) in Christchurch and the death of 185 people. Some of the highest recorded ground motions anywhere were recorded (2.1g vertical and 1.8g horizontal). Significantly more land damage (liquefaction, lateral spreading, slope stability failure and rock roll) occurred. Two further significant earthquakes occurred on 13 June 2011 and the latest major event on 23 December 2011. There have been some 14,000 events during the sequence, refer Figure 1.

The intensity, on-going nature, and the level of ground damage in an urban environment make the sequence a ‘black swan’ event, truly an outlier of unexpectedly large magnitude and consequence (Taleb, 2001). The current NZ Treasury estimates of the costs amount to \$NZ40B (\$US34B), approximately 20% of NZ’s GDP. There has even been recent speculation that the final costs may mount to \$NZ50B.

The recovery is now into its fourth year and reasonable repair and rebuilding progress on the ground is being made. Many challenges remain, with some of the ‘wicked’ problems still to be solved. While New Zealanders have always been aware of earthquake risk, the impact on Christchurch and its residents has affected the general New Zealand attitude to earthquakes. The Canterbury rebuild and implementing lessons from the sequence are high government priorities.



## Risk, resilience and sustainability framework

Illustrating some of the issues that have faced the NZ government and the people of Christchurch, a risk, resilience, sustainability framework is used, refer Figure 2. (Blake 2013)

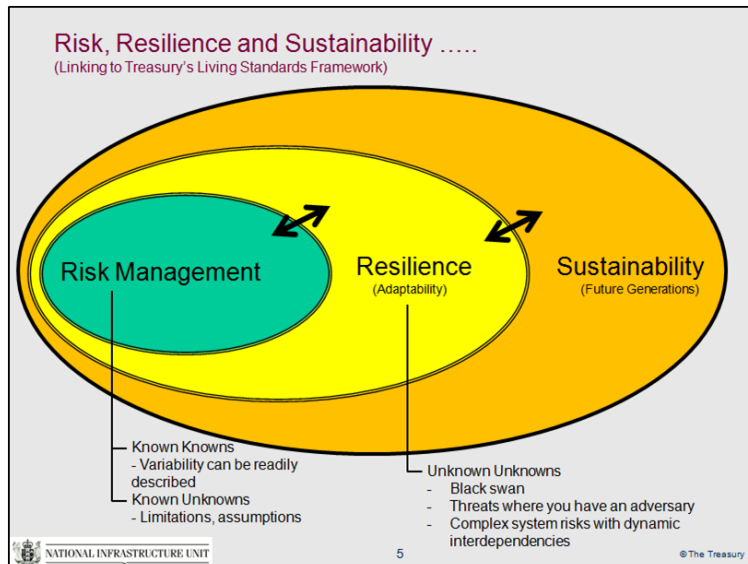


Figure 2 – Blake/Fairclough 2013

While there may be points of contention with this model at a detailed level – buildings constructed for low carbon emissions are not necessarily resilient – it is useful at a conceptual level to provide some coherence to the relationship between risk, resilience and sustainability. The NZ Treasury proposition in explaining their Higher Living Standards framework “is that by practising resilience, we are enabling sustainability and focusing on resilience will be a step towards thinking about sustainability”. (Blake 2013)

## Risk

The earthquake hazard is well researched in New Zealand (Stirling GNS 2010) and New Zealand has been at the forefront internationally of seismic engineering design of structures. Design codes are well developed, both to quantify the hazard by location – demand on buildings – and to provide design methods – building capacity (NZS 1170, etc.). Modern code complying buildings are therefore well capable of resisting significant earthquake shaking. Extreme, rare events may well overwhelm the capacity of any building and cause damage and casualties, the case in Christchurch with the CBD now largely demolished.

Even the liquefaction hazard was reasonably understood in Canterbury. A number of liquefaction reports and maps had been produced from the early 1990s and liquefaction had occurred in the Canterbury Plains following earthquakes from the late nineteenth century (Brackley 2012). However, the impact of liquefaction hazard on the development of urban Christchurch was seriously underestimated. Most modern commercial or industrial development had considered liquefaction in the design to some degree, but it was not specifically recognised as a requirement in the Building Code or its supporting documents.



New Zealand also has a strong civil defence framework using the 4Rs: Reduction (identifying and reducing the impact of hazards); Readiness (developing operational capability before an emergency occurs); Response (actions taken during or directly after an emergency); Recovery (activities after initial impact stabilised until community's capacity for self-help restored). (MCDEM 2002).

Reduction: The Building Act, Code and building control process to provide minimum requirements for standards of construction are factors in reducing earthquake risk for new building work. These are informed by hazard, materials and engineering systems research. Lessons from observations, investigations and research are being drawn from Canterbury and improvements to codes and standards will be made as lessons are understood and implemented. This is addressed in more detail below under the section on resilience. New Zealand also legislates to reduce the seismic risk of existing buildings. As a result of the Canterbury earthquakes, regulations are being considered by Parliament to reduce the time owners have to strengthen earthquake-prone buildings.

