Chapter 8. Urban Areas

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Executive Summary

Successful adaptation to climate change globally depends centrally on what is done in urban centres since these now house more than half the world's population, concentrate most of its assets and economic activities and are projected to house almost all the increase in the world's population in the next few decades.

Although much of the investment needed for adaptation will have to come from individuals, households and firms, its effectiveness depends on what local governments do, encourage, support and prevent as well as their contribution to providing needed infrastructure and services. This includes frameworks for land-use management (with new sites available for development and key ecological services protected) and for ensuring that needed building standards are implemented and where needed adjusted.

Many of the measures needed for climate change adaptation in urban areas fall within the responsibilities of local governments because local risks and vulnerabilities are rooted in local contexts and because much of the risk reducing infrastructure and services are within their responsibilities. This incorporation of climate change adaptation into each urban centre's development planning and investments is well served by an iterative process of learning about changing risks and opportunities to inform an assessment of policy options and decisions. Engagement with local stakeholders can ensure the needs and priorities of vulnerable groups get attention and that the private sector is brought into discussions. However, it is challenging to get local governments to address the above in their priorities and investment plans.

Infrastructure and service deficits: There is great diversity among the world's urban centres in at least three factors relevant to adaptation: the scale and nature of risks that climate change is bringing and will bring; the extent to which each urban centre's population lives in good quality homes served with conventional infrastructure and services that provides a foundation for adaptation; and the extent to which urban governments are acting or able to act on adaptation and being supported to do so by higher levels of government and where needed international agencies. The adaptive capacity of a city is much influenced by the quality and coverage of infrastructure (piped water supplies, sewers and drains, all weather roads, electricity provision …) and services that include policing, health care, emergency services and measure to reduce disaster risk.

Issues of particular relevance to low and middle income nations: Most urban centres in these nations have large deficits in such provision and little capacity to address this. UN estimates suggest that one billion people live in informal settlements in urban areas with inadequate or no provision for infrastructure and services. Here, poverty and social inequality may be aggravated by climate change and the lack of adaptive capacity.

The role of housing in climate change adaptation: The key role that housing should have in providing its inhabitants and their assets with protection against extreme weather events is often under-estimated.

Sites at high risk: Many cities are on sites that face particularly high levels of risk – for instance coastal cities where much of the urban area is low elevation and where ports, certain industries, settlements and infrastructure are at risk from sea-level rise and storm surges, cities where heat waves are common, cities which already face extreme weather events whose intensity or frequency is likely to increase, and cities with large constraints on fresh water supplies. In urban centres with infrastructure deficits and a proportion of their population in informal settlements, risk and vulnerability are often highly concentrated in informal settlements on floodplains, alongside rivers or on steep slopes.

Cities are complex systems with multiple inter-dependencies between different systems – for instance the dependence of water supplies, drainage, traffic management, telecommunications, health care services and some trains on electricity supply, the dependence of emergency services on all-weather roads, communications systems and robust health care centres and the dependence of urban populations and economies on food and resources from beyond their boundaries. Urban centres that have developed within the globalized systems of production depend on reliable supply chains may face particular difficulties. Thus raising urban adaptive capacity requires institutions that facilitate coordination across multiple, nested and poly-centric authorities and have the capacity to mainstream adaptation measures.

Agglomeration economies: Many of the challenges and opportunities for adapting urban areas come from the concentration of people and enterprises. Urban agglomeration economies are usually discussed in regard to enterprises but there are also potential agglomeration economies in cities for adaptation and resilience in lower unit costs for providing each building needed infrastructure and services (solid waste collection, schools, health care, emergency services) and bringing together people, communities and institutions to respond collectively. Where local governments are ineffective to act on these, this concentration brings disadvantages, including many relevant to adaptation such as higher risks from flooding, high winds and heat waves.

A large part of the world's urban population and much of its anticipated expansion is in medium and small sized urban centres in low- and middle-income nations where local adaptive capacities are limited

Many urban locations will face particular challenges related to water – including ensuring sufficient supplies (and the capacities to manage with reduced freshwater availability) and managing waste water flows

Learning from experience. The last five years have brought many examples of city governments assessing what adaptation needs. These have included the designation of a unit within city government with responsibility for adaptation, measures to engage key sectors so they understand why they need to engage with adaptation, the importance of local champions to initiate measures but the need to institutionalize measures to ensure continuity and the importance of dialogue and discussion with all key stakeholders. There is also a recognition of the need to review building codes, infrastructure standards and land-use management. City governments that have taken adaptation seriously and the institutions that have supported this including local universities and research centres and representative organizations of those living in informal settlements. One way to engage local government attention is the demonstration of adaptation's importance for a city's continuing economic success.

