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Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia

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ABSTRACT

The science of climate change is now well established. Predicted weather-related events like sea level rise, increased storm events, and extreme heat waves imply an urgent need for new approaches to settlement design to enable human and non-human species to adapt to these increased risks. A wide variety of policy responses are emerging at local and regional levels – from sustainable urban form, to alternative energy production and new approaches to biodiversity conservation. However, little attempt has been made to ensure that strategies to *adapt* to the inevitable impacts of enhanced climate change (such as additional open space to enable water inundation) support ongoing policies intended to *mitigate* local contributions to climate change (such as attempts to increase urban densities to reduce car dependency). In some cases mitigation and adaptation are complementary but in other cases these policy goals may conflict. This research examined leading case examples of land-use plans and policies designed to address climate change. Focusing predominantly on cases from the United States and Australia, we identified whether the policies address adaptation, mitigation or both and whether the practices put mitigation and adaptation in potential conflict with each other. We found that half of the actions identified contain potential conflicts to achieving adaptation and mitigation simultaneously.

Introduction

Climate change is becoming widely recognized as the key global challenge of this century. The publishing of the Fourth Assessment Report from the International Panel on Climate Change (IPCC AR4) (Intergovernmental Panel on Climate Change, 2007a) and the bestowal of the 2007 Nobel Peace Prize on the IPCC marked the effective end of informed debate on whether climate change is human induced and real – both are true to a very high level of certainty. Attention has now moved to what we will do about climate change. At the national and international levels, while strong conflicts remain, there is a general agreement about what steps need to be taken to reduce greenhouse gas emissions. Even at the local level, with the widespread acceptance of Local Agenda 21 and the positive influence of the International Council for Local Environmental Initiatives (ICLEI) in encouraging municipalities to first inventory and then plan to reduce their greenhouse gases, some consensus on appropriate actions is clear, although certainly there is not enough actual action locally, nationally, or internationally to meet the target reductions in emissions. What has become increasingly apparent in the last 2 or 3 years is that because we have not acted fast enough to reduce emissions, the accumulation of greenhouse gases in the atmosphere to date means that significant changes in the global climate are already unavoidable. Thus, the issue of adaptation, alongside mitigation, is emerging as one of the most pressing issues nations and cities face. While *mitigation* planning works to reduce current and future greenhouse gas emissions, including emissions that are generated through the built environment and transportation sectors, *adaptation* seeks to adjust the built and social environment to minimize the negative outcomes of now-unavoidable climate change. Thus, mitigation and adaptation must be treated as twin issues. As noted by the IPCC in their Fourth Assessment Report (IPCC, 2007a: p. 65):

> There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation is necessary both in the short term and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed … (However) Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt. Reliance on adaptation alone could eventually lead to a magnitude of climate change to which effective adaptation is not possible, or will only be available at very high social, environmental and economic costs.

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A common frame for the goals of human–natural systems that has been gaining currency lately is that of resilience. Resiliency as a metaphor and policy goal has been borrowed from ecosystems theory and now extended to human systems. Resilience can be understood as the capacity to accommodate, or successfully adapt to, external threats, such as the impacts of enhanced climate change. The IPCC describes resilience as:

> The ability to absorb disturbances, to be changed and then to re-organize and still have the same identity (retain the same basic structure and ways of functioning). It includes the ability to learn from the disturbance. A resilient system is forgiving of external shocks. As resilience declines the magnitude of a shock from which it cannot recover gets smaller and smaller. Resilience shifts attention from purely growth and efficiency to needed recovery and flexibility (IPCC, 2007a: p. 65).

Resilient communities are the overarching goal, adaptation and mitigation are the methods to achieve the intermediate objective of reducing vulnerability and thus the overall biophysical, social and economic risks associated with climate change.