Readiness: This includes having plans in place for effective local, regional or national response to the emergency. A National Civil Defence Emergency Management Plan provides a framework for the civil defence and emergency management sector in implementing emergency management practices and solutions across New Zealand. New Zealand also has a long history of learning from earthquakes elsewhere by sending reconnaissance teams to observe and sometimes assist (e.g. Maule, Chile; Padang, West Sumatra; Northridge and Loma Prieta, California; Kobe and Tohoku, Japan) normally through the auspices of the New Zealand Society for Earthquake Engineering and the Earthquake Commission (EQC). These have all strengthened New Zealand's capacity to manage in the event of emergency, either from direct lessons or by providing people with necessary experience. The post disaster building evaluation process (tagging) used in Christchurch, was developed with international collaboration, drawing from North American documents (ATC 20) and the experience from other earthquakes. To contribute to readiness for next time, this process is being given statutory recognition in the Building Act, and a summit group of experienced people is being established by MBIE to support any response.

Response: Many lessons have also been drawn from the response phase of the earthquake sequence. Local and regional states of emergency have been declared under the Civil Defence & Emergency Management Act on a number of occasions. However, the February 2011 Port Hills earthquake was the first time that a national state of emergency had been declared. Reviews into the response to the Canterbury Earthquakes have identified improvements to be implemented, including civil defence & emergency management and the Fire Service handling of the CTV building collapse (McLean & Oughton, Pilling, Coroner).

Recovery: The recovery in Canterbury is a huge and complex task. A new government department, the Canterbury Earthquake Recovery Authority, was created by Act of Parliament providing powers to work with partners to coordinate an efficient and effective

work programme for recovery. The recovery strategy includes leadership and integration, economic, social, cultural, built environment and natural environment issues. A Christchurch Central Recovery Plan has been developed following extensive public consultation. Investment is being attracted into the various precincts being established: arts, justice, health, innovation, retail, inner city residential development connected by a green frame. Strong public feedback has advocated green spaces, accessibility and sustainability. An alliance of contractors, the Stronger Christchurch Infrastructure Rebuild Team, SCIRT, has been established to rebuild the extensively damaged **roads, fresh water, wastewater and storm water networks, costing in the order of \$2B**. The residential rebuild, particularly in eastern Christchurch where land damage issues are greatest, has been slow. Confidence to rebuild was initially low because of on-going seismic activity. It has also been complicated by insurance arrangements; demand on resources: engineering, consenting and trade with consequential quality concerns: and accommodation scarcity both for residents having houses repaired or rebuilt and for out of town workforce. Coping with these issues has seen the need for psycho-social support for many.

Another useful framework for consideration of risk is to avoid, control, transfer, or accept the risk. Avoidance in this context is principally in land planning – don't build on land where there is a significant liquefaction or land stability risk. One of the early decisions following the February Port Hills earthquake was to create a Red Zone where multiple hazard exposure (liquefaction, flooding, tsunami, slope stability, rock roll) made reconstruction of damaged property and infrastructure not viable. The Government made purchase offers to about 7000 homeowners on the flat and 700 in the Port Hills to avoid future risk. Work is also underway to consider a better national natural hazards risk framework to avoid constructing the 'Red Zones' of tomorrow. This would include clear geotechnical investigation requirements at various land use planning stages. Controlling the risk is similar to the issues raised in risk Reduction above. Society accepts the risk for some hazards. Although significant effort is put into understanding rare and extreme hazards such as volcanic activity, tsunami, or meteor strike, they are, to date, not recognised in building controls.

Transferring the risk has been a feature of New Zealand's earthquake planning for many years. A national fund managed by EQC provides first call earthquake insurance for all residential property with fire insurance. This is topped up by private insurance (>\$100k). This has meant that New Zealand has very high insurance coverage, approximately 95% of households are covered for earthquake risk, verses some 13% in California with a similar earthquake hazard. The scale of damage, with some 160,000 houses submitting in excess of 450,000 insurance claims, and multiple nature of events meant that claims were not able to be fully assessed before the next quake. Apportionment of damage to events was important to determine EQC versus private insurer and reinsurer liability. Insurance concepts have been tested and clarified in court rulings. Many issues are yet to be resolved, such as land damage liability, and increased flooding vulnerability from land settlement, both tectonic and liquefaction induced. These factors have resulted in one of the biggest and the most complex insurance and reinsurance event anywhere. (King 2014). There has also been speculation that

the very high earthquake insurance penetration has resulted in buildings being rebuilt rather than repaired.

