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Australian Cities and Climate Change

Abstract

Rising sea levels, heat waves, bush fires, cyclones, drought and flood present a growing threat to Australian settlements. Policy responses to these climate change driven concerns are polarised. The two main political parties at the federal level display starkly different perspectives on approaches to greenhouse gas reduction. Nationally and at a state level, mitigation of climate change vies with adaptation concerns and policy makers flip flop between top down and bottom up solutions. This paper examines the characteristics of Australian cities in the light of a changing climate. It discusses government actions at federal, state and local levels, contrasting top-down mitigation driven concerns to more bottom-up adaptation focussed responses. Climate driven research, policy and action are examined to address questions of urban resilience. Can Australian cities adapt to a changing climate both to reduce the risks from climate change and to reduce their greenhouse footprint or do their historic land use patterns and resident behaviours represent ingrained characteristics that are an obstacle to appropriate adaptation?

Introduction

Climate has always exerted a powerful influence over Australian settlement and land use patterns. Throughout Australian prehistory up until the late 18th century, the distribution and density of the aboriginal population was driven by the availability of water and food resources, which resulted from the prevailing regional climate. The attractions of economic prosperity flowing from a resource rich country and long hot summers on the beach have been key drivers of much twentieth century immigration to Australia, particularly from northern Europe. The coastal location of the major cities owes much to climate conditions, which offered access to international trade and the moderating influence of the sea to counter the often extreme summer temperatures. Yet Australia's climate is highly uncertain. Years of drought (for example 2001 – 2009) may be followed by deluge. A La Nina phase of the Southern Ocean oscillation (BoM, 2014) can flip the continent's climate from dry to wet in the space of a season, whilst the consequent impacts on agriculture and the rural economy may resonate for a decade or more. Climate change adds a further critical dimension to this already precarious situation.

Australia's urban areas are vulnerable to a range of climate driven concerns. Long term shifts in rainfall patterns are likely to present water resource challenges to several cities. Over the last decade, Perth, Adelaide, Melbourne and Sydney have all invested in desalination plants in anticipation of future water shortages. Extreme events such as bush fires, driven by prolonged dry conditions and lengthy heat waves and flash flooding from increasingly concentrated rainfall events, are becoming more frequent and severe. In 2009 bush fires ravaged the state of Victoria with significant loss of life and property. New South Wales (NSW) faced extreme bush fires in 2013 and South Australia (SA) in early 2015. In 2011 Brisbane was devastated by floods which inundated the city centre causing massive damage estimated at more than AU$10 billion. Perth has been threatened by bush fires in 2011 and Victoria and NSW have both faced major flooding in recent years. Tropical North Queensland has suffered devastating cyclones notably in 2006 and 2011. Such serious and frequently occurring events raise serious questions about land use allocation decisions and the ability of populations and institutions to adapt to a changing climate. They also highlight the

debate on greenhouse gas (GHG) mitigation policy, which over the past decade has become a polarising issue in federal politics. This paper explores the nature of the climate threat to Australian cities by relating recent climate research to their form and characteristics and current development trends and policies. It begins by outlining the likely scale of climate change and the implied risks for urban settlements across Australia including not only the established state capitals but smaller country towns. It then examines the political response, noting contrasts between levels of government and between types of action taken. Mitigation of climate change relates to the reduction of GHG emissions to lessen the future impact of climate change, whilst adaptation policy recognises the inevitability of climate change and seeks ways to accommodate or live with these changes (IPCC, 2007a:33). The discussion highlights the climate debate at the national level, noting the failure of GHG mitigation policy, in contrast to some leading edge success in adaptation research. State and local concerns are then addressed raising questions around the compatibility of climate mitigation and adaptation policy and the relative balance and effectiveness of top-down versus bottom-up solutions to climate change. At each level of the government hierarchy the available knowledge and research, policy framework and action on the ground are discussed. In a country noted for its climatic extremes, what role can urban planning play in generating resilience in the face of long term and irreversible climate change?