Research question and method

A key challenge in achieving the dual goals of climate change planning is that the land-use policy options to address adaptation and mitigation may conflict. Preliminary testing of whether there are and of what sort those conflicts might be, and any clear ways to reduce them, is the topic of this paper. Despite clear recognition by the IPCC of the need to ensure that adaptation actions do not undermine mitigation attempts, let alone broader sustainability goals (IPCC, 2007b, 2007c), surprisingly little research exists on the types of conflicts that might arise in practice. This is understandable given the institutional divergences that have arisen between adaptation and mitigation responses at national, regional and local levels, reflecting the different scales at which these responses operate and take effect (McEvoy & Handley, 2006). Mitigation strategies seek to reduce global warming over the long term, while adaptation strategies protect local communities from sudden and immediate dangers. It is certainly possible to conceptualise ways for mitigation and adaptation strategies to complement one another. For instance, shifting to decentralized low carbon forms of energy generation reduces greenhouse gas emissions. Shifting to wind, solar or wave energy is also a key adaptation strategy as smaller, more decentralized forms of power generation reduce the risks associated with widespread power loss through severe storm event, or from peak power loads under temperature extremes.

However, it is equally possible to conceptualise scenarios in which mitigation and adaptation goals are in conflict with each other. For instance, urban containment through higher density often results in a loss of permeable surfaces and tree cover, intensifying stormwater and flood risks associated with changed climatic scenarios, and in some climatic conditions exacerbating the discomfort and health impacts of hotter summers. Strategic planning processes are intended to provide a way of resolving competing goals, so it is likely that once identified, ways to overcome or offset many of the latent conflicts between mitigation and adaptation approaches will be developed. However, at the present time very little of the existing guidance on planning for climate change mitigation or adaptation identifies areas of potential conflict in urban policy decisions, let alone ways to resolve such dilemmas.

Our research used an international comparison approach to maximize the broad relevance of our findings and increase the pool of examples, which was needed given the early adoption stage of local or regional climate change/land-use policies. We focus on coastal communities largely beyond the metropolitan areas, where potential tensions between adaptation and mitigation actions may arise due to three factors:

- The frontline exposure of low lying coastal communities and of regional agricultural areas at increased risk of extreme climatic events such as sea level rise, storm surges, wildfires or drought;
- Relatively precarious local economies often dependent on the preservation of natural amenity and climatic appeal to attract tourists and affluent second home owners;
- Even in many wealthier communities, the existence of a significant population of service workers with lower incomes, and increased concentrations of older populations (amenity retirees), who have limited capacity to adapt their housing or living circumstances, exacerbating the risks of health impacts and fatalities arising from intense heat waves or disasters (Gurran, Hamin, & Norman, 2008).

While such issues affect socially disadvantaged metropolitan areas too, what is interesting about natural amenity communities is their need to ensure that vulnerable natural systems – species, habitat, and the ecological processes on which they depend – are also able to adapt to climatic change.

Examining local level policy responses is important because it is the specific qualities of particular urban settings and climatic zones that determine relative vulnerability to particular climate change impacts and it is at this scale that most adaptation actions should be defined. In turn, it is at this level that particular decisions regarding mitigation responses might conflict with or exacerbate climatic exposure, thus undermining adaptation attempts or vice versa.

The research methods involved:

1. A review of international, U.S. and Australian literature on climate change, to identify impacts for coastal or amenity communities; and to establish leading practice principles and approaches in planning to reduce settlement contributions to greenhouse gas emissions, and to adapt to climatic changes already under way.
2. A targeted review of local planning practices relating to climate change mitigation or adaptation. The review focused on recent work undertaken by coastal amenity communities in Australia and the United States but also includes a limited group of leading practice examples from other local government areas internationally. The review includes planning approaches directly or indirectly relevant to both mitigation and adaptation. The review is summarized in the matrix included in the Appendix. We do not attempt to count the number of communities undertaking any particular action, and instead sought to identify a wide range of actions which are being undertaken by any community to specifically address climate change, or when appropriate, to specifically address sustainable development. We added review of some plans identified as targeting sustainable development because there were very few examples of local plans or policies specifically for climate change, but, many plans and actions with a sustainability goal also address the key challenges of climate change, and thus were included in the analysis matrix.
3. Based on the principles explained below, the identified practices were categorized as adaptive or mitigating, and a determination was made as to whether in most cases the action could create a negative outcome for the alternative goal – adaptation or mitigation. These actions were identified as potential conflict actions. We then theorize about ways in which these potential conflicts could be avoided.