The contribution of household and community-based adaptation: In many informal settlements that face high risks from climate change, household and community-based adaptation have reduced risks. The scale and range of what this can achieve is increased where local governments support this. It is now more common for local and national governments to work with the inhabitants of informal settlements to install or upgrade infrastructure and services and address insecure tenure; this can build their resilience to climate change impacts.

Developing locally-relevant adaptation plans and the data to support this. Governments, households and the private sector need relevant, reliable local information to encourage them to act and inform their actions. The data needed for this at a local scale are usually inadequate. Few cities have quantified risks (especially second and third order impacts) and even fewer have developed detailed costings of possible responses. More reliable, locally specific and downscaled projections of climate change impacts and tools for risk screening and management can help engage the interest of local governments, businesses and civil society organizations.

Ecosystem based adaptation's potential to support a range of policy goals including food security, water purification, waste water treatment and flood risk reduction as well as mitigation is becoming more evident through the experiences tried in particular cities. So too are the potential contributions of green infrastructure. However, climate change will impact ecosystem services by altering ecosystem functions such as temperature and precipitation regimes, evaporation, humidity and soil moisture levels

Effective local action requires support from higher levels of governments. To be effective adaptors, local governments need a mandate for climate change responses, supportive policy and legislative frameworks and support for collaboration between local governments.

City-based disaster risk reduction has 30 years of experience in identifying needed measures for risk reduction based on detailed local studies of hazards, risks and vulnerabilities. Some national governments have set up national frameworks to support local government and civil society capacities. This is a valuable foundation for assessing and acting on climate-change related risks and vulnerabilities, although climate change adaptation needs to go beyond this to take account of how hazards, risks and vulnerabilities will or might change over time.

Mitigation co-benefits: The scale, nature and location of private investment in and around urban centres and of public investment in infrastructure have major implications for present and future levels of greenhouse gas emissions. This highlights the importance of adaptation that also delivers mitigation co-benefits, as discussed in WG III. Since most of the growth in the world's population is anticipated in urban areas in low- and middle-income nations, how this is housed and serviced has large implications for future emission-levels.

From adaptation to resilience: There is a new literature for urban areas that considers how to build resilience at the city scale with more attention to needed institutional and inter-institutional measures. This includes the capacity to withstand unexpected impacts, attention to cooperation with other local governments, flexibility, redundancy and planning for safe failure.

Since effective adaptation for urban centres needs local responses and includes major roles for local governments and civil society (especially those representing those most at risk), consideration needs to be given mechanisms by which international support for adaptation can work at scale while supporting local processes.

8.1. Introduction

8.1.1. Key Issues

Successful adaptation to climate change depends centrally on what is done in urban centres – that now house more than half the world's population and concentrate most of its assets and economic activities. As this chapter emphasizes, this needs to include responses by multiple levels of government, individuals and communities, the private sector and civil society. What is done in urban centres also has major implications for mitigation, especially future levels of greenhouse gas emissions and for delivering co-benefits, as discussed in WG III. This chapter focuses on the connections between urbanization and climate change and on the possibilities for urban governments, enterprises and populations to adapt to and develop resilience to its direct and indirect impacts.

As discussed in 8.4, it has been suggested that most of the investment required for sound adaptation will come from a multitude of small-scale private decisions spanning individuals, households and firms. Furthermore, the level of funding needed for urban adaptation exceeds the capacities of local and national governments and international agencies. This might suggest little role for governments – and especially local governments. But whether or not the 'multitude' of small scale private decisions do contribute to adaptation (and resilience to climate change's impacts) depend on what local governments do, encourage, support and prevent – as well as their contribution to providing needed infrastructure and services. An important part of this is providing an appropriate regulatory framework that supports adaptation (and prevents maladaptation) in the choices made by individuals, households and firms – for instance in the management of land use (with new sites available for development and key ecological services protected) and the application of building standards within their jurisdiction.