Risks from climate change

Seven out of the ten warmest years have occurred since 2002. Since 1950 the mean annual temperature has risen by around 1 degree centigrade. In 2014 Australia experienced its third hottest year on record. Annual rainfall was higher than normal in the tropical north and lower in the west and South east of the country. Between 13 -18 January 2014 Melbourne recorded four consecutive days at over 41^{o}C and Adelaide 5 days over 42^{o}C. Temperatures more than 10^{o} above average were recorded across southern Australia between 30 January and 2 February (BoM, 2015). The climate record for 2014 demonstrates the predicted future pattern of Australian weather with increasingly intense and lengthy heat waves and differential rainfall patterns. Figure 1 summarises recent climate trends across Australia.

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New South Wales and the Perth region are becoming drier whilst the tropical north and the central interior around Alice Springs are receiving more rainfall, often in intense periods which lead to flash flooding. Tropical cyclones are becoming more intense and extending progressively farther south. More intense storms and high winds capable of damaging buildings and infrastructure are becoming more frequent across southern Australia. The storm surges which accompany these events increasingly threaten coastal settlements and bush fires which are related to periods of extreme heat are occurring earlier in the season each year as temperatures increase and fuel load from winter vegetation growth ignites. Each state and city faces a combination of climate risks summarised in Table 1.

The physical form of housing and buildings does not differ significantly between cities. A predilection for single storey lightweight structures either of wood or brick veneer with large window openings and roofs constructed from tile or metal sheeting is typical of much Australian housing. Whilst the National Construction Code differentiates between climate zones, defining seven from the tropical north to the alpine southern zone and sets different standards in respect of insulation and

resilience to wind strength, it is debateable whether these standards are sufficient to cope with the extreme manifestations of weather that are becoming increasingly frequent. Recent events demonstrate that Australian houses burn easily, are readily damaged by cyclones and high winds and may be swept away by floods and storm surge. The eleven day Melbourne heat wave of 2009 demonstrated the impact of extreme climatic events on normal city functions. 374 more people in the city died than would normally be expected during this period. Half a million residents were deprived of power and around a quarter of rail services were cancelled as result of buckled track (DIT, 2011: 129). Heat waves present significant problems, not least to the poor and vulnerable age groups such as the very young and old. As a result of the poor thermal performance of most Australian homes mechanical air conditioning is common, but the peak load problem produced during hot weather results either in rolling electricity black outs or very expensive infrastructure services (Saman et al, 2103).

Outside of the major cities Australia's many small country towns face similar risks from a changing climate. These are often exacerbated by remoteness and the fact that many rely on a limited industrial base, often agriculture, which can be significantly impacted by prolonged droughts. A study by Beer et al (2013) notes that inland settlements' adaptive capacity often lags behind that of coastal settlements and that remoteness and lack of investment are critical indicators of vulnerability. Remote indigenous settlements are particularly at risk from climate change for these reasons.

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Federal politics and government funded research

The government response to climate change has implications across many areas of policy and society and is not solely concerned with cities. Nevertheless cities are a central aspect in that they are major sources of GHG emissions and represent population concentrations. Around 68% of the Australian population live in its six major cities. Along with the USA, Australia was notable for its refusal to sign the Kyoto Protocol. Nevertheless, federal government departments have input significant resources into climate research and data collection over the past two decades. Both the Bureau of Meteorology and the Department of Climate Change maintain data on climate trends and greenhouse gas emissions, the latter using IPCC approved methodology for data collection and reporting. In 2007 the incoming Labor government under Prime Minister Kevin Rudd made signing the Kyoto treaty a centrepiece of Labor's political agenda, contrasting its recognition of the importance of action on climate change to the position of the previous Liberal government. In opposition Labor had commissioned a wide ranging review of climate change impacts and policy by Professor Ross Garnaut (2008). Drawing on Garnaut's analysis Rudd attempted to introduce a carbon cap and trade scheme which would position Australia as a leader in carbon mitigation. Unable to push his legislation through the federal Senate he became increasingly frustrated by opposition from several quarters including the Greens. In fact the emissions reduction targets proposed in the legislation were minimal in comparison with the IPCC recommendations at the time. The Carbon Pollution Reduction Scheme (CPRS) advocated by Labor proposed a 5% reduction over year 2000 emissions levels by 2020 and a further 20% should other major international GHG emitters agree to go further at the 2009 Copenhagen climate summit. Meanwhile the IPCC was advocating up to 40% cuts on 1990 levels (IPCC, 2007b:67).