There are significant limitations to these findings. Two key ones are that while we spent a great deal of time on literature search to find our case studies in the table, we will certainly have missed some and thus do not claim that the table represents the universe of mitigation or adaptation actions; and, the specifics of how any one place or project is built will ultimately determine whether our generalized finding of conflict or not is correct. Further, our focus on amenity communities brings certain tensions between mitigation and adaptation into sharp relief, particularly in relation to biodiversity. Parallel empirical analyses of adaptation/mitigation tensions emerging in major city regions will likely reveal several other dilemmas. We view this paper as the start of investigations, rather than the end, and anticipate that we and other writers will revise these as the basic premises are tested in more detail.

In the sections below we first discuss key concepts and approaches underlying mitigation planning, then the responses increasingly advocated for climate change adaptation, before highlighting areas of potential conflict.

Mitigation policy goals

The perceived appropriate and necessary policy actions on local land use toward greenhouse gas mitigation can be gleaned from both literature and practice. For example, a new book by Ewing, Bartholomew, Winkelman, Walters, and Chen (2008) argues that we need to build more compactly to reduce vehicle miles traveled (VMT).[1] Based on a summary of existing literature, the text identifies five key factors of urban design that will assist in reducing VMT:

- Density – higher persons, jobs and/or dwelling units per unit area;
- Diversity – greater mix of land uses to include residential, employment, and retail/services in close proximity to each other;
- Design – smaller block size or larger number of intersections per square mile, more sidewalk coverage, smaller building setbacks, smaller street width, more pedestrian crossings, more street trees;
- Destination accessibility – more jobs or other attractions reachable within a reasonable travel time; tends to be highest in urban cores;
- Distance to transit – shorter distance from home or work to nearest rail station or bus stop (Ewing et al. 2008: pp. 70–71).

They find that it would require a doubling in density to achieve a five per cent reduction in both VT and VMT, while a doubling in all the first four actions would reduce VMT by a third. Most of this reduction comes from destination accessibility, which reduces VMT substantially when doubled. The message of the book is that smart growth as it has been commonly defined is an essential step toward achieving climate change mitigation goals.

The authors of the study make a number of recommendations on local land-use policy. In relation to process, these include undertaking a local climate action plan, revising building codes for altered climate scenarios, and investing in civic education and engagement. Specific physical planning recommendations include favouring smart growth projects which situate denser housing and services near transit stations and contain urban growth boundaries, ensuring a jobs/housing balance, so that workforce housing is near jobs, and adopting pedestrian friendly site and building design standards (the provided examples suggest maximum setbacks of 20 feet, with a small amount of parking allowed only in the back of the building; see Bartholomew, 2008: pp. 150–153).

Other works connects urban form to non-transport related energy use (Ewing & Rong, 2008; Randolph, 2008). The premise is that lower density and detached housing tends to be larger than multi unit developments or attached housing, requiring more energy to heat and cool, and additional energy output to establish and maintain electricity transmission and distribution (Ewing & Rong, 2008; Randolph, 2008). The significance of urban form and household energy use aside from transportation impacts is underscored by the fact that that the residential sector in the United States consumes more than one fifth of total energy use in that nation (Ewing & Rong, 2008). The relationship of household energy use and urban form thus reinforces the need for more compact cities and housing types, both to reduce carbon dioxide generation from vehicle miles but also to reduce local domestic emissions.

A representative approach to the current practice in mitigation is the US Mayor's Climate Protection Agreement (ICLEI and the City of Seattle undated), organized by the non-profit organization ICLEI,[2] whose primary goal is to encourage energy efficiency to reduce local contributions to greenhouse gas production. While originating in Seattle in 2004, 300 cities have now signed the agreement. In the text box below we reproduce a section of the Mayor's Climate Protection Agreement signed by these many cities, to provide a sense of the recommended land-use related actions for mitigation of greenhouse gases.

US Mayor's Climate Protection Agreement, sample actions and measures

Government measures
- Short term
  - Plant shade trees in and around local government parking lots and facilities
- Long term
  - Co-locate facilities to reduce travel time and maximize building use
  - Utilize brownfield sites where possible

Community measures
- Short term
  - Maintain healthy urban forests and street trees
  - Promote tree planting to increase shading and to absorb CO_2
- Long term
  - Preserve open space
  - Promote high-density and in-fill development through zoning policies
  - Institute growth boundaries, ordinances or programs to limit suburban sprawl
  - Give incentives and bonuses for development in existing downtown areas and areas near public transit
  - Encourage brownfield development
  - Discourage sprawl through impact, facility, mitigation, and permit fees.

