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HEATWAVE AND BUILDING CODES IN NEW SOUTH WALES: ISSUES AND PROSPECTS

Report for Resilience NSW

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ABSTRACT

This report reviews key literature and considers the overall comprehensiveness of the NSW building codes in terms of their contributions to selected elements of heatwave resilience. It identifies success, opportunities and issues relating to the contribution of building codes to natural hazard resilience. Overall, this report suggests that there is no effective acknowledgement of heatwave in the National Construction Code, and that there is limited integration between building and other key systems such as land use planning, health services and emergency preparedness and response. A range of areas are proposed for attention.

EXECUTIVE SUMMARY

Heatwave is responsible for approximately half of natural hazard deaths in Australia. Better use and integration of building codes with other mechanisms could allow for significant reduction in heatwave risks, and support adaptation to a changing climate.

Currently, the National Construction Code (NCC) does not address heatwave or the role of structures in risk reduction relating to heatwave.

While some advances have been made in public health, emergency response and land use planning, these approaches are not integrated with building codes.

There are eight focus areas (described in more detail in the following sections) where further research and action is needed that focus on heatwave:

1. internal building temperatures,
2. heatwave ratings,
3. future heatwave risks,
4. addressing occupant and building vulnerabilities; and geographical differences,
5. integration of land use planning and other relevant mechanisms,
6. retrofitting buildings,
7. risk-based settlement planning, and
8. use of passive and redundancy systems.

This report suggests that systemic change be undertaken to address these shortcomings in accordance with the NSW Emergency Risk Management Framework that states at Outcome 8:

> A strong focus in the emergency management sector on continual improvement, proactive mitigation and management of emergency risks is engrained using a change management approach (Office of Emergency Management, 2017: 4).

Key aspects discussed in the research include:

- community and infrastructure resilience outcomes in the context of buildings,
- current NSW heatwave management policy,
- impacts to health and emergency service operations,
- key aspects of the National Construction Code,
- study methods to analyse the building codes and heatwave, and
- results and key areas for attention.

INTRODUCTION

This report examines the efficacy of New South Wales' building codes in terms of resilience to heatwaves as one of the main natural hazards faced in the state. The main purpose of building codes and associated processes is to achieve standards of materials and construction that ensure the achievement of established expectations of human health and safety in the short and long term. Ching and Winkel (2018: 2) explain the significance of these codes in the following way:

> The protection of the health, safety and welfare of the public… is the reason that building regulations exist (Ching & Winkel, 2018: 2)

In terms of fatality numbers, Handmer et al (2018) suggest that over 50% of natural hazard deaths in Australia between 1967 and 2013 were caused by heatwaves. For Heatwave deaths in Victoria during the 2009 bushfire season amounted to 374, compared with 173 directly attributed to the fires themselves. Ongoing deaths per annum in Australia are currently estimated at approximately 2000 (Jackson WJ, 2016; Philpott & Kesteven, 2016). It is also noteworthy that heatwave deaths per annum are predicted to double by 2050 (Jackson WJ, 2016). In decreasing rank order based on numbers of average deaths per year heatwave is followed by floods and bushfires, landslide, severe storm and earthquake (Handmer, Ladds, & Magee, 2018; Laddsa, Keating, Handmer, & Magee, 2017).

Heatwaves are defined as:

> A period of abnormally hot weather lasting over several days, and can be characterised as three or more days of high maximum and high minimum temperatures that are unusual for that location (NSW Government, 2018).

Building codes are premised on the development of regulatory processes that anticipate and take account of typical construction practices and materials with the aim to provide safe environments for habitation and occupation. At the same time, they establish regulatory safeguards that anticipate and avoid problems (such as natural hazards), while enabling flexibility for cost-effective approaches for the construction of homes, schools, businesses and other structures. Building codes seek to avoid reasonably predictable problems in human settlements that would not normally be achieved without overarching regulation and oversight. The codes are primarily oriented to the physical characteristics of structures, although these are oriented to achieving human – oriented goals such as health, safety and efficiency.

It is also recognised that in addition to physical building characteristics, the wider design and arrangement of towns, cities and regions are also key drivers of risk profiles, insofar as these are key elements of the ways that hazards interact with settlements (Alan March & Kornakova, 2017). For example, a small town located in a bushfire prone area with limited transport options, communications, response and warning systems is likely to be more vulnerable than a similar community that has actively developed fuel reduction, building maintenance, community and household plans, warning, evacuation and response capabilities.

This report reviews key literature and considers the overall comprehensiveness of NSW building codes in terms of their contributions to selected elements of heatwave resilience. It identifies opportunities and issues relating to the contribution of building codes to natural hazard resilience. Overall, this report suggests that there is no effective acknowledgement of heatwave in the National Construction Code, and that there is limited integration between building and other key systems such as land use planning, health services and emergency response. A range of areas for attention are proposed.