The debate on climate action thrust the issue into the media spotlight making it a central issue in Australian federal politics. This debate must be viewed in the context of the Australian economy. Parallel with the attempts by Labor to introduce action on climate change, the world was rocked by the Global Financial Crisis (GFC) commencing in 2007. Australia was one of the few nations largely untouched by its effects. Its position as a major supplier of mineral resources to China shielded Australia from the crisis, but highlighted the dependence of the nation on this trading relationship. Measured by volume, coal and iron ore constitute Australia's major exports to China and the nation remains the world's leading exporter of coal. Coal also fuels 75% of Australian electricity production (Australian Government, 2012). Climate change mitigation policy has become a focus for opposition to any policy which might impact on the continued viability of the economy. Australian lifestyle and prosperity contribute to the politicisation of climate change. Australia's ecological footprint exceeds 7 global hectares per person (the carrying capacity of the earth is calculated to be 1.7 global hectares per person). Australians rank 15th in the world in respect of per capita energy use (ABARE, 2010). Per capita GHG emissions of 28.1 tonnes carbon dioxide equivalent (t CO2-e) in 2006 (Garnaut, 2007:153), contrast sharply to an average of 10.3 t CO2-e in the fifteen European countries making up the EU-15 (EU, 2009) positioning Australia as one of the biggest per capita carbon polluters in the world. This profligacy in natural resource usage plays out in the physical form and performance of its cities. Because of their relatively low density Australian urban areas are extremely car dependant. Cars are the predominant mode of transport for journeys to work and a high proportion of leisure, school and retail trips are made by private car because of zoning policies which have separated public facilities from housing. Space has always proved an attractive attributes of Australian residential areas so both allotment sizes and house floor areas have historically been much larger than counterparts in Europe and Asia. In 2009 the median new free standing house in Australia had a floor area of 240 square meters making it the largest in the world. The combination of these factors suggests that Australia is living beyond its environmental means but climate mitigation policy threatens to impact on this prosperous lifestyle. Labor suffered multiple setbacks in its attempts to address GHG emissions, one of the most high profile cases being the abortive home insulation scheme. The roll out of a national home insulation programme sponsored by federal government was marred by the death of several installers and a number of house fires, ostensibly the result of poor management and training and insufficient assessment of risk (Hanger, 2014). As a result a common sense programme designed to reduce the nation's residential emissions turned into a political fiasco which climate sceptic politicians were successful in deriding as a waste of public resources.

Following the failure of Rudd's CPRS, the next Labor Prime Minister, Julia Gillard, pinned her hopes on a carbon tax. Although enacted, it proved flawed in its conception, further enhanced the political divide at the federal level and was repealed by the incoming Liberal government in 2013. The carbon tax was central to the 2013 federal election. Whilst Labor's best intentions in addressing future GHG emissions may be criticised in their design and were clearly thwarted by political opposition, the incoming Liberal perspective was sharply contrasting. The new Prime Minister Tony Abbott, was quoted in opposition as believing that "*climate change is crap*" (Turnbull, 2009) and clarified his position on GHG abatement by commenting that in his view "*coal is good for humanity*" (Massola et al, 2014). Events move quickly in Australian federal politics. In September 2015 Abbott was ousted as prime minister by Malcolm Turnbull who had previously lost the Liberal leadership to Abbot because

of his defence of action on climate change. The administration's policy stance on climate change has so far shown no change, though the rhetoric is more conciliatory.