In reviewing adaptation needs and possibilities for urban areas, the documentation points to two key conclusions. The first it how much the adaptive capacity of a city depends on past plans and investments in infrastructure and services and existing capacities for such investments, for land-use management, and for ensuring buildings meet health and safety standards. This provides the foundation for city resilience on which adaptation can be built. For most cities in low-income and many in middle-income nations, there is little of this foundation of resilience. The second is the importance of city and municipal governments acting now to incorporate climate change adaptation into their development plans and policies. But to do so requires not only building the foundation of resilience but also to mobilize new resources and continuously develop local capacities to respond. This is not to diminish the key roles of other actors including the private sector, the demands and priorities of residents, civil society and higher levels of government. But it will fall to city and municipal government to provide the scaffolding and regulatory framework within which all other stakeholders contribute and collaborate. Thus, adaptation in urban areas depends heavily upon the competence and capacity of local governments and a locally rooted iterative process of learning about changing risks and opportunities, making decisions, and revising strategies in collaboration with a range of actors.

8.1.2. Scope of the Chapter

This chapter focuses on what we know about how climate change will impact on urban centres and their populations and enterprises, what measures can be taken to adapt to these changes (and protect vulnerable groups) and the institutional and governance changes needed to underpin this. Both this chapter and chapter 9 on rural areas highlight the multiple linkages between rural and urban areas. This chapter also has overlaps with Chapter 10, especially in regard to infrastructure, although this chapter focuses on urban infrastructure and in particular the infrastructure that comes within the responsibilities or jurisdiction of urban governments.

There is no international agreement as to how urban centres or populations should be defined or distinguished from rural populations and there is considerable variation in how governments choose to define urban areas (see United Nations 2012). This influences the proportion of the population said to live in urban areas for any nation. Many nations define as urban centres all settlements with populations above a threshold - for instance 1,000 or 2,500 or 5,000 inhabitants are commonly used. This means that a nation's urban population and level of urbanization can vary substantially, depending on which threshold is used (or other criteria chosen and applied). Virtually all nations classify settlements with 20,000 plus inhabitants as urban. It is around the proportion of the population that live in settlements between a few hundred and 20,000 inhabitants that national differences emerge. There is also the ambiguity as to the dividing line between rural and urban. In some instances, urban boundaries include large rural areas while in others, urban centres have grown beyond official boundaries and into areas that are within neighbouring jurisdictions and may be defined as rural. Most large cities have more than one boundary – for instance one based on the local government jurisdiction or linked to the built up area, another based on the metropolitan region or planning region. Boundaries for metropolitan areas or extended metropolitan regions often include substantial rural populations. Most suburban areas are within urban boundaries – but not always. In addition, just as urban centres depend on rural resources and eco-system services, it is common for a proportion of a city's workforce to live outside the city and commute – and this may include many that live in settlements designated as rural.

8.1.3. Context – An Urbanizing World

In 2008, for the first time, more than half the world's population was living in urban centres and the proportion living in urban areas continues to grow (United Nations 2012). Three quarters of the world's urban population and most of its largest cities are now in low- and middle-income nations. UN projections suggest that almost all the increase in the world's population up to 2050 will be in urban centres in what are currently low- and middle-income nations (see Table 8-1). It is within urban centres within most nations and globally that most GDP is generated and most new investment has concentrated (World Bank 2008, Satterthwaite et al. 2010). Clearly, in terms only of the population, economic activities and climate risk they concentrate and the progressive increase in such concentration, adapting urban areas to climate change needs serious attention.

[INSERT TABLE 8-1 HERE
Table 8-1: The distribution of the world's urban population by region, 1950–2010 with projections to 2030 and 2050.]

There is an economic logic underpinning most urbanization as all wealthy nations are predominantly urbanized and as rapid urbanization in low- and middle-income nations is associated with rapid economic growth (ibid). Most of the world's largest cities are also in its largest economies (ibid). If rapid urbanization and rapid city population growth is usually associated with economic success, it suggests that more resources can be drawn on to support adaptation. But in most urban centres in low- and middle-income nations, including many successful cities, local governments have been unable to keep up with the economic and physical expansion and there are large deficits in provision for infrastructure and services that have relevance for climate change adaptation. Around one in seven of the world's population live in poor quality, overcrowded accommodation in urban areas with inadequate or no provision for basic infrastructure and services and mostly in informal settlements (UN Habitat 2003). Within the world's urban population, it is in these settlements that much of the risk and vulnerability to climate change is concentrated.

Many aspects of urban change in recent decades have been so rapid that they have overwhelmed government capacity to manage it. Of the world's cities with 750,000 plus inhabitants in 2010, 52 had populations growing more than twenty fold since 1960 and 116 had populations growing more than tenfold.[1]

[FOOTNOTE 1: Unless otherwise stated, the statistics on urban and city populations come from an analysis of the data in United Nations (2012).]