LITERATURE REVIEW

Natural hazards cause significant impacts in Australia each year interspersed by periodic peak events. Many of these impacts have significant ramifications for the built environment, both in terms of direct and consequential economic costs, and human impacts including injuries and fatalities. While the reliability and comparability of cost estimates remains challenging (Laddsa et al., 2017), it is clear that Australia ranks as one of the most affected by natural hazards globally (Guha-Sapir, Hoyois, & Below, 2013). In the future, total annual insured cost in 2050 of disasters is projected to be $39 billion, up from $18.2 billion per year in 2017 (Deloitte Access Economics, 2017a). Laddsa et al (2017) suggest that costs from natural hazards from highest to lowest are: storm, flood, tropical cyclone, bushfire, earthquake, and landslide, although this ranking is contested and spatially uneven across Australia. It is expected that without significant mitigation, total costs of natural disasters will increase more than two and a half times from the time of writing to 2050 (Deloitte Access Economics, 2017b: iii).

While the economic impacts of natural hazards are a persuasive reason to take action, direct impacts on humans in terms of injury, suffering and death are also significant, particularly in terms of heatwave. Further, heatwaves have not traditionally been treated in the same way as other hazards such as flood or fire, even while their impacts in Australia have long been recorded. For example, 435 deaths occurred in the 1895-6 Australian summer heatwave (Coates, Haynes, O'Brienab, McAneney, & Oliveir, 2014). More recently, while 173 deaths occurred during the 2009 bushfire season as a direct result of the fires, a total of 374 deaths were attributed to heatwave over the same period. Ongoing heatwave deaths per annum in Australia are currently estimated at 2000 (Jackson WJ, 2016; Philpott & Kesteven, 2016). It is also noteworthy that heatwave deaths per annum are predicted to double by 2050 (Jackson WJ, 2016).

Increasing resilience to heatwaves in building codes presents a number of challenges that relate to the drivers of risks and the possibilities and limitations of building codes themselves. The term resilience has a long and varied history that has been adapted in a number of ways over time. In its broadest sense, resilience can be understood as the ability of a person, community, material or system to deal with change or disturbance. Alexander's 2013 review from the perspective of disaster found that definitions of resilience over time have included many applications. These are as diverse as psychological (Bonnano, 2004), engineering, ecological, social, economic and wider socio-political resilience (Alexander, 2013).

A highly influential approach is that of ecological resilience, pioneered by Holling (1973). It follows an approach based on the death, persistence or adaptation of various aquatic species subjected to stresses such as pollution. It suggests that more resilient species and systems can better withstand a given amount of shock or stress prior to failure and subsequent possible transformation (C. Holling, 1973). In contrast, engineering resilience is oriented to understanding the properties of materials and their ability to deal with stresses and then return to "normal" or to subsequently to fail or be sub-optimal, such as a spar of a bridge when a heavy load is applied (Walker et al., 2006). A key concern for many regarding the traditional engineering view of resilience is that a return to a pre-shock state merely reproduces the conditions associated with vulnerability. More recently, socio-ecological resilience has been understood as the "ability of a system to resist change during a disturbance and/or efficiently return to equilibrium after a disturbance in an effort to maintain current system dynamics" (C. S. Holling, Gunderson, & Peterson, 2002). While these uses of the term resilience are significant, an ongoing challenge is to meaningfully apply resilience concepts to human settlements (March, 2012). Urban and regional areas face ongoing change across diverse and dynamic systems that require integration and ongoing improvement to be effective (March et al., 2018). Meerow et al suggest a useful definition that can inform a wider approach to understanding an urban and regional systems' resilience.

> Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to radically transform systems that limit current or future adaptive capacity (Meerow, Newell, & Stults, 2016: 45).

At a national Australian level, the National Strategy for Disaster Resilience does not specifically define resilience but sets out many characteristics and conditions that support improved resilience. In particular, it quotes the Insurance Council 2008 in respect of resilient communities as follows.

> Communities that develop a high level of resilience are better able to withstand a crisis event and have an enhanced ability to recover from residual impacts. Communities that possess resilience characteristics can also arrive on the other side of a crisis in a stronger position than pre-event. For example:
>
> - a community with well-rehearsed emergency plans
> - superior fire mitigation processes in the cooler months
> - appropriate building controls, suitable to local hazards and risks
> - widely adopted personal and business financial mitigation measures (e.g. insurance suitable to the risks)
> - is likely to suffer less during an extreme fire event and is likely to be able to recover quickly; financially, physically and as a community.' Insurance Council of Australia 2008, Improving Community Resilience to Extreme Weather Events in (COAG, 2011).

The glossary of the Australian Institute of Disaster Resilience defines resilience following the UNDRR (then UNISDR) as:

> The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR (United Nations International Strategy for Disaster Reduction), 2015).

Resilience itself is not defined specifically in key NSW risk management documents, even while there are many references to its importance in operational and explanatory ways, such as in the *Local Emergency Management Committee Information Guide* and *Implementing Emergency Risk Management Through the Integrated Planning and Reporting Framework*. Importantly the NSW State Level Emergency Risk Management Plan requires that:

> State and local government play a vital role in planning for and managing the sustainable development of communities and increasing their resilience to emergencies through prevention and mitigation.