If mitigation of climate change has run into a political impasse at the national level, adaptation to climate change has shown more promise at least in terms of research effort. The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 to generate the information needed by decision makers in government and in vulnerable sectors and communities to manage the risk of climate change impacts (NCCARF, 2013). Initially funded for five years, NCCARF has survived changes in leadership and political control at federal level and, despite reduced funding following its initial phase, continues to be active. Its research record is substantial with 154 research reports listed on the NCCARF website covering a broad range of climate adaptation research from aboriginal responses to climate change (Memmot, 2013), through spatial planning instruments for climate change adaptation (Macintosh, 2013) to consideration of the future of Australian country towns (Beer et al, 2013). The research and data represented by the NCCARF repository stands up to international comparison and represents an immensely valuable resource for government and policy makers. In tandem with this research effort, the federal government rolled out its Local Adaptation Pathways Program grants to local government to assist in planning and risk assessment for climate change as well as assessments on coastal, biodiversity and heritage vulnerability. The degree of adaptive response to changing climatic conditions in Australian urban areas is discussed later. For the moment it should be noted that the funding and collection of climate data and research has proved far less contentious than has the implementation of policy response to climate change at a federal level. The application of much of this knowledge to urban policy is more a matter for the states and territories than the federal government, a fact which might go some way to explaining the contrasting attitude of federal government to mitigation and adaptation to climate change. For both sides of federal politics the implementation of climate mitigation policy appears to be so at odds with critical economic conditions that it has proved impossible to progress.

The state level perspective

The lack of progress on GHG mitigation at the national level contrasts with activity lower down the government hierarchy. The ability of Australian states to set their own policy agenda on a range of issues, independent of federal government, is demonstrated by the approach taken by a number of the states. Both South Australia (SA) and Victoria have introduced GHG mitigation targets supported by state legislation (Government of South Australia, 2007; Victorian Government, 2010). The Victorian legislation was amended following the introduction of the federal carbon tax due to concerns about duplication and overly burdensome impacts on industry. Both Victoria and SA also pursued a vigorous renewable energy policy with SA in particular making a significant contribution to the national energy mix with 16 large wind farms in operation by 2014. The introduction of a feed in tariff for small solar installations in 2008 also resulted in SA having the highest proportion of households (24.3%) with solar photovoltaic installations of all the Australian states (see Table 1).

Urban planning policy is traditionally a preserve of Australian state government. Whilst some federal administrations, usually from the Left, have dabbled with urban policy intervention, there is no long term policy continuity or established national view on cities, a fact underlined by the abolition in 2013 by the Liberal government, of the Major Cities Unit, constituted by the previous Labor administration. Each state has its own planning legislation but despite some differences in operation,

the policy stance of the large cities across Australia displays some coherence. Over the last decade all the capital cities have opted for a degree of control over urban fringe expansion, favouring consolidation and density increase in the urban core and surrounding suburbs. This strategy has as much to do with attempts to improve urban vitality, reduce motor vehicle pollution and congestion and improve housing affordability, as with climate change, but allied to attempts to lure commuters from their cars and on to public transport, it may be viewed as an attempt to reduce GHG emissions and address the high ecological footprint issue. Perth's investment in rail corridors and Adelaide's transit corridor focussed policy represent examples of attempts to shift Australian drivers away from their cars and onto public transport. At a strategic level the recent raft of metropolitan plans produced by the six major capital cities, Brisbane, Sydney, Canberra, Melbourne, Adelaide and Perth, all make arguments for urban consolidation, restraint on further fringe expansion, greater urbanity, particularly around the CBD, transit corridors and activity centres, with more mixed use zoning.