The increasing concentration of the world's urban population and its largest cities outside the nations with the highest incomes that Table 8-1 shows represents an important change. Over the 19th and 20th centuries, most of the world's urban population and most of its largest cities were in its most prosperous nations. Urban areas in low- and middle-income nations now have close to two-fifths of the world's total population and close to three-quarters of its urban population. They also have most of the world's large cities. Of the 23 'mega-cities' (cities whose population was reported to exceed 10 million) by 2011 (United Nations 2012), only 5 were in high-income nations (two in Japan, two in USA, one in France). Of the remaining 18, four were in China; three were in India and two in Brazil. However, over three fifths of the world's urban population is in urban centres with less than 1 million inhabitants and it is in these that much of the growth in urban population is likely to occur.

Underlying these population statistics are large and often complex economic, social, political and demographic changes including the multiplication in the size of the world's economy and the shift in economic activities and employment structures from agriculture to industry and services (and within services to information production and exchange). Also the growth in the size and importance of cities whose economies increased and changed as a result of globalization (Sassen 2006) and the many cities that are now centres of extended metropolitan regions

Perhaps the main difficulty that this chapter faces is in providing a summary of trends for settlements that have more than half the world's population when there is such diversity among the world's urban centres in terms of the scale and nature of risks that climate change will bring, the extent to which each urban centre's population lives in good quality homes served with conventional infrastructure and services that provides the basis for adaptation (what this chapter terms accumulated resilience) and the extent to which urban governments are acting or able to act on adaptation and being supported to do so by higher levels of government and where needed international agencies. Table 8-2 illustrates this diversity in relation to the second and third of these factors and how each urban centre falls within a spectrum in at least four key factors that influence adaptation: local government capacity, the proportion of the population served with risk-reducing infrastructure and services; the proportion of the population living in housing built to health and safety standards; and the levels of risk from climate change's direct and indirect impacts. This chapter also draws on detailed case studies of three cities to illustrate this diversity – New York (Solecki 2012), Durban (Roberts et al. 2012) and Dar es Salaam (Kiunsi 2012).

[INSERT TABLE 8-2 HERE
Table 8-2: The large spectrum in the capacity of urban centres to adapt to climate change. [Note: One of the challenges for this chapter is to convey the very large differences in adaptive capacity between urban centres. There are tens of thousands of urban centres worldwide with very large and measureable differences between them in population, area, economic output, human development, ecological footprint and greenhouse gas emissions. The

differences in adaptive capacity are far less easy to quantify. This table seeks to illustrate differences in adaptive capacity and factors that influence it.]]

Many attributes of urban centres can be measured and compared. Populations vary from settlements with only a few thousand inhabitants to the largest cities with 20-36 million inhabitants. Areas varying from less than one to thousands of square kilometres. Average life expectancy at birth for urban centres varies from over 80 years to under 40 years – and under-five mortality rates varies by a factor of 20 or more (Mitlin and Satterthwaite 2012). Average per capita incomes vary by a factor of at least 300; so too do the investment capacities of urban governments (UCLG 2011). Greenhouse gas emissions per person vary by more than 100 (Dodman 2009, Hoornweg et al. 2011). There are large differences between urban centres in the extent to which their economies are dependent on climate-sensitive resources (including commercial agriculture and tourism). There are also large variations in the scale and nature of impacts from extreme weather. As Table 8-2 suggests, there are urban indicators that are relevant for accumulated resilience to climate change impacts (the proportion of the population with water piped to their homes, sewers, drains, health care and emergency services) but less so for the scale and nature of climate change related risks and for the quality of government.

Recent analyses of disaster impacts show that urban centres concentrate a high proportion of the population most affected by extreme weather events (United Nations 2009, 2011). As shown in Table 8-2, a high proportion of such urban centres have local governments that lack the capacity to reduce such disaster risk and very large deficits in the infrastructure and institutions needed to do so. Their low-income households may require particular assistance due to greater exposure to hazards, lower adaptive capacity, more limited access to infrastructure or insurance, and fewer possibilities to relocate to safer accommodation as compared to wealthier residents. But there are also many cities that have high resilience to extreme weather and have the infrastructure and institutions that provide resilience to the exacerbation of extreme weather events and change in resource availabilities associated with climate change.

All successful urban centres have had to adapt to environmental conditions and resource availabilities, although local resource constraints have often been overcome by drawing resources and using sinks from 'distant elsewheres' (Rees 1992, McGranahan 2007); this includes importing goods that are resource intensive and whose fabrication involves high greenhouse gas emissions.

