Adaptation to Climate Change through Building Regulation

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Introduction

Climate plays an integral role in our lives for a whole range of decisions about where we decide to live, what we wear, whether we recreate outside or inside, how we think and act in our workplace and how we feel generally. Any significant change in climate is likely to have some effect on the social and lifestyle needs of Australians at home, in the workplace and in the community.

There is international scientific consensus that various extreme weather related events are very likely to change in magnitude, frequency and location as a result of global warming (Solomon *et al*., 2007). Significant trends have already been observed in recent decades, namely increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (e.g. Trenberth *et al*., 2007).

Climate also has the potential to impact on buildings and the urban environment in a number of ways, through damage and impacts from more intense cyclones and hail storms, flash flooding events and subsidence due to heavy rainfall, clay soil shrinkage from drier conditions, increased fire risk, as well as changes in demand for space heating and summer cooling. In other words, there is no doubt that climate change already has and will continue to have broad and far-reaching effects on our society, lifestyles, economy and governance.

The aim of this chapter is to provide an overview of: the climate change related threats to the built environment; how current building regulations deal with climate risk; and how building regulations could be applied or amended to address climate change.

Non-linear Building Impacts

Our current building design standards have been developed under the assumptions that historic climatic impacts and patterns are good predictors of future loadings on constructions. Consequently, there is an obvious risk that with increases in extreme weather events, present design standards will be exceeded more frequently. However, in addition to the more gradual increased atmospheric greenhouse gas (GHG) concentrations and warming, several factors are contributing to the risk of non-linear or abrupt changes in the climate and related building impacts.

Such non-linear factors may stem from the surpassing of natural thresholds. The Intergovernmental Panel on Climate Change (IPCC, 2007) warns that "key vulnerabilities may be linked to systemic thresholds where non-linear processes cause a system to shift from one major state to another".[1] In other words, there is no certainty that climate change will manifest itself as gradual increases in severity and frequency of extreme weather events over time.

Another non-linear relationship exists between stress on buildings from storm and cyclone events and increases in building damage. As wind speeds increase, the pressure and construction loading increase to the square of the basic wind. Thus, a 10% and 20% increase in basic wind speed will increase wind pressures by 21% and 44%, respectively. Increased wind pressure may exacerbate safety risks when building collapses lead to chain events from flying or floating debris (Smith, 1998).

Perception and Behavioural Adaptation

Perhaps one of the most fundamental questions to be asked in terms of buildings and climate change is how people will react to further change – will they accept changes to the internal environments of buildings, or will they adapt buildings to counter them? Another behavioural adaptation option would be to move to a different building, a different town or city or even a different climatic region.

As discussed previously, global warming can have non-linear effects on climate variables, ecological systems and physical structures. The same may be true for "normative thresholds" defined by stakeholders or decision-makers (IPCC, 2007). For example, a normative threshold can be associated with a magnitude of sea-level rise no longer considered acceptable by low-lying coastal dwellers. There are a number of instances where stakeholder perception and normative thresholds may come into play with consistently projected climate change effects:

- Projections by CSIRO and the Bureau of Meteorology (2007) suggest a substantial increase in fire weather risk at most sites in south-eastern Australia.[2] Cities like Sydney and Canberra have large populations living in or adjacent to peri-urban bushland and both these cities have had major bushfires penetrate the city boundaries in recent years. When such experiences are perceived as rare or uncommon events, most people will remain where they are on the basis that the amenity of the location outweighs the risk. Some may do little more than take out insurance, others might ensure that they have cleared a fire break around their homes, and others still may modify their homes so as to be better equipped to meet the next bushfire (BRANZ, 2007).

- Projections also show reductions in the frequency of sea breezes over areas of eastern Sydney (i.e. near the coast) and possible increases in the frequency of temperature inversions over western and particularly south-western Sydney (on the lee side of the Blue Mountains). Such changes would increase air temperatures at these locations and decrease Sydney's overall air quality. Changes to the built environment may be needed

[1] For example a sudden change in the Asian monsoon or disintegration of the West Antarctic ice sheet or positive feedbacks from ecosystems switching from a sink to a source of CO_2 (IPCC, 2007).
[2] Such risk may exist elsewhere in Australia, but this has not been examined in depth yet.

to deal with the potential health risks of hotter conditions and reduced air quality, such as installation of air-conditioning or better insulation (BRANZ, 2007).