Cities and Green House Gas mitigation

Mitigation of GHG emissions is regularly cited as one of the desirable outcomes of the policy package outlined above. As commuting distances fall, more trips are made by public transport, bicycle and walking and residential floor space is pegged back to smaller units, the hope is that urban GHG emissions will reduce. Whilst there are multiple potential benefits from such policies, the pace of observable change is less convincing.

National construction statistics show that the number of building approvals for single family houses has trended at around 9,000 per month since 2005. However the trend for other forms of housing such as units and apartments has steadily increased from 3000 per month in 2005 to around 6500 per month in 2014 (ABS, 2014). So there is some evidence that a sea change in the type of dwelling provision is occurring. There remains a debate as to whether this upsurge in higher density apartment provision represents a changing demand profile driven by demographics and climate policy or is driven by investors looking for new outlets (Elliot, 2015). A good deal of development continues to occur on the urban fringe despite metropolitan policies which aim to reduce this proportion of total housing development. Residential allotment sizes appear to be reducing when viewed through the lens of recent development plan policy. Minimum allotment areas of 200 – 250 m^2 are relatively common in contrast to a decade ago when they were more typically 4-500m^2. However, according to Residential Developer magazine, new housing developments show little evidence of reduction in allotment size whilst at the same time individual dwelling floor space is increasing. "*While there are a higher proportion of allotments approved under 450 square metres (12 per cent today versus 5 per cent a decade ago), the proportion of allotments sized between 450 and 800 square metres has not changed*" (Matusik, 2009).

The desirability of mixed use zoning as a strategy to reduce the need to travel has been widely recognised in development plans but remains a policy initiative which is mainly applied in city centres and on transit corridors. Urban consolidation requires careful management, not least because it carries the potential to exacerbate certain problems such as storm water runoff and urban heat island effects. As a result, additional strategies such as the use of water sensitive urban design and green roofs are required to ameliorate and regulate these urban density impacts. Even then, some commentators argue for a variety of environmental and social benefits best achieved by the traditional low density Australian suburb (Lewis, 1999; Dodson & Gleeson, 2007). Furthermore,

there is not yet a conclusive case to suggest that high density apartment living is actually less energy intensive than lower density suburban solutions particularly when embodied as well as operational energy is taken into account (Perkins et al, 2009). Large areas of suburbia remain unchanged both physically and in respect of their zoning. Yet according to several commentators (Newman & Kenworthy, 1999; Lehman) these suburbs represent the nub of the climate problem of Australian cities in many respects including GHG mitigation and adaptation.

Australia remains a highly car dependant nation. 60% of households report owning two or more cars and less than 10% of households do not have access to a car. Although public transport usage is higher in the state capitals than in other smaller urban or rural areas it remains a minority travel mode. Across the state capitals in 2006 less than 20% of journeys to work (JTW) were made by public transport whilst private cars accounted for 75% of such trips. Public transport ridership across Australian capital cities for JTW varies from Sydney at 26% in 2006, Adelaide 14% and Canberra as low as 8% (Australian Social Trends, 2008). Increases in ridership are recorded in most capital cities in the period 1996- 2010 and forecasts suggest these trends will continue albeit at a slower rate in the next decade (Department of Infrastructure and Transport, 2013). The main limitation to increased participation appears to be distance from frequent public transport. This phenomenon is of course a function of the low density sprawling nature of Australian cities and implies significant expenditure in new infrastructure if it is to be adequately addressed. Whilst there has been investment in rail and trams in several cities, this is mainly federally funded. An overwhelming proportion of federal funding on transport infrastructure continues to be spent on roads (Australian Government, 2014).