The growth of urban population over the 20th century has also caused a very large anthropogenic transformation of terrestrial biomes. Urban centres cover only a small proportion of the world's land surface; Schneider et al 2009 suggested that they cover only 0.51 percent of the total land area and among the world's regions only in Western Europe did they cover more than 1 percent (Ellis et al., 2010) . However, their physical and ecological footprints are much larger, as urban based enterprises and consumers draw on a much larger land area. The net ecological impact includes the decline in the share of wild and semi natural areas from about 70 percent to under 50 percent of the land area. This was largely to accommodate the demand for crop and pastoral land to support human consumption, leading not only to a decrease in biodiversity but a threat to ecological services that supported both rural and urban areas.

Many of the challenges and opportunities for urban adaptation are derived from the central features of city life – the concentration of people, buildings, economic activities and social and cultural institutions (Dodman and Romero-Lankao 2011). A key part of urban centres' adaptive capacity is related to agglomeration economies. Urban agglomeration economies are usually discussed in relation to the advantages for enterprises locating there. But the concentrations of people, enterprises and institutions in urban areas also provides potential agglomeration economies in lower unit costs for providing each building with piped water, sewers, drains and a range of services (solid waste collection, schools, health care, emergency services) and bringing together people, communities and institutions to respond collectively (Hardoy et al. 2001). But these need to be acted on and to have local governments capable of acting on them. In most urban centres in low- and middle-income nations, these are not acted upon and the result is very large deficiencies in infrastructure and services. Although urban centres in high-income nations are much better served, there may also face particular challenges – for instance in addressing aging infrastructure and in adapting energy and resource building stock and infrastructure and services to the altered risk set that climate change's direct and indirect impacts will bring (see Zimmerman and Faris 2010 for discussions of this for New York).

Effective city governments will also need to work with range of government and civil society institutions at local and supra-local levels. It also depends on support from higher levels of government. In addition, as this chapter discusses, concentration of people and economic activities also present particular challenges for climate change adaptation – including the management of storm and surface run-off and measures to reduce heat islands. Large cities also concentrate demand and need for ecological services and natural resources (water, food and biomass), energy and electricity and these may rely on supply chains that climate change will disrupt. Thus, the increasing concentration of the world's population in urban centres is likely to bring increased risk concentration of a range of climate-related hazards for a large and growing proportion of the world's population – while also having the potential to support more effective adaptation.

8.1.4. Vulnerability and Resilience

For each of the direct and indirect impacts of climate change, there are groups of urban dwellers that face higher health and other risks (illness, injury, mortality, damage to or loss of homes and assets). This susceptibility can be on the basis of age (for instance infants or elderly people's greater susceptibility to particular hazards such as heat waves) or health status (for instance those with particular diseases, injuries or disabilities that make them more susceptible to these impacts). These are often termed vulnerable groups – although to state the obvious, these are only vulnerable to climate change impacts if the hazard poses a risk; remove the vulnerable population's exposure to the hazard (e.g. drains preventing flooding) and there is no impact. There are also adaptations by individuals, households, communities, private enterprises or government service providers that may reduce risks or reduce exposure.

Although there are many definitions of vulnerability (see for instance Fussel 2007), they agree that it centres on an inability to avoid harm when exposed to a hazard – including an inability to avoid the hazard, anticipate it (and take measures to avoid it or limit its impact), cope with it and recover from it (bounce back). So vulnerable groups may be identified on the basis of all four of these. Infants may face serious health risks when water supplies are contaminated by flooding but rapid and effective treatment for diarrhoea and quickly re-establishing availability of drinking quality water greatly reduces impacts (Bartlett 2008).

The term vulnerability is also applied to sectors and vulnerable sectors may include food processing, tourism, water, energy and mobility infrastructure and their cross-linkages e.g. perishable commodities dependent on efficient transport. Much tourism is sensitive to climate change as it may damage key tourist assets e.g. coral reefs and beaches. Energy price changes will affect travel costs.

Certain types of infrastructure are more at risk: e.g. most transport, drainage and electricity transmission systems and many water supply abstraction and treatment works. Infrastructure plans and investments generally include some scope for coping with climate variability but in many locations these will need to increase reserve margins, back up capacity and other structural adaptation measures. Cities as complex, inter-connected systems are vulnerable to these interconnections – for instance the dependence of water supplies, drainage, traffic management, telecommunications, health care services and some trains on electricity supply and the dependence of emergency services on all-weather roads and functioning bridges (da Silva et al 2012, Solecki 2012)

8.1.4.1. Differentials in Risk and Vulnerability within Urban Centres

In urban centres where all buildings meet health