Effective building regulation needs to adequately address both physical impacts from climate change effects and stakeholders' norms and tolerance of conditions and risk. In the following section we will examine the physical threats to buildings in Australia resulting from climate change impacts in more detail.

Threats from Climate Change

The main impacts of climate change on the built environment in Australia are expected to be centred on: health effects from over-heating and increased energy consumption due to higher temperatures; increased damage from more intense tropical cyclones and storms and stronger winds; increased cracking of drier soils and ground movement impacting on foundations and pipe work; damage from flooding and saltwater inundation; and increased bushfire risk (BRANZ, 2007; Hennessy *et al*., 2007).

Heat impacts

The main heat effects of climate change stem from an increase in the frequency of warm days and warm nights and a decrease in the frequency of cool days and cool nights. The number of days per year with uncomfortable indoor temperatures is expected to continue to increase markedly for most parts of Australia. By the 2030s the average number of days above 35°C is projected to increase by an average of 20% to 35% in Sydney, Melbourne, Perth, Hobart and Adelaide and by over 600% in Darwin (CSIRO and BoM, 2007).

As a result of increases in hot days, demand for air-conditioning may increase unless more energy efficient passive cooling techniques are employed. In contrast, simulations show an increase in favourable conditions for the production of solar hot water, leading to a decrease in the electrical or gas auxiliary energy required to meet hot water demands and to reduce space heating demands during winter (Wilbanks *et al*., 2007).

In terms of water scarcity, climate change projections show up to 20% more drought-months over most of Australia by 2030, with up to a 40% increase by 2070 in eastern parts and 80% in south-western Australia (CSIRO and BoM, 2007). Temperature extremes and large variations are likely to cause damage to built infrastructure, namely the thermal movement of roofing, cladding, window systems, and other building parts, resulting in the cracking and deterioration of paints, sealants and other protective surface finishes. Furthermore, soil drying (and swelling in wet conditions) can affect building foundations, especially in clay soils (Bengtsson *et al*., 2007 and BRANZ, 2007).

Impact of more intense cyclones and storms

Regional studies indicate a likely overall increase in the proportion of intense tropical cyclones, but a possible decrease in the total number of cyclones (CSIRO and BoM, 2007; Schneider *et al*., 2007). These projections are compatible with studies of cyclones and storms in Australia from 1981-2003 (Hennessy 2004: Kuleshov 2003). Hennessy *et al*. (2006) project increases in tropical cyclone wind-speeds of between 5-10% in the northern parts of Australia over the next 50 year period. CSIRO and the Bureau of Meteorology (2007, p103) report on several studies indicating a pole-ward extension of tropical cyclones with global warming.

Building impacts from more intense tropical cyclones and storms include (BRANZ, 2007):

- structural loading by pressure forces, leading to structural failure (e.g. removal of individual tiles or iron sheeting through to uplifting of entire roofs or walls);

- general structural failure of building components leading to potential building collapse and destruction;
- impact damage from flying debris; and
- rain/moisture penetration leading to internal damage.

As discussed earlier there is a non-linear relationship between increased wind speeds and the loading effect on buildings. It is likely that there will be damage to residential buildings as a result of the predicted higher wind speeds across most of Australia. However, due to the heavier weight of construction of office buildings, these are more likely to cope with the added pressures, although they are still susceptible to impact damage from flying debris (especially glazing).

Changes in precipitation

CSIRO and BoM (2007) report that extreme daily precipitation (highest 1%) tend to increase in the north and decrease in the south with widespread general increases in summer and autumn.

Changes to extreme events would have the potential to impact on infrastructure, communities and industry, leading to strains on sewerage and drainage systems, greater insurance losses, possible black-outs, challenges for emergency services (Hennessy *et al*., 2006 and 2007; CSIRO and BoM, 2007), and a jeopardising of the water tightness and integrity of houses (BRANZ, 2007).