Source: ICLEI and the City of Seattle (n.d., p. 11).

[1] Ewing et al. are quite vague about what constitute 'compact' development, except in one text box, which states: "In 2003, average density of residential development in U.S. urban areas was about 7.6 units per acre. As a result of shifting market demand, new developments between 2007 and 2025 would average 13 units per acre, and the average density of metropolitan areas overall would rise to approximately 9 units per acre (p. 8)." Again, the text is not clear, but the implication of the context and wording is that roughly 13 units per acre is a viable goal in terms of what the market will accept while also achieving lower VMT.

[2] Their full organizational title is ICLEI: Local Governments for Sustainability, and their web address is http://www.iclei.org/.

In summary, the consensus in greenhouse gas mitigation is that the appropriate local land-use policies must limit sprawl and create denser built forms, while maintaining urban forests if at all possible.

Adaptation

Research and policy action on planning for adaptation of cities and towns is just now emerging (IPCC, 2007b). Because so much of Australia is quite vulnerable to natural disasters, there has been more work there than in the United States, although it remains quite preliminary. In, for instance, the National Climate Change Adaptation Framework (Council of Australian Governments, 2007), the focus is on identifying areas for communities and governments to cooperate, and identifying needed research. The framework for adaptation is largely one of first establishing the local level and kind of physical vulnerability to natural disasters, and then encouraging local studies to determine appropriate responses (Pizarro, Blakely, & Dee, 2006). Generally, responding and planning for natural disasters has a much longer and deeper literature than adaptation (see for instance Hamnett, 2006), and thus adaptation benefits from this. For example, the issue of vulnerability measures is picked up by Gurran et al. (2008).

Some of the key actions that communities are undertaking for adaptation include changing infrastructure and disaster plans to include forecasts for climate change (for instance, the State of South Australia requires local plans to include provisions for potential climate induced sea level rise), planning for larger river floodplains and protecting wetlands in areas likely to see increased severe storm events from climate change (as undertaken by Noosa Shire in Australia's southeast), providing corridors for species movement as climate changes and species ranges need to change (Port Stephens Shire in New South Wales (NSW) has proclaimed a koala habitat plan of management for this purpose), and changing building codes to reflect the need for more natural cooling/less contribution to the heat island effect (see Queensland's Gold Coast Design for Climate Policy).[3]

Within the United States, there have been only very preliminary steps taken on planning for or implementing adaptation. Three notable efforts include the pilot study of adaptation planning by ICLEI for Keene, New Hampshire (City of Keene, 2007); the water infrastructure planning being undertaken by the New York City Department of Environmental Protection (NYC Department of Environmental Protection Climate Change Program, 2008; Rosenzweig et al., 2007), and the specific work by King County, Washington (2007). More examples from both countries are detailed in the table in the Appendix of the article. A point that stands out for many of the noted actions is that they require significant land to undertake, often through the provision of open space used for instance for stormwater management, sea level rise planning, or for migration corridors.

Mitigation, adaptation, and land-use conflict

To summarize, the key land-use pattern implication of climate change mitigation is concentrating development so that car travel and building energy use is reduced; it brings a strong new impetus to the existing anti-sprawl/smart growth campaign. Alongside land-use densification, however, we see the importance of maintaining an urban forest to cool buildings and sidewalks, as well as to sequester carbon. Important actions with less clear space implications are the provision of alternative energy. Solar roofs, for instance, are still entirely feasible in a dense environment, but given less roof space per person, may not provide as much per capita energy as in a lower density, bigger per person roof environment. Just where alternative energy facilities should be located in light of the need to densify urban populations is a topic that requires a great deal more investigation. Under the mitigation perspective, very high-density is a desirable urban form, although a more moderate density may also be suitable.

A key point of adaptation is that many actions, although certainly not all, require more land left in open space, and/or a less dense built environment. Current approaches to floodwater management suggest less piping and more natural infiltration; bioswales require space that pipes do not. More water to manage often means more space needed to manage it. Similarly, adding (or not removing) space-using greenery is an important step in preventing or treating urban heat island effects (Stone, 2005). Buildings that are more moderate in height and placed to enable ventilation between individual dwellings provide adaptation to higher temperatures, but tend to reduce density. While there is little adaptation benefit from low density, sprawling development, under adaptation it appears that moderate density with significant fingers of green infrastructure running through the city may be the most effective form.