The December 2018 version of NSW EMPLAN states that:

> Disaster resilience is an outcome derived from a sharing of responsibility between all levels of government, business, the non-government sector and the community who then act on this basis prior to, during and after a disaster. Disaster resilience is significantly increased by active planning and preparation. A shared understanding of the disaster risks at community level is a vital precursor (para. 119).

The NSW Government Heatwave Subplan (2018), a subsidiary document to the New South Wales State Emergency Management Plan (EMPLAN) details the control and coordination arrangements for aspects of the preparation for, response to, and immediate recovery from a heatwave. It does not use resilience as a term but does set out a range of key operational standards to reduce the impacts of heatwaves. It is generally oriented to response and recovery rather than prevention, leaving unclear with whom responsibility for prevention rests. This is particularly important when the multiple agencies and interests related to heatwave prevention are considered.

Minimising the impacts of extreme heat: A guide for local government (2016) sets out a range of broad measures that can be taken by local government in an integrated way that responds to the wider framework set out by EMPLAN and the Heatwave Subplan (Office of Environment and Heritage, 2016). While no detail for action is is provided, key elements in *Minimising the Impacts of Extreme Heat* include:

- prevention via urban design and land-use planning,
- council operations and processes,
- communicating with local stakeholders,
- responding, and
- recovery

HEATWAVE IMPACTS ON HUMAN HEALTH

Occurrences of excess mortality resulting from heatwaves is well documented over time in Australia (Coates et al., 2014). Heatwaves impact upon human health by bringing about heat stroke, often also associated with exacerbation of other medical conditions. These other conditions may include cramps, exhaustion, dehydration and other impacts that are often not directly identified as heat-related such as cardiovascular and cerebrovascular disease, respiratory disorders, acute renal failure, neurologic conditions, and mental illnesses (Hajat S & Kosatky T, 2010). It is also suggested that heat related morbidity and mortality may often be underestimated due to the complex interactions with other factors (Kravchenko, Abernethy, Fawzy, & Lyerly, 2013). Further, hospital admissions relating to morbidity are less studied and documented than mortality.

In the United States, heat exposure is normally understood as a primary or contributing cause of death when core body temperature is higher than 40.6°C (Luber G & McGeehin M, 2008). The US National Association of Medical Examiners' classifies a death as heat-related if the person is "found in an enclosed environment with a high ambient temperature without adequate cooling devices and the individual had been known to be alive at the onset of the heatwave" (Donoghue ER et al., 1997).

The body typically eliminates heat during thermal stress through sweat production and evaporation, increasing cardiac output, and redirecting blood flow to the skin, thus increasing heat loss via radiation and conduction. As the cardiovascular and cerebrovascular system, central nervous system, and respiratory systems are very sensitive to heat, the increase in mortality during heat waves has been attributed predominantly to these systems (Kilbourne EM, 1999).

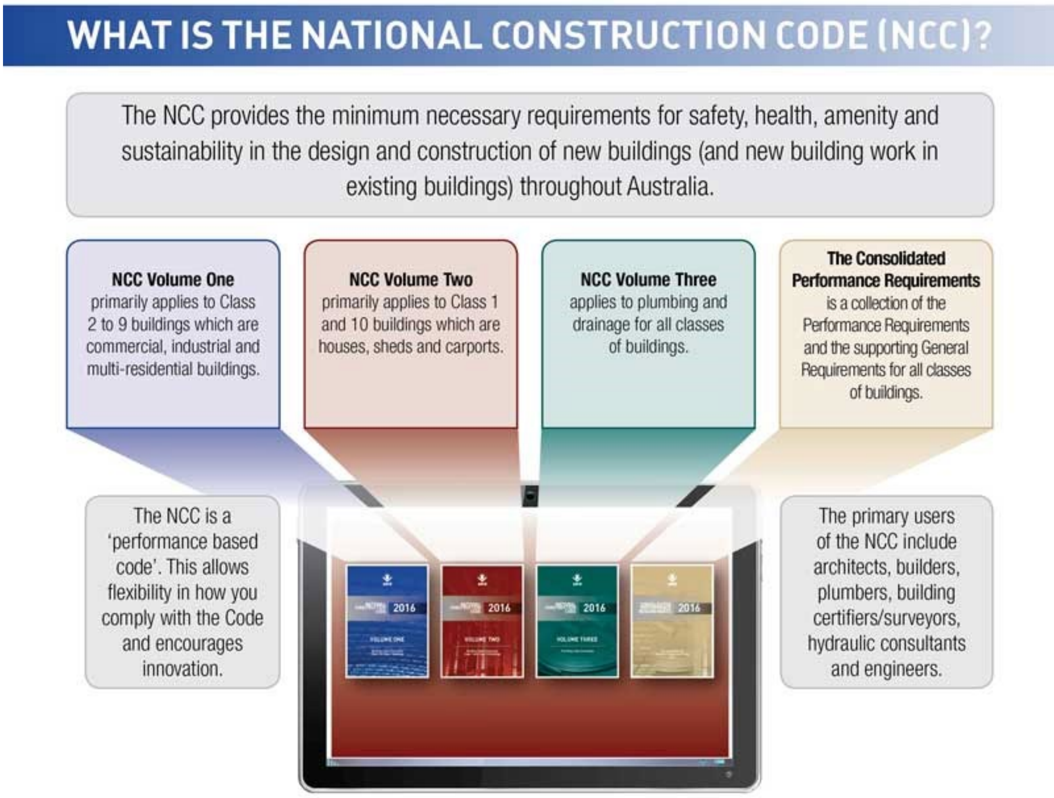
Heat can also have a negative impact on pregnant women and can be detrimental to the foetus. Maternal hyperthermia has been associated with increased risk for neural tube defects, heart defects and higher risks of congenital cataracts (Moretti ME, Bar-Oz B, Fried S, & Koren G, 2005). Research suggests that people who are used to cooler weather or shorter periods of extreme heat are more vulnerable to heatwave impacts, and may have limited adaption and coping strategies, including in their buildings. A complicating factor is that persons reliant on air-conditioning are more susceptible when it fails or is not available in work places, homes or vehicles (Kravchenko et al., 2013).