It should also be noted that an increase in the variation of short intensive wet spells and prolonged dry spells may lead to degradation and failure of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater (CSIRO, 2007). The many Australian jurisdictions where hazard liability is not mandatory, or is poorly quantified (Yeo, 2003), are particularly vulnerable to flooding event.[3]

Impact of sea-level rise

One of the major climate change effects is the increase in the rate of sea-level rise over the next centuries. Some coastal properties will become more vulnerable and unstable due to increased coastal erosion and sea-level rise. Other properties will experience increased flooding from rivers and water run-off (IPCC, 2007).

The IPCC specifically addresses the exacerbated risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding for ongoing coastal development and population growth in areas such as Cairns and south-east Queensland (Hennessy *et al*., 2007). A recent local assessment for the Western Port region in Victoria identified the uncertainty or lack of planning controls in areas affected by coastal inundation resulting from sea-level rise and increases in intense rainfalls as the top priority climate change risks for settlements in the region (Kinrade and Justus, 2008).

Impact of increased bushfire risk

Bushfires have remained a natural feature of the Australian environment for centuries, albeit one that continues to cost hundreds of lives and causes extensive economic damage (Australian Institute of Criminology, 2004). The Canberra wildfire in January 2003 caused US$261 million damage with about 500 houses destroyed, four people killed, and hundreds injured. Three of the city's four dams were contaminated for several months by sediment laden run-off (e.g. Hennessy *et al*., 2007).

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[3] Governments sometimes provide financial relief to the uninsured from large natural disasters and such costs are likely to rise. Insurance costs are very likely to rise in areas with increased risk (Hennessy *et al*., 2007).

The predicted increases in temperature, drought conditions, and wind in particular, have implications for the severity of exposure fires, external fire spread, the hazards of airborne embers, and increased ember-strike in the urban environment (Bowditch, 2006; Ellis, 2002).

With a projected warming 21st century climate, fires are virtually certain to increase in intensity and frequency (Hennessy *et al*., 2007). For instance, by 2020, the number of days with very high or extreme fire danger could average 13-14 in Richmond (now 11.5), 26-29 in Canberra (now 23), and 53-57 in Wagga Wagga (now 50). In Victoria, the annual average number of very high and extreme forest fire danger days are projected to increase by 1 to 11 days by 2020 (Hennessy *et al*., 2006).

Resilience of Australia's Building Stock

The key challenges for the Australian building stock discussed here are related to: indoor over-heating; tropical cyclones, intense storms, and increased wind speeds; flooding; degradation of foundations; and bushfires. In order to evaluate these, we must first briefly examine the non-linearity of extreme events versus building damage and the general vulnerability and resilience of the new built and existing building stock.

In the Australian Government report entitled "An Assessment of the Need to Adapt Buildings to the Unavoidable Consequences of Climate Change" (BRANZ, 2007), three broad conclusions are drawn about the resilience of Australia's new building stock:

1. New buildings are reasonably resilient to expected changes in average climate conditions but may not be as resilient to changes in extreme events such as storms and flooding;
2. Some recent changes to buildings codes and practices, while not designed to address the impacts of climate change, have increased the resilience of new buildings. For example, higher energy efficiency standards mean that buildings are better able to cope with more frequent hot spells;
3. There is considerable scope to improve the resilience of new buildings although further research may be required before specific measures can be formulated. Options are discussed below under 'possible adaptation measures'.

The resilience of Australia's older building stock to the likely impacts of climate change is more difficult to assess, partly due to lack of information on older buildings. Good maintenance and upgrading where appropriate is the key to resilience for older buildings. Buildings that include sustainable measures (e.g. strong passive solar design principles or efficient water usage systems such as grey water systems) will be more resilient to the impacts of climate change.

The Building Code of Australia

This section focuses on what measures the Building Code of Australia (BCA) currently takes in the regulation of building design and construction in light of the climate change impacts outlined in previous sections.