To provide an initial test of this problem of where mitigation and adaptation conflict and correspond, we prepared the table in the Appendix which lists the actions that we have been able to identify towns and cities as undertaking to address the land-use implications of climate change. We grouped these by sector affected, and then judged whether they achieved the goals of mitigation (reduction of greenhouse gas), adaptation (adjusting the built or social environment to have greater resilience in the face of climate changes), or both. Where we judged there was a potential for conflict, we noted that in the last column. The key to this judgment rested on whether the action proposed tended to increase density in the urban environment, appeared neutral, or whether it served to reduce possible urban densities. There are of course great complexities that this analysis simplifies, and which may make our findings less correct for specific cases. For example, restricting building in the local 500-year river floodplain may simply move buildings to a different regional location. But given that most cities are built alongside rivers or other waterways capable of flooding, and that U.S. experience at least indicates it is very difficult to get communities to accept increases in density, we judge that it *usually* will reduce *overall* urban density, and thus judge that the appropriate actions for adaptation may conflict to the appropriate actions for mitigation. With these criteria, we find that 22 out of 50 of the actions being undertaken or recommended for implementation have the potential to create conflicts between adaptation and mitigation.

Two examples of conflicts between adaptation and mitigation

To illustrate these issues, we provide two indicative examples from our review of local climate change responses. Byron Shire in the far north coast of Australia's New South Wales has adopted specific climate change parameters for temperature increases, sea level rises, rainfall intensities, cyclone intensities and storm surges (Gurran et al., 2008). Its Strategic Planning and Climate Change approach includes a 100 year planning period for proposals or issues that may be affected by climate change, and undertakes to incorporate climate change planning scenarios into all relevant plans and responsibilities (including infrastructure, land-use planning, and development assessment). The planning parameters are designed to change following subsequent IPCC information or recommendations from Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) or

[3] More details on each of these plans/actions are available in Gurran, Hamin, and Norman (2008).

the New South Wales Department of Environment and Climate Change.

However, applying the parameters in practice implies a dramatic reduction in available areas for new development and redevelopment within the existing Byron village centre, potentially competing with the Shire's other sustainability and climate change mitigation objectives, such as reducing local vehicle miles traveled by promoting walking and cycling. The issue has come to the forefront with decisions regarding the siting and construction of the new council library. The current site, acquired prior to the determination of the climate change planning parameters in late 2007, is centrally located in the Shire but now falls within the expanded flood zone, necessitating very extensive adaptation works if the site is to be used at all. Ironically one of the solutions is to use the ground level of the site as a car park, elevating the building to a level beyond predicted flood waters. The alternative would relocate the library to higher ground beyond the city centre, meaning that most users would need to drive to access it.

This example highlights the difficulties in practice of retrofitting adaptation strategies over existing settlement, while continuing to promote forms of development within these areas that reduce, rather than exacerbate, greenhouse gas emissions.

The second example demonstrates some of the dilemmas that arise in designing new residential development. The case in point, Port Stephens, on the mid northern New South Wales coast, has an established planning policy whereby new housing areas must maintain sufficient Eucalypt cover and other environmental features to preserve the habitat of the local koala population (Gurran et al., 2008). The policy (known as *Port Stephen's Comprehensive Koala Plan of Management*) provides a good model of how areas of endogenous vegetation must be protected and expanded to assist native plants and animals to adapt to increasing pressures under changed climatic conditions. However, the model results in very low density, car dependent housing. Even if some of the household energy needs associated with these koala conservation estates can be satisfied in the future through locally generated renewable sources, they will remain car dependent and situated at some distance from centres of services and employment. Nesting the housing within natural bushland also increases exposure to other dangers likely to extend to the coastal zone under climate change scenarios – such as increased frequency and intensity of forest fires.