SUMMARY OF THE NATIONAL CONSTRUCTION CODE

The NCC is a code containing all Performance Requirements for the construction of buildings. It is built around a hierarchy of guidance and code compliance levels, with the Performance Requirements being the minimum level that buildings, building elements, and plumbing and drainage systems must meet. A building, plumbing or drainage solution will comply with the NCC if it satisfies the Performance Requirements, which are the mandatory requirements of the NCC.

> All building work must comply with the requirements of the Building Code of Australia (BCA).The Building Code of Australia (BCA) is contained within the National Construction Code (NCC) and provides the minimum necessary requirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia (Housing Industry Association of Australia, 2020).

The Performance Requirements are also supported by General Requirements,



which cover other aspects of applying the NCC including its interpretation, reference documents, the acceptance of design and construction (including related evidence of suitability/documentation) and the classification of buildings within the NCC.

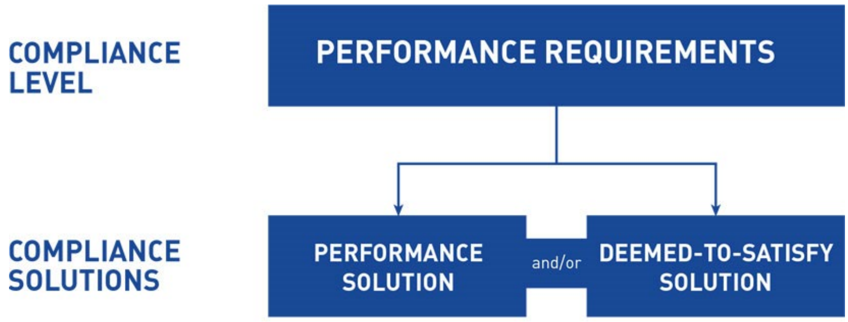
The key to the performance-based NCC is that there is no obligation to adopt any particular material, component, design factor or construction method. This provides for a choice of compliance pathways. The Performance Requirements can be met using either a Performance Solution (Alternative Solution) or using a Deemed-to-Satisfy (DTS) Solution.

Performance Solution

A Performance Solution is unique for each individual situation. These solutions are often flexible in achieving the outcomes and encouraging innovative design and technology use. A Performance Solution directly addresses the Performance Requirements by using one or more of the Assessment Methods available in the NCC.

Deemed-to-Satisfy Solution

A DTS Solution follows a set recipe of what, when and how to do something. It uses the DTS Solutions from the NCC, which include materials, components, design factors, and construction methods that, if used, are deemed to meet the Performance Requirements.



The NCC is an initiative of the Council of Australian Governments (COAG) developed to incorporate all on-site construction requirements into a single code. The NCC is comprised of the Building Code of Australia (BCA), Volume One and Two; and the Plumbing Code of Australia (PCA), Volume Three.

- NCC Volume One primarily applies to Class 2 to 9 (multi-residential, commercial, industrial and public) buildings and structures.
- NCC Volume Two primarily applies to Class 1 (residential) and 10 (non-habitable) buildings and structures.

- NCC Volume Three applies to plumbing and drainage for all classes of buildings.

ANALYSING HEATWAVE TREATMENTS IN BUILDING PROVISIONS

Managing the risks associated with heatwave requires recognition and management of a range of drivers that influence its impacts upon people, buildings and other human made structures – also acknowledging the range of wider forces, institutional systems, processes and regulations that influence our ability to improve resilience. Accordingly, Meerow's (2016) wider approach to resilience is taken as a starting point, recognising the broad spectrum of elements contributing to heatwave resilience, such as age, health, socio-economic status, climate change, and geographic location.

Based on the key literature described above, the building codes were examined and compared against best practice heatwave risk avoidance and treatment using the following key analytical focuses.

1. Mechanisms of Risk Treatment: Exposure, Vulnerability/ Resistance and Hazard (Australian Institute for Disaster Resilience, 2015).
2. Regulation Processes of Applying Codes
3. Emphasis on Prepare, Respond or Recover
4. Interactions with other non-building systems (March & Dovers, 2017).