The Australian Buildings Codes Board (ABCB) writes the BCA on behalf of the governments of Australia. The BCA is the national building code referenced in all State and Territory building legislation and sets minimum standards for all aspects of building work. These are expressed as Performance Requirements and Deemed-to-Satisfy Provisions.

The BCA is given legal effect by building regulatory legislation in each State and Territory, which also includes the administrative provisions necessary. This legislation consists of an Act of Parliament and subordinate legislation which empowers the regulation of certain aspects of buildings and structures, and contains the administrative provisions necessary to give effect to the legislation. Any provision of the BCA may be overridden by, or is subject to, modification under State or Territory legislation.

The stated goal of the BCA is to enable the achievement of nationally consistent, minimum necessary standards of relevant, health, safety (including structural safety and safety from fire), amenity and sustainability objectives. The BCA contains technical provisions for the design and construction of buildings, covering such matters as structure, fire resistance, access and egress, services and equipment, and energy efficiency, as well as certain aspects of health and amenity (ABCB, 2008c).

The ABCB use the Proposal for Change (PFC) process to consider technical proposals for changes to the BCA. PFCs are considered by the ABCB's Building Codes Committee (BCC) each time the Committee meets. The role of the BCC, which consists of representatives of all levels of government as well as industry representatives, is to provide advice, guidance and make recommendations relating to technical matters relevant to the BCA. If the proposal is considered to have merit, the BCC may recommend that changes be included in the next public comment draft of the BCA or, for more complex proposals, it may recommend that the proposal be included in the ABCB's work program for further research, analysis and consultation (ABCB, 2008d).

Building indoor heating and cooling

Measures to improve energy efficiency and reduce GHG emissions typically improve resilience against overheating.[4] Houses with good solar design features such as properly shaded north- and west-facing windows, minimal west-facing windows, or provision for effective ventilation should be the least affected. Houses without such features, or poor solar design, could suffer from severely overheated conditions.

The BCA covers 10 building classes in two volumes: Volume 1 of the BCA covers Class 2 to 9 (primarily commercial and institutional); and Volume 2 covers Class 1 and 10 buildings (primarily houses).[5]

Residential buildings

The energy efficiency provisions for houses were originally introduced into the BCA on 1 January 2003. Enhanced provisions, which establish a higher level of energy efficiency, were introduced into the BCA on 1 May 2006. The energy efficiency provisions only apply to new building work, new houses, and any new work in an existing house (ABCB, 2007).

The provisions were progressively adopted in the Northern Territory, Queensland, South Australia, Tasmania and Western Australia. Separate energy efficiency regulations were adopted in the Australian Capital Territory, New South Wales and Victoria. The BCA Energy Efficiency Provisions include (ABCB, 2008a):

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[4] A well-designed building with ample eaves and windows and good air circulation aided by fans may reduce (and in some areas eliminate) the need for air-conditioning in the home, yet the installation and continuous use of domestic air-conditioning is still on an upwards trajectory (Energy Efficient Strategies, 2008).

[5] Volume 1 of the BCA covers Class 2 to 9 buildings (such as apartments, hotels and motels, single caretaker's flat attached to a commercial building, offices, shops, carparks, warehouses, factories, hospitals, theatres, churches, libraries and gymnasiums etc). Volume 2 of the BCA covers Class 1 and 10 buildings (such as single dwellings, small boarding houses and garages).

- The ability of the roof, walls and floor to resist heat transfer;
- The resistance to heat flow and solar radiation of the glazing;
- The sealing of the house;
- The provision of air movement for free cooling, in terms of openings and breeze paths;
- The insulation and sealing of air-conditioning ductwork and hot water piping.

Multi-residential and commercial buildings

Development of the BCA energy efficiency provisions for multi-residential and commercial buildings proceeded in two stages (ABCB, 2008b). First, provisions for Class 2, 3 and 4 buildings (e.g. apartments, hotels) were included in BCA 2005. The provisions cover the following:

- The ability of the roof, walls and floor to resist heat transfer;
- The resistance to heat flow and solar radiation of the glazing;
- Sealing of the building;
- The provision of air movement for free cooling, in terms of openings and breeze paths;
- The efficiency and energy saving features of heating, ventilation and air-conditioning systems and hot water supply;
- Power allowances for lighting and electric power saving features;
- Access to certain energy efficiency equipment for maintenance purposes.