A number of localised attempts to reduce the carbon footprint of Australian cities through research and demonstration schemes may be noted. Examples include inner Melbourne's Moreland Energy Foundation, established by Moreland City Council in the wake of the Victorian utility privatisation. The Foundation has been extremely active in promoting energy efficiency in the community, supporting research to reduce carbon emissions and fostering community engagement in climate action. Townsville in northern Queensland has taken a similar approach using its Energy Transformation Townsville Project (Townsville City Council, 2015). Location, as well as concern over climate change, is a key driver here since, as a result of its distance from major power stations, transmission losses account for 80% of Townsville's electricity demand. Both Moreland and Townsville were also participants in the federal government sponsored Solar Cities program (2007-2013), a partnership between local councils in seven Australian urban areas and the main utility companies to provide smart meters, energy efficiency kits and low cost solar panels to consumers in an attempt to kick start community uptake of the technologies. Furthermore, the offer of feed in tariffs (FiT) across most of the states has resulted in a significant uptake of solar PV technology (see Table 1). The City of Onkaparinga in southern metropolitan Adelaide has instituted a local climate levy through the rating system to help fund council led energy security initiatives such as a demonstration renewable energy precinct (City of Onkaparinga, 2010). Sydney City Council pursued an ambitious $5 billion project aimed at taking the City centre off the coal fired electricity grid by switching to a localised, gas fuelled trigeneration scheme, though the project has been scaled back to cover only a number of public buildings such as the Town Hall and Sydney University (Campion in Daily Telegraph, 2013).

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In addition to numerous examples of place specific attempts to address climate change, the development industry has been encouraged to produce more sustainable, energy efficient buildings. A study by Horne and Hayles (2008) demonstrated the lamentable energy performance of Australian homes when compared internationally. The subsequent development of building energy rating schemes has paved the way for their nationwide application. Since 2011 the National Construction Code mandates all new homes must be constructed to at least a 6 star energy rating using the National Housing Energy Rating Scheme (NatHERS) 10 star assessment framework or equivalent. Commercial buildings are assessed using parallel schemes, notably the National Australian Built Environment Energy Rating Scheme (NABERS) 6 star scale (where 6 stars demonstrates market leading performance and is twice as efficient as 5 star building) and the Green Star scheme. A combination of reduced running costs and pressure from large building floor space users, notably state governments, has ensured that the majority of new office building in Australian cities ranks highly on these scales in respect of its energy efficiency.

Adaptation to climate change

Parallel with the above efforts to reduce GHG emissions, interest in how urban form and land use location might adapt to accommodate a changing climate has proved the focus of increasing debate. Part of this concern must be attributed to the research output of NCCARF, which included a research theme on Settlements and Infrastructure. A general theme adopted by several authors relates to the concept of increasing the resilience of settlements to climate change (Davoudi, 2012; Wilkinson, 2012; Carter et al, 2015). Broadly, this concept is concerned with enhancing the ability of settlements to deal with climate induced threats such as bush fires, heat waves and storm surges and to recover quickly from their effects when these occur. Here we observe a high degree of overlap between policies relating to resilience and the more wide ranging concerns relating to urban sustainability. Recycling of water and waste, the collection of solar and wind energy, the use of green roofs and walls to ameliorate temperature extremes and the application of energy efficient building techniques and devices, represent examples of specific technical solutions which may improve both resilience and sustainability. Zoning policies which seek to avoid development in vulnerable areas such as flood plains, low lying coastal areas and bush fire prone regions, suggest there is no shortage of understanding of available policy responses to climate adaptation. However learning to live with new and increased threats to the urban environment is not as simple as having a good grasp of the available policy toolkit.

A number of different factors need to be considered when urban adaptation to changing climate is examined. First, what are the likely climatic changes which might occur over a given time frame and what threats and risks do they pose to urban settlement? Second, how might these risks be addressed? Often there are multiple strategies for managing risks. An example is provided by concerns about sea level rise, which poses the threat of more frequent flooding from storm surge events, or accelerated erosion of coastal locations that may involve risk to human life and property loss. The IPCC (1992) has identified three potential responses, namely, defend, adapt or retreat, but the choice of which response to adopt is complex and governed by a range of factors. The value of threatened areas, whether measured in dollars or some broader environmental valuation technique, is clearly one aspect. Public and particularly, resident opinion, is another critical aspect. The impact of a chosen policy solution on neighbouring areas is also important. For example, protecting coastal locations with armoured sea defences can have detrimental effects on other beach locations further