Key elements of best practice are presented below followed by issues and opportunities for improvement. The results are divided into key operational elements for the assessment of heatwave resilience. Managing the risks associated with heatwave requires an integrated approach that includes each of the following elements. Summaries of these elements are provided in later sections in conjunction with the review of treatments in the National Construction Code. These are presented as best practice themes and are used as key headings in the findings.

1. Maintenance of internal temperatures to "safe" levels
2. Modelling of ongoing and future heatwaves and vulnerable population
3. Knowledge of vulnerable persons types and distribution within population
4. Knowledge of vulnerabilities by location, activity and building type
5. Integration of Building Code, Urban Design and Urban Planning Mechanisms
6. Prevention and remediation of heatwave across agencies and spatial management systems
7. Retrofitting and future-proofing options are maintained where practicable

8. Ensuring settlements include a hierarchy of complementary structures and spaces appropriate to the risks faced
9. Use of passive and redundancy systems.

RESULTS: BUILDING CODES AND HEATWAVE RISK REDUCTION IN NSW

A striking characteristic of the National Construction Code in terms of heatwave is its general silence. This is in some ways unsurprising, given that heatwave has not traditionally been acknowledged as a "natural disaster" in the same way as hazards such as fire or flood have received attention. However, there is a long history in Australia of preventable deaths and injury associated with heatwave. Inclusion of heatwave standards in building codes would contribute to the range of wider solutions currently being sought. The following sections set out summaries of assessment against key risk management elements.

MAINTENANCE OF INTERNAL TEMPERATURES TO "SAFE" LEVELS

Buildings are potentially a key mechanism by which people can avoid or minimise exposure to heat. However, there is little to no data or advice relating to the performance of buildings in heatwave and the relationships between outdoor and indoor temperature is limited (Loughnan, Tapper, Phan, Lynch, & McInnes, 2013). However, the increasing load placed on air-conditioning systems during heatwaves or days of extreme heat, have led to air-conditioning failures, resulting in buildings not being able to be occupied and failures of the electricity grid due to peak demand generated by air-conditioning use. This influences the ability of private and public buildings to provide a function during heatwave to keep occupants safe. For example, an office block may provide a shelter for employees during a heatwave, but if power is lost, may become a danger instead.

Extended exposure to heat causes heat exhaustion, heat stroke, and often also exacerbates other health conditions. Other contributing factors include the absence or failure of air conditioning, often combined with high humidity or factors such as air pollution. In addition, some populations are more vulnerable, including the elderly, children, outdoor physical workers, certain racial groups, low socio-economic status and those who are isolated geographically or practically. Further, many deaths occur as a result of heat outside the main period identified as a heatwave (Kravchenko et al., 2013).

Research indicates that having facilities that allow even a few hours per day in a favourable temperature and humidity-controlled environment will reduce heat related morbidity and mortality (Semenza JC, Rubin CH, & Falter KH, 1995). Existing public health approaches to heatwave are usually directed to improved public understanding; developing response plans; improving reported morbidities and mortalities during heatwaves; and improving community responses (Kravchenko et al., 2013).

Unfortunately, little attention has been given to the design and regulation of buildings themselves. While wider strategies may include improving community access to residencies and publicly available climate controlled spaces, there are no standards or regulations specifically oriented to building and design to cater for this, alongside more well-known approaches such as encouraging increased fluid intake, advice for reducing outdoor exposure and activity, and community monitoring and outreach (O'Neill et al., 2009). An additional complication noted in the UK and other northern hemisphere locations is that improvements to cold-weather insulation and energy efficiency may also be leading to poorer heatwave performance over time as energy savings are sought as a primary goal (Poritt, Cropper, Shao, & Goodier, 2013).

The following issues arise when best practice is compared to current NSW approaches in terms of maintaining internal temperatures to "safe" levels.

1. The NCC is silent regarding heatwave, particularly with relation to building performance in terms of sustained heat and related aspects of comfort as they relate to vulnerable people. Buildings are controlled through Section J and Section 3.12 (or BASIX) energy efficiency controls of the NCC, with a level of consistency provided by all habitable buidings required to meet minimum controls for thermal performance. The NatHERS (Nationwide House Energy Rating Scheme, a framework that allows approved software tools to rate the heating and cooling loads of Australian homes by their building fabric) and NSW's (Building Sustainability Index) BASIX system does not directly seek to ensure avoidance of heatwave impacts, particularly taking into account heatwave scenarios. Rather it is oriented to assessing the potential energy usage of structures while achieving targets and performance standards by location. Basix seeks to achieve:
   a. Water savings target
   b. Energy savings targets
   c. Thermal performance, including a **heating cap and a cooling cap**[1]