Secondly, provisions for Class 5, 6, 7, 8 and 9 buildings (e.g. offices, shops, warehouses, factories, health care buildings, auditoriums, schools) were included in BCA 2006. The new provisions extended the provisions that already existed in for Class 2 to 4 buildings to Class 5 to 9 buildings with requirements for:

- Building fabric – roofs, walls and floors;
- External glazing;
- Heating, ventilation and air-conditioning systems (HVAC);
- Lighting and power.

Minimum energy efficiency provisions are being incorporated into the BCA to eliminate poor or less than acceptable practice from industry and it is intended that these will help to reduce the GHG emissions from the building sector.

Scope for improvements

Although a number of energy efficiency measures are already in place for both residential and commercial buildings through BCA provisions, there remain further potential measures to reduce the vulnerability of buildings and occupants to over-heating. For example, mandatory passive solar design and requirements for minimum standards on cross-ventilation contribute to more comfortable summer indoor temperatures without needing to rely on energy-intensive space cooling means.

Additionally, potential links across planning and building standards could work to maintain healthy, safe and energy-saving living and working conditions even with temperature increases. Examples of such combined provisions could include requirements that people working in outdoor or semi-outdoor conditions have access to shaded rest areas and standards for building spacing and green spaces.

Degradation of foundations

The degradation of foundations can have a significant impact on the service the building can provide. The most likely risks are movements of pipes causing leaks (e.g. water and gas pipes), weakening of the structure to the extent that the building is compromised by high winds or storm events, and for commercial and larger buildings, potential lift malfunction.

The BCA currently takes into account potential changes in soil type. However, at this stage, the amount of risk associated with degradation of foundations through climate change impacts is unknown and requires greater exploration.

Cyclone-proofing and wind ratings

The principle BCA reference is *AS/NZS 1170.2:2002: Structural design actions – Wind actions* for design values of wind actions for use in structural design. Wind speeds and direction factors are provided for a range of probabilities of exceedance. The standard includes factors such as the environment around the structure, the geometry of the structure, and the dynamic interaction of the structure with the wind.

AS/NZS 1170.2:2002 also divides Australia and New Zealand into wind regions as well as non-cyclonic regions and cyclonic regions. The projected increase in wind speeds and intensity of cyclones will put additional pressure on the timely adjustment of buildings and the wind region map could be employed as a measure to incorporate wind speed projections to take climate change into account, where necessary. Indeed, although design criteria for cyclones, storms and high winds are currently based on historic weather data, adjusting this data for climate change has already begun.

Flooding

The current BCA requirements for flooding are generally ad hoc, with most residential buildings not specifically designed to cope with flooding. While there are building codes for other natural hazards (e.g. bushfire) there are none specifically for buildings in flood-prone areas. Instead, each area that is subject to flooding will have its own set of rules typically applied at local government level and these are often based on historic data without adjustments for climate change. Therefore, this design consideration is overlooked resulting in some houses being more vulnerable to damage (both structural and non-structural) when flooding occurs.

At the time of writing, the ABCB was considering options through a regulatory review process to minimise damage for buildings in flood-prone areas. Potential code amendments include requirements for flood-resistant building materials (such as water-resistant materials and waterproof seals), stronger foundations, and elevated floor heights. Additionally, gutter and downpipe sizes, including stormwater control measures, are further areas where increased performance requirements could reduce building risk (BRANZ, 2007).

Local authorities play a key role in protection from floods, inundation and coastal flooding. It is recommended that local government adopt a precautionary approach to coastal development and take increased vulnerability of coastal properties into account in modelling of flooding, coastal erosion and sea inundation. These are often in the best position to assist and take appropriate protective measures to reduce wave energy and possibly move or abandon houses which cannot be economically protected.