along the coast, where erosion may be accelerated. So the choice of adaptation strategy is not a simple task. Finally, broader questions of governance are raised. Who is actually responsible for making these policy choices and how will they play out in respect of recurrent funding, risk management and design? In some cases government may use the land use planning system to set the policy framework, but in others different statutory or public sector mechanisms may be required and in both instances, the eventual cost and responsibility for ongoing management may fall on individual householders, companies or other agencies. Community involvement in decision making is therefore critical to success. Stanley et al (2013) undertook a study for NCCARF which explains the complexity of this decision making process. Posing the question *What would a Climate Adapted Settlement Look Like,* their report stresses the importance of community support to ensure the success of any chosen strategy. In particular, following Jacksons' work for the UK Sustainable Development Commission, they note that:

"simply telling people to reduce their consumption and live more sustainably, for example, by insulating their homes, driving less and putting on a jumper, will not work. There is a need to change the perverse forces that drive people to consumerism in the form of status competition and also provide opportunities for people to participate in meaningful ways, to contribute creatively to the life of society" (Stanley et al, 2013:23).

Thus, the process of climate adaptation requires fundamental shifts in the underlying drivers of behaviour which produce and manage urban development and the adaptive responses to climate change may vary between settlements depending on local conditions and attitudes. The design and application of policy to achieve the required behaviour change represents a significantly wider agenda than just land use planning.

The location, size and level of investment in Australian urban settlements is a critical factor when adaptive response to changing climate is considered. The five major Australian cities are all located on coastal floodplains, susceptible to both marine storm surge and flash flooding from inland. Federally funded research has provided an overview of the coastal threat to settlements and natural environments accurate to one meter, thus identifying those locations which face inundation up to 2100 (DCC, 2009) (the current predictions for SLR vary around the Australian coast but typically are of the order of 1 meter by 2100). Over the next centuries, as with many coastal cities around the world, these cities' very existence may become untenable as sea levels rise perhaps by several meters. However, established investment in public infrastructure and private property dictates a level of inertia which effectively precludes retreat and implies policy will focus on protection, accommodation or even business as usual. In a number of locations facing imminent threat detailed analysis is taking place. These studies tend not to look beyond 2100 and focus on time horizons of twenty to thirty years in order to achieve the required level of public engagement (AWE, 2009; Western et al, 2013). The coastal frontage in the major cities is mostly already protected by hard defences and these are likely to be augmented as sea levels continue to rise. State coastal policy is probably most advanced in South Australia where statutory referral of all development applications within the coastal zone to a state regulator has already led to a number of refusals and where development is permitted, proponents must demonstrate that floor levels are sufficient to exceed a rise of one metre. Nevertheless, politics comes into play even at this level and similar restrictions were withdrawn in NSW in 2012 Queensland in 2013 following changes of state government (Government of NSW, 2012; Government of Queensland, 2014).

Adaptation aimed at making Australian cities more resilient to climate change represents a well researched issue which is beginning to gain traction with state and local governments. The major threats of cyclone, flood, bush fire and heat wave demand significant policy revision which, as the SLR example outlined above demonstrates, may not be straightforward to implement. A key concern is subsidiarity, namely the best level at which to intervene. A frequent complaint from local government focusses on the top down imposition of one-size-fits-all policies which pay scant regard to local circumstances, whilst state governments worry about the initiative and expertise available to effect change at grass roots level (Kellett et al, 2015). As with GHG mitigation the tension between top down and bottom up policy and action poses critical questions of governance and threatens to restrict action to deal with the effects of climate change.