   The estimations of the heating and cooling caps may not be sufficient given heatwave scenarios. Further the climate assumptions used in current modelling in NSW are drastically underestimated (Updahyay et al .2019). Updahyay et al (2019) in their modelling of a NSW homes using the established software for performance modelling, found that a home achieving a 7.6 star rating (out of 10) using AccuRate software, failed to meet the heating threashold legally required in NSW for 2030. The research found that a house designed for 2030 would fail today's building code because it would be optimised for cooling efficiency (i.e. shade) at the expense of heating efficiency (i.e. solar gain). Practical analysis of higher rated homes (using NatHERS) found whilst improved winter performance was achieved, reducing the need for heating. The study found that energy use increased in summer, as a result of needing to cool the dwellings (Ambrose et al. 2013). This issue has also been found in New Zealand where focus on improving winter temperatures through building codes or HomeStar rating has resulted in exacerbating summertime temperatures (Ade and Rehm, 2020)

2. There is no recognition of the implications that heatwave may have for different activities in structures such as between workplaces of different types (eg consider the differences between offices, manufacturing plants, and warehouses); dwellings; or health facilities.

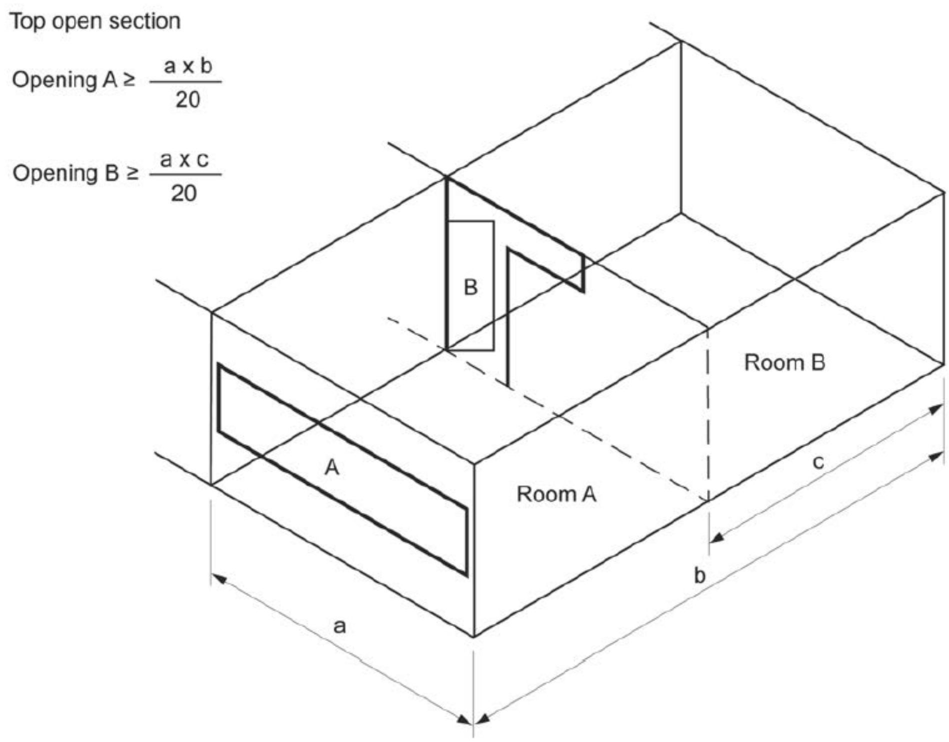
[1] The cooling cap is a measure of how much "cooling" is required to keep the building thermally comfortable averaged over area of the building a year and is not a measure of how uncomfortable the dwelling during a peak hot period.

3. There is a reliance on energy rating (thermal comfort), Worksafe practices or other mechanisms that do not account for sustained heat impacts over a number of consecutive days such as those associated with heatwaves, except as secondary concerns. This means that cumulative effects over a number of days are not accounted for, and that failures in other systems such as electricity supply and therefore loss of airconditioning units will have even greater negative impacts.

4. No comfort/ discomfort performance tests exist besides thermal comfort tests established primarily for energy saving purposes - thermal comfort is not just degrees Celsius (in addition to humidity, ventilation, air movement) but includes sustained heat and freshness. Alternatives such as the "Excess Heat Factor" – an index based on a three-day-averaged daily mean temperature (DMT), intended to capture heatwave intensity as it applies to human health outcomes - (Hatvani-Kovacs, Belusko, Pockett, & Boland, 2016) exist but are not integrated with the Building Codes.

5. Current regulations allow some internal rooms to be non-ventilated, potentially exacerbating heatwave effects (see National Construction Code BCA Vol 1 - F4.7 Ventilation borrowed from adjoining room).

Figure F4.7 Method for determining areas of openings for borrowed ventilation



6. Co-incidental risks such as those associated with bushfire smoke during successive hot days, power outages or flooding during hot weather where occupants are assumed to be safe while sheltering in place pose multiple cascading risks and are not addressed in the NCC.

7. There is silence on innovations such as albedo effects relating to heatwave (although lighter colour roofs are encouraged through both BASIX, and Section J), the role of relative humidity in different climates, breezes, vegetation, new innovative "performance" materials (Oldfield, 2018) that include heat sinks (Ramakrishnana, Wang, Sanjayana, & Wilson, 2016) or other mechanisms such as "cool roofs" ("Climatological Variability of Fire Weather in Australia,").