### **Resilience**

Resilience relates to minimising the effect from whatever might occur, the ability to ‘bounce back’. The sequence has highlighted areas lacking resilience, and rebuilding a city provides opportunities to improve. Experience from previous international earthquakes demonstrated the need for clear technical repair and rebuild guidelines for insurers, homeowners, designers and other parties. While the worst areas were Red Zoned, rebuilding or repairs were still required on liquefaction-prone land or areas of mass movement in the Port Hills. The Building Act and Code did not anticipate such a scenario and supporting documents to support repair and rebuilding were not available. MBIE used expert engineering and remediation specialists, its Engineering Advisory Group, EAG, to provide this. The resulting guidance, now the benchmark for insurers and their Project Management Offices, councils and designers, has been rolled out progressively as data has been analysed and considered, new research results have become available, or new developments have occurred (MBIE 2012). Improving resilience where appropriate, while mindful of costs has been the philosophy behind this work. The same philosophy has also been applied in developing detailed engineering evaluation guidance for earthquake-affected commercial and industrial buildings, and repair of industrial buildings.

Changes to building regulatory requirements were made early on in the sequence to require improved foundations recognising the liquefaction hazard and to increase the seismic hazard factor in Canterbury, increasing the seismic design loading by 35% (Z from 0.22 to 0.30) to recognise an increased hazard in Canterbury over the next few decades (DBH 2011). Intensive investigations were carried out into building failure and recommendations made. (DBH 2012, CERC 2012). A significant work plan has been set for government agencies and professional bodies.

Better understanding of building performance to improve resilience is being progressed by active international collaboration and research. Collaborative international research is considering the performance of reinforced concrete buildings during the sequence and the recommendations made by the Canterbury Earthquake Royal Commission. Some unexpected damage patterns have challenged existing post elastic behaviour assumptions. Recent ground improvement trials in the red zone will provide new solutions to mitigate the effects of liquefaction. Intense geotechnical investigations in Christchurch have been captured in the Canterbury Geotechnical Database with some 30,000 data points (CPT, borehole data, ground water, etc) collected and able to be accessed by the design community. This sharing of information has already produced substantial savings for investigation and design and has changed the way that consulting firms compete. Consideration is now being given to establishing a national database, supporting an NZ wide natural hazards risk framework.



## **Sustainability**

New Zealand's moderate climate and high renewable energy resources (hydro power, wind, geothermal) make improvement to building energy efficiency, often the sustainability focus, less relevant. Approximately 50% of New Zealand's CO<sub>2</sub> emissions are from agriculture, predominantly from dairying, exacerbated over the past decade in Canterbury, with the region going from 28,000 cows in 2000 to 827,000 in 2012. Even these increased carbon emissions will be dwarfed by the embodied carbon required to demolish and rebuild some 1700 CBD buildings. Christchurch, established from the early nineteenth century, was built largely on a swamp. Planning laws have allowed suburban expansion without understanding the hazards. Waste and hazardous waste disposal from city and suburban demolition is costly and contentious. However, the rebuild does provide the opportunity to build back in a more resilient and sustainable way. Initiatives to improve thermal insulation when repairing houses are occurring, not without some resistance because of concern about affecting overall rebuild timelines and betterment, not being the responsibility of insurers. New houses and buildings will be required to be built to more recent higher standards. District plan changes are being made to restrict building in hazard-prone areas. Adaptation measures include recognition of sea level rise affecting flood levels, resulting in minimum floor levels to be raised in flood-prone areas. Pre-earthquake central Christchurch had significant planning issues. There was too much unused poor quality building space and had low numbers of people resident. It wasn't seen as a thriving, dynamic centre. New plans with emphasis on green spaces, public transport and mixed residential, recreation and business hubs have the potential to enhance the economic, social and environmental sustainability.

## **Conclusions**

Many lessons from Canterbury will benefit the rest of New Zealand to improve overall resilience and sustainability. However future earthquakes elsewhere will present different issues (landslides, logistics and access, lifelines) so there will always be a need to be flexible and pro-active, to consider the "what-if" scenarios, monitor best international practice and have appropriate enabling legislation. Improved resilience will improve economic sustainability. Clearly New Zealand cannot afford 20% GDP shocks often. Investment confidence would plummet and international reinsurance would likely be unavailable. Similarly social cohesion and environmental sustainability are linked to improving the resilience of the built environment. This is balanced by the opportunity for renewal.

Canterbury has demonstrated the importance of collaboration, between engineers, architects, planners, seismologists, regulators, and politicians. Even between structural and geotechnical engineers. With such interdisciplinary communication, hazards can be better recognised and mitigated, building performance can be improved, cities can be more liveable, our environment better protected. Regulators need to be openly thinking about such possibilities when designing regulatory schemes, being pro-active but flexible as different issues will arise. Seeking and being open to international expertise and collaboration has been important in Canterbury. Rebuilding for those affected is a priority in the recovery process. However, equally important are the lessons, whether they be an improved understanding of building





performance in earthquakes or from past mistakes. On behalf of all those who perished and their families, we can't waste the opportunity to learn, to reduce the risk associated with future events, and to improve the resilience and sustainability of our towns and cities.

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