Significance

To us, the table and these examples suggest that climate change creates a "density conundrum." Mitigating climate change requires a denser urban environment to reduce vehicle miles traveled and building energy use, while adapting to climate change requires open space available for stormwater management of severe storm events, species migration, and urban cooling, among other goals. The answer here is not that we must do one or the other, but that we need to seek urban form answers that allow communities to minimize the conflicts. The likely best urban form, we argue, must bring greenspace within settlements focused along green transportation routes and floodplains (ribbons and corridors) rather than large expanses. Those open spaces must also be designed to achieve multiple goals – urban agriculture and floodplain protection, for instance. Larger blocks of open space are limited to peripheries – beach foreshores where open space provides recreation and leisure as well as space to adapt to changes in sea level, greenbelts or foodbelts where they are able to reinforce internal settlement containment. The urban form which will respond best to the needs of both adaptation and mitigation will be the one where available resources achieve multiple goals. Buildings will need to provide more natural cooling potential, solar power, and moderate density so as to enable transit options. Open space, in particular, will need to be very carefully planned to maximize its multiple benefits while minimizing its reductions in density of development. While heroic responses to biodiversity conservation, such as Port Stephen's iconic koala habitat plan of management, seek to balance settlement aspirations with wildlife needs, the correct response may be to avoid such sensitive locations altogether. Rather than creating dispersed, car dependent housing, genuine wildlife protection in an era of increasing climate volatility likely preserves and extends remaining habitat and provides connected corridors for species migration, resulting in contained, denser, discrete and multifunctional human settlements. While not embedded within the bush, as envisaged by the koala habitat plan and other innovative tools like it, such places would be selectively greened and cooled by corridors of low fire risk vegetation and networked via high speed rapid transit to other settlements. Actions like these with careful design have the potential to mitigate the space requirements of adaptation, and adapt the density needs of mitigation to create resilient, lower carbon, and potentially quite beautiful urban forms.

Appendix. Leading practice community action

Environment	Example	Adapt	Mitigate	Potential conflict?
Biodiversity				
Use coastal setback areas to reintroduce and restore local biodiversity, protect important vegetation and coastal habitat within an environmental protection zone or equivalent.	Victor Harbor, South Australia (SA), Australia (AUS)	✓		Y
Connect habitat through dedicated habitat protection corridors.	Port Stephens Comprehensive Koala Plan of Management, New South Wales (NSW), AUS	✓		Y
Create planning system incentives and requirements for new developments to retain and restore local biodiversity.	Maroochy, Green Offset Scheme, Queensland (QLD), AUS	✓		Y
Coastal processes and beaches				
Protect low lying and exposed areas, and reintroduce natural 'soft' defense measures.	Suffolk District Council, United Kingdom (UK)	✓		Y
Prohibit development that threatens coastal processes or requires filling of wetlands or mangroves. Require referral to expert agencies for development in particularly vulnerable areas or of a certain scale.	Noosa Coastal Protection precinct, QLD, AUS	✓		Y
Introduce environmental assessment requirements for areas where existing information is insufficient to determine the impact of potential development scenarios without additional and costly research.	Stirling, UK	✓		

Appendix (*continued*)

Environment	Example	Adapt	Mitigate	Potential conflict?
Natural hazards				
Specify sea level/natural hazard thresholds or indicators (informed by climate projections) as a basis for setting coastline building rules for setback/elevation/removal of buildings.	Byron Shire, NSW, AUS, Gold Coast City Council, QLD, AUS	✓		
Revise land-use designations and permitted building forms in the light of natural hazard assessment, informed by climate change projections.	Byron Shire, NSW, AUS	✓		
Establish policy framework for re-situating land uses that may become unsafe or unsuitable in the future due to climate change.	Clarence Council, Tasmania (TAS), AUS	✓		Y

Housing/infrastructure/transport/economy	Example	Adapt	Mitigate	Potential conflict?
Housing/infrastructure				
Increase density of homes and mixing of uses.			✓	Y
Assess location of and design standards for existing and planned infrastructure, and assess vulnerability to sudden or cumulative climate change impacts.	Climate Change risk assessment for Victoria	✓		
Revise infrastructure capacity plans to take future climate scenarios into account, rather than historical weather events, and adjust settlement thresholds accordingly.	Gold Coast, QLD (flood plan revisions)	✓		
Identify and reserve locations for relocation of major infrastructure and for new decentralized energy, water, or waste management plants.	UK Draft Planning Policy on Climate Change	✓	✓	Y
Prioritise new infrastructure that delivers multiple environmental services while serving basic settlement needs.	Richmond Valley Council WSUD DCP, NSW	✓	✓	
Major developments should self provide basic infrastructure services – energy, water, waste, through strategies such as micro-energy generation, water retention, demand reduction technologies, reuse, and recycling; and waste minimization, reuse, and disposal.	Thuringowa Sustainable Village Project, QLD	✓	✓	Y