8. No inclusion of "cool spaces" ideas for vulnerable groups of population of for larger buildings (Ramakrishnana et al., 2016). Cool spaces are places where people can refuge and find relief from heat, often associated with other support and coordination services for vulnerable groups.

9. No requirement for A/C but assumption that it will be used and no recognition of capacity for later addition of A/C to structures. Complexity is added in this regard because non-provision of A/C might lead to comfort being achieved through passive means alone – although the effectiveness of such means in heatwaves is diminished. Further, it should be noted that the use of active cooling systems is effectively assumed by the thermal performance modelling systems, and building codes encourage construction suited to installation of A/C (e.g. sealed building envelope and minimum insulation).

10. "Smart" systems not accounted for in heatwave contexts. These would include systems that flush heat and take in cool air in the night (assuming cool air is available) (Ramakrishnana et al., 2016). Further, very few passive cooling systems are encouraged (e.g. drapes, blinds, stack effect, fans, breeze capture, etc.)

MODELLING OF ONGOING AND FUTURE HEATWAVES AND VULNERABLE POPULATIONS

Ongoing work is occurring internationally in public health, modelling and risk reduction fields to model and predict heatwaves spatially (by climate zone and location[2]) (Diaz et al., 2015), socio-economic and demographic change (Black, Veitch, Wilson, & Hansen, 2013), building type and characteristics, and land use (Kravchenko et al., 2013).

1. No assessment or accounting for (e.g. future proofing) likely future heatwave risks, including frequency and distribution of heatwaves, and increasing vulnerability of population is included in the building codes.
2. Social and demographic change not accounted for in the building codes.

[2] Current work is being undertaken by the Bureau of Meteorology and other health entities.

KNOWLEDGE OF VULNERABLE PERSONS TYPES AND DISTRIBUTION WITHIN POPULATION, AND OF VULNERABILITIES BY LOCATION, ACTIVITY AND BUILDING TYPE

The challenges associated with developing accurate data of the location and characteristics of heatwave-vulnerable members of the population are well known. Relevant agencies can become aware of facilities that have concentrations of vulnerable people (Diaz et al., 2015; Jackson WJ, 2016) . Older persons, the disabled, and at risk homebound people need frequent checks – however, this needs to be linked with knowledge about the quality of structures in terms of heatwave (Kravchenko et al., 2013).

1. Currently, building codes do not differentiate between persons' vulnerability, including broad classes of occupancy "type" and activities conducted
2. No inclusion of "Cool Spaces" ideas for vulnerable groups of population of for larger buildings (Ramakrishnana et al., 2016)
3. Impacts and interactions with pets are ignored
4. No provision or understanding of provision of care within domestic settings is included.
5. No differentiation between geographical places, climatic areas, weather systems
6. No additional care for special needs and disabled included
7. No consideration of buildings exposed to bushfire and flood risks where power failure risks may be sustained

INTEGRATION OF BUILDING CODE, URBAN DESIGN AND URBAN PLANNING MECHANISMS

Integration of relevant systems and processes is fundamental to achieving wider disaster risk reduction goals. Integration requires identification of shared and interdependent goals, followed by development of synergistic actions that complement other agengies' goals, across a wide suite of activities. Relevant actions often cut across varied time frames, functional activities, agency roles and responsibilities (UNISDR (United Nations International Strategy for Disaster Reduction), 2015). The integration of built environment processes such as building, urban planning, urban design, transportation and emergency provision can be particularly important (March et al., 2018). The building codes are not integrated in a number of ways, including the following:

1. No forward scenario test of likely heat island effect contribution of new individual or groups of buildings is currently required. While important advances are being made to improve tree canopy cover, this represents only one aspect of the suite of actions required.
2. Limited links into urban planning or urban design and building codes and silence regarding wider integration

3. No siting requirements, plantings, colour (e.g. albedo), surface treatments, humidity contributions or other integration aspects
4. No wider recognition of ventilation and breezes, also being dependent on location and climate
5. Mechanical and electricity-based systems increase overall heat in a given area, are expensive, prone to failure in peak demand and emergency periods, and or not being used by the vulnerable due to cost
6. The building code is silent regarding contribution of buildings to heat effects in new land release and subdivision processes
7. There is no provision for integrated approaches to understanding buildings as being both a source of heat impacts and a potential place of safety at individual site and wider scales.

There are opportunities to address these shortcomings including:

- increased cross government collaboration and better integration of land use planning resources
- improvements to minimum performance standards of electricity-based systems and encouraging resilience energy infrastructure within buildings.

PREVENTION AND REMEDIATION OF HEATWAVE ACROSS AGENCIES AND SPATIAL MANAGEMENT SYSTEMS

Interactions between heatwave mitigation and adaptation need to be considered, particularly acknowledging that new buildings and developments may directly contribute to worsening local heatwave effects (Ramakrishnana et al., 2016).