Bushfires

The BCA refers to the standard *AS3959-1999 Construction of Buildings in Bushfire-Prone Areas* for detached residential buildings (Class 1), attached dwellings, hotels and motels (Class 2 and 3). There are currently no specific requirements for building classes covering shops and offices.

Although the frequency of bushfires is likely to increase, the nature of a bushfire makes it unlikely that the frequency in any area can be more than 15 years (the time allowed for the bush to regenerate). Therefore dwellings built to meet AS3959-1999 should cope with acceptable levels. However, AS3959-1999 was not introduced into the Building Code until 1996 and many older homes may have used materials and building techniques that reduce the risk of fire entering the building.

State legislation may create separate compliance requirements to the BCA. For instance the Planning for Bushfire Protection 2001 (PFBP2001) in NSW prescribes minimum separation distances between structures and vegetation and recommends that construction standards follow the Australian Standard AS3959-1999 (Ellis, 2002).

The Cost of Adaptation

In Australia, around 87% of economic damage due to natural disasters (storms, floods, cyclones, earthquakes, fires and landslides) is caused by weather related events (Hennessy *et al*., 2007). The general message from studies evaluating the economic costs and benefits from adaptation to climate change is that the sooner adaptation planning begins the better prepared the population – including vulnerable industries and communities – will be for the impacts of climate change (e.g. Stern, 2006). Evaluations of costs and benefits from building adaptation in Australia and New Zealand have shown strong net economic benefits from passive designs of new buildings and retrofits of existing buildings (BRANZ, 2007; Bengtsson *et al*. 2007). The New Zealand study, which can be assumed to be directly translatable to many parts of Australia, also shows net economic benefits for retrofitting the existing housing stock for increased wind loading (by using more nails in roof cladding), regional bush fire risk (baseboard mesh to ensure sparks are kept out of the sub-floor), and sea-level rise (relocation of part of the coastal building stock inland).

Conclusion

There is international scientific consensus that various extreme events are very likely to change in magnitude and/or frequency and location with global warming and significant trends have already been observed in recent decades. Changes in the climate may come gradually over long periods of time or in step changes in climate patterns, building damage, stakeholder perceptions and risk tolerance. Building regulation has an important role to play in helping to prepare society for such effects. Regional and international studies support that early adaptation measures to climate change generally provide net economic benefits.

Further research and investigation is necessary in order to develop a framework that allows climate change to be harmoniously incorporated into both land-use planning and building standards, so that these work together effectively to ensure no ‘gaps’ in the building process. This is particularly important for both urban water use and flooding. Developing such a framework will allow localised areas, namely councils, to concentrate of the specific issues in their area while using the framework guidelines to ensure consistency with other councils.

Future proofing and protecting Australian buildings against climate change may require incorporation of adaptation options into the BCA. The inclusion of sustainability as a goal in the

BCA provides such an opportunity by incorporating separate clauses, new clauses, or worked in as part of existing clauses.

In some instances, there may also be a case for reviewing building codes and standards. For example, design criteria for cyclones, storms and high winds are based on current climate conditions and there may be value in updating these to take into account possible future increases in high wind events and changes in cyclone risk zones.

A related issue is the link between building standards and planning systems. The vulnerability of buildings to climate change impacts depends on a combination of building standards and planning decisions. For example, building code requirements for flooding are generally ad hoc, with most residential buildings designed to cope with flooding based on previous flooding events, or there are no requirements at all. However, this may not be important if planning decisions ensure that buildings are not sited on flood plains, areas at risk of erosion, or are protected by suitable engineering structures in the first place.

In other cases, existing standards may be adequate but there may be a need to apply them in a different manner. For example, buildings built in compliance with the standard AS3959-1999 should cope with bushfire risk but changes in risk may change the areas in which this standard needs to apply. There may also be a need to retrofit homes built before 1996, when the standard was introduced into the building code.

Finally, an appropriate policy mix is required to shape a climate change adapted built environment, with market incentive mechanisms complementing regulation, legislation and code. Insurance companies, investment companies and governments can play a key role in developing market incentive mechanisms to foster necessary change.

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