Appendix (*continued*)

Housing/infrastructure/transport/economy	Example	Adapt	Mitigate	Potential conflict?
Water				
Emphasise the protection of natural hydrological systems to improve their resilience to possible climate change impacts.		✓		Y
Prioritise water supply options that are associated with minimal contributions to climate change impacts, including water demand management strategies particularly developments associated with major water needs like tourist facilities.	Gold Coast 'Water Future Strategy', QLD	✓	✓	
Maintain spaces for floods and water retention in regions where rainfall patterns are likely to become more volatile.	Cairns, QLD	✓		Y
Transportation				
Design and reconfigure settlements to reduce the need for trip generation and to maximize viability of public transport. Assess the transportation impacts of major new developments.	Thuringowa Sustainable Village Project, QLD	✓	✓	Y
Ensure that new settlements are accessible by all weather roads or alternative routes.		✓		
Energy				
Draft renewable friendly energy planning codes, so broader environmental benefits can be assessed with local impacts.	Cornwall, UK		✓	
Create planning requirements for major new developments to preserve and utilize local sources of renewable energy as much as possible, or provide offset payments to stimulate investment in local energy generation.	Aspen/Pitkin County, USA		✓	
Protect solar access to ensure that developments retain capacity for onsite solar energy generation.	Boulder, Colorado, USA		✓	Y
Enforce building and urban design requirements that minimize energy requirements and maximize thermal comfort.	BASIX, NSW, AUS Chicago, Illinois (IL) "Cool Roofs program"	✓	✓	Y
Waste				
Reserve local sites to accommodate waste sorting, recycling and reuse, and requiring that major developments include a sustainable waste strategy as a condition of planning approval.	Coffs Coast Resource Recovery Park, NSW, AUS		✓	Y

(*continued on next page*)

Appendix (*continued*)

Housing/infrastructure/transport/economy	Example	Adapt	Mitigate	Potential conflict?
Establish provisions for composting at site or neighbourhood level, reducing land fill and water needs.	Byron Shire, NSW, AUS		✓	Y
Economy				
Ensure that new tourism developments are not exposed to future climate change impacts.	Miami Dade County, Florida, USA	✓		
Improve climatic comfort of key destinations through climate sensitive urban design	Gold Coast City Design for Climate Policy, QLD, AUS	✓	✓	
Feature climate friendly design requirements for tourism development, appealing to eco tourism markets.		✓	✓	
Enable multifunction use of agricultural lands, provided that additional uses do not threaten the long term agricultural quality of the land.		✓		
Support planning policies that prioritise and foster local food production and consumption.	Keene, New Hampshire USA; Byron Shire, NSW, AUS	✓	✓	Y
Protect wetlands and require natural buffer areas between agricultural lands and waterways, to reduce impacts of flooding on marine life and fisheries.		✓		Y

Community wellbeing	Example	Adapt	Mitigate	Potential conflict?
Health				
Tailor urban and building design guidelines to local climatic conditions.	Maroochy, Design for Climate Code, QLD	✓	✓	
Consider impact of planning requirements on potential for spread of water borne and vector borne disease.	Hunter & Mid North Coast Mosquito sensitive design projects, NSW, AUS			
Require shading, shelter, and appropriate vegetation to cool areas of open space and walkways or cycle paths.	Gold Coast Design for Climate Policy, QLD, AUS	✓	✓	Y
Review design standards for manufactured home estates and caravan parks for safety and energy efficiency.		✓	✓	
Quality of life and amenity				
Increase coastal setbacks and natural or 'soft' defense measures through land-use overlays and planned retreat zones.	Noosa Coastal Protection precinct, QLD, AUS	✓		Y
Use natural restoration works to increase visitor and recreational opportunities associated with the area.	Freiston Shore, Lincolnshire, UK	✓		

Appendix (*continued*)