1. Current codes do not account for new buildings' contribution to (or lessening of) heat build-up in a given area
2. Outputs from mechanical systems typically increase overall heat in a given area, are expensive, and prone to fail or not be used by vulnerable populations
3. There is silence in the code regarding vegetation. Urban planning or other mechanisms can achieve this, but require direct integration approaches
4. There is no acknowledgement in the code of the links between energy efficiency, cost savings and health impacts. The overlaps between energy efficiency, thermal comfort, passive design and health impacts due to heat are numerous. Notably, the Australian government has reported the links in chapter 6 of the "Current and Future Impacts of Climate Change on Housing, Buildings and Infrastructure" report (2018), and the ABCD has previously recommended that "*…preliminary investigations on the hazards of heatwaves …*" be undertaken in the "Resilience of Buildings to Extreme Weather Events" report (2014).
5. There is silence on regarding spatial/geographical accessibility to health services

6. No requirement for buildings to complement local and state area "heat health plans"

RETROFITTING AND FUTURE-PROOFING WHERE PRACTICABLE

There is considerable opportunity to improve structures' performance in terms of energy efficiency and heatwave performance as they are renovated and maintained over time to improve the quality of the overall housing stock over time – particularly older structures (Poritt et al., 2013).

1. There is currently no inclusion of retrofitting measures or anticipation of future improvement to improve performance and future-proofing capabilities.

ENSURING SETTLEMENTS INCLUDE A HIERARCHY OF COMPLEMENTARY STRUCTURES AND SPACES APPROPRIATE TO THE RISKS FACED

The roles of individual buildings contribute to wider heatwave impacts and provision of heatwave services needed in wider geographical areas. This needs to be undertaken in an integrated and spatially organised manner (March & Dovers, 2017).

1. Actual performance of a building and role in wider community is not specified, such as public or other large buildings that could act as a refuge.
2. No inclusion of "Cool Spaces" ideas for vulnerable groups of population of for larger buildings

USE OF PASSIVE OR REDUNDANCY SYSTEMS AND INTERACTIONS WITH OTHER SYSTEMS

Use of simple and "non-brittle" solutions are often a more reliable and cost effective approach to risk reduction (Alexander, 2013; A March et al., 2018) and this is also seen as appropriate where possible in heatwave (Sandink, 2013).

1. No requirement for backup systems is specified, particularly for electricity-based systems such as air-conditioning
2. No additional role or responsibility for large or public buildings established
3. Price or source of electricity ignored
4. Interactions between natural ventilation and internal space security are not dealt with. There is also silence on links with acoustic privacy and comfort, and fire standards
5. Blinds, curtains and shade systems are not included, however minimum external shading is required by the code.

KEY AREAS FOR ATTENTION & ACTION

Reducing the risks associated with heatwaves requires an integrated suite of actions to be undertaken over a range of spatial scales and time horizons. While this report has focused upon building codes, the activities, policies and regulatory mechanisms of diverse agencies and stakeholders require modification for any actions to be effective. The following have been identified as useful areas for attention.

1: POLICY ACTION AND CHANGE

- Resilience NSW to lead broader agency coordination and integration of policy and strategy in collaboration with relevant agencies, included but not limited to agencies involved in housing, building and planning matters.
- Develop actions to seek modification of the National Construction Code to address heatwave.
- Seek mechanisms relating to retrofitting including that future-proofing options are maintained in buildings where practicable
- Ensuring settlements include a hierarchy of complementary structures and spaces (such as cool spaces) appropriate to the risks faced that may include actions outside Building Code approaches.
- Seek that a range of passive and redundancy systems are promoted
- Develop precinct based or commercial centre approaches to integration including design, land use activity, response capability, heat island effect and provision of cool places across all agencies.
- Develop heatwave subplans that target specific geographic areas, actions themes, topic areas and agencies – as relevant to regional and local challenges and capabilities.
- Seek outcomes across a wide range of integrated policy actions (including for below themes)

2: RESEARCH AND KNOWLEDGE DEVELOPMENT

- Develop understandings of ways to achieve internal building temperatures to “safe” levels
- Develop modelling of ongoing and future heatwaves and vulnerable populations at risk
- Improve knowledge of vulnerable persons types and distribution within the population, and into the future as demographics, socio-economic and climate change occurs. Undertake research into ways to utilise this knowledge and by whom
- Develop knowledge of heatwave vulnerabilities of people and infrastructure by location, activity and building type. Undertake research into ways to utilise this knowledge and by whom

- Develop education and advocacy approaches that can be more widely applied and adapted
- Undertake a risk assessment of building code issues at a local level

3: INTEGRATION

- Develop cross sectoral integration approaches. An example may be between building, urban planning, health sector and response agencies to improve the design and ongoing management of new precincts to include a range prevention and response elements
- Develop directions for procedural and regulatory integration of building code, urban design and land use planning and health services mechanisms
- Develop connections and appropriate actions between building types and heatwave "ratings" in geographic locations, and for vulnerable groups or structures

4: DIRECT ACTIONS AND DEMONSTRATION EXAMPLES

- Establish emergency service workplace protocols to protect workforce and continuity of service in heatwave
- Integrate heatwave risk reduction approaches into the design of all new emergency management buildings, workplaces and workplans
- Seek out and document other demonstration projects

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