Conclusion

Every urban settlement in Australia faces multiple threats from climate change which demand attention. The physical siting, design and layout of the buildings and infrastructure which constitute Australian cities present significant challenges to both adaptation and mitigation. The response to these challenges must be viewed at multiple levels and requires federal government to set appropriate GHG reduction targets and crucially, to demonstrate the political will to achieve these. Such top down policy action demands reinforcement by localised bottom-up initiatives that address both climate mitigation and adaptation. In respect of land use planning and zoning there exists some debate about the nature of good policy. Whilst most large Australian cities are seeking to limit development on the fringe and increase both their urban density and public transport ridership in the interests of GHG mitigation, these policies have yet to be consistently implemented on a large scale. Furthermore, these policy initiatives carry complex unintended side effects. Increased urban densities can enhance urban heat island effects and storm water runoff. Other pressing urban concerns such as housing affordability, an ageing demographic, access to facilities and the cost of infrastructure in future urban development may be similarly influenced. Developing urban resilience to a changing climate comes at a financial, social and economic cost. At every level, local, state and national, climate change is proving a divisive political issue which is often seen as threatening economic development or existing quality of life, so there is a lack of consensus on how, or even whether, to respond. The land use planning system represents a central tool to address the climate threat but in the absence of a clear sense of policy direction nationally, it is not surprising that state and local governments are sometimes hesitant to commit to radical change. The level of investment and understanding of the causes and impacts of climate change is high, as is the technical range of potential solutions but the commitment to action is less apparent. As elsewhere in the world, the pace of change lags behind the rhetoric and political will is shaky, despite Australian cities being some of the most globally vulnerable to multiple climate change driven threats.

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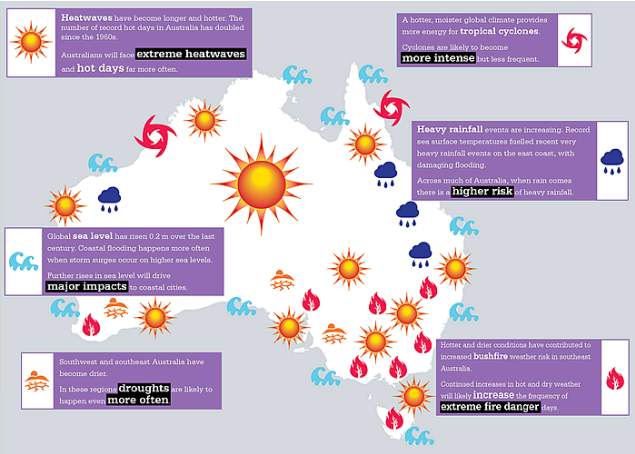
Figures

Figure 1: Recent climate events in Australia



Source: Australian Broadcasting Corporation, ABC.net.au

Tables

Table 1: Climate threats to the five major state capital cities.

	Cyclone	Bushfire	Flooding	Drought	Heatwave
Brisbane	✓	✓	✓	✓	✓
Sydney		✓	✓	✓	✓
Melbourne		✓	✓	✓	✓
Adelaide		✓	✓	✓	✓
Perth	✓	✓	✓	✓	✓

Assessment based on internet search for media reports of events over the period 2008-2015.

Table 2: Small scale (up to 100kW) Domestic and Commercial Solar PV uptake by State (2014)

Solar PV			
State	**Installed**	**Dwellings**	**% of Dwellings**
Australian Capital Territory	15,646	145,229	10.7
Queensland	434,406	1,826,449	23.7
South Australia	184,880	727,676	25.4
Victoria	249,752	2,277,967	10.9
New South Wales	294,250	2,864,531	10.2
Western Australia	190,845	960,717	19.8
Tasmania	47,967	232,370	20.6
Northern Territory	3,855	81,190	4.7

Based on ABS Census Quickstats (total dwellings) and Clean Energy Council (2014) Clean Energy Australia Report (Annual Solar PV Installations: p43). Commercial installations account for less than 10% of total installations per annum. The table assumes an even distribution of commercial installations across all states.