Community wellbeing	Example	Adapt	Mitigate	Potential conflict?
Link walkways and areas of natural habitat and vegetation.		✓		Y
Use urban shade strategies to improve visitor facilities and outdoor amenity.	SunSmart Victoria Shade Development Guide, AUS	✓	✓	
Emergency management				
Maintain space for emergency access, shelter and evacuation; reserve locations for intermediate post emergency recovery (these locations may be multifunction).		✓		
Weatherization program to reduce home energy use and improve resilience to storms for low income families.	Portland, Oregon (OR), USA	✓	✓	
Actively plan ahead for settlement reorientation or design following a major natural disaster, and ensure supportive land-use decisions.		✓		
Governance				
'Mainstream' climate change across planning and management decisions. Adopt strong objectives for climate change mitigation and adaptation within statutory land-use plans.	Waverley LEP NSW; Yarra Ranges	✓	✓	
Collaborate with other local governments at regional level on future climate scenarios and potential responses.	Western Coast Greenhouse Alliance	✓		
Establish effective and ongoing public involvement processes for identifying and prioritizing mitigation and adaptation responses.	Clarence, Tasmania	✓	✓	

Table adapted from Gurran et al. (2008). Planning for climate change: leading practice principles and models for sea change communities in coastal Australia. Sydney, University of Sydney, Faculty of Architecture and the Sea Change Task Force. Summary: 22 potential conflicts out of approximately 50 actions.

References

City of Keene, NH. (2007). Adapting to climate change: planning a climate resilient community. *ICLEI: Local Governments for Sustainability*.

Council of Australian Governments. (2007). National climate change adaptation framework. Canberra, ACT, COAG Secretariat.

Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., & Chen, D. (2008). *Growing cooler: The evidence on urban development and climate change*. Washington, DC: Urban Land Institute.

Ewing, R., & Rong, F. (2008). The impact of urban form on U.S. residential energy use. *Housing Policy Debate, 19*(1), 1.

Gurran, N., Hamin, E., & Norman, B. (2008). *Planning for climate change: Leading practice principles and models for sea change communities in coastal Australia*. Sydney: University of Sydney, Faculty of Architecture and the Sea Change Task Force.

Hamnett, S. (2006). Special edition on learning from urban disasters: planning for resilient cities. *Built Environment, 32*(4).

ICLEI and the City of Seattle. (n.d.). *U.S. Mayors' climate protection agreement*. http://www.iclei.org/documents/USA/documents/CCP/Climate_Action_Handbook-0906.pdf. Accessed 20.06.08.

Intergovernmental Panel on Climate Change. (2007a). *Climate change 2007: Synthesis report, fourth assessment report*. Cambridge: IPCC and Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2007b). *Climate change 2007: Climate change impacts, adaptation and vulnerability*. Summary for policy makers, April 6 2007.

Intergovernmental Panel on Climate Change (IPCC). (2007c). Contribution of Working Group III to the Fourth Assessment Report of the Intergovernment Panel on Climate Change. In B. Mertz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Climate change 2007: Mitigation*. Cambridge: Cambridge University Press.

King County, Washington. (2007). *2007 King County climate plan*. http://www.metrokc.gov/exec/news/2007/pdf/ClimatePlan.pdf. Accessed 26.06.08.

McEvoy, D., & Handley, L. (2006). Adaptation and mitigation in urban areas: synergies and conflicts. *Municipal Engineer, 159*(4), 185–191.

NYC Department of Environmental Protection Climate Change Program. (2008). *The NYC DEP climate change program assessment and action plan, report 1*. http://www.nyc.gov/html/dep/. Accessed 20.06.08.

Pizarro, R. E., Blakely, E., & Dee, J. (2006). Urban planning and policy faces climate change. *Built Environment, 32*(4), 400–412.

Randolph, J. (2008). Comment on Reid Ewing and Fan Rong's "The impact of urban form on U.S. residential energy use". *Housing Policy Debate, 19*(1), 45.

Rosenzweig, C., Major, D., Demong, K., Stanton, C., Horton, R., & Stults, M. (2007). Managing climate change risks in New York city's water system: assessment and adaptation planning. *Mitigation and Adaptation Strategies for Global Change, 12*(8), 1391–1409.

Stone, B. (2005). Urban heat and air pollution: an emerging role for planners in the climate change debate. *Journal of the American Planning Association, 71*(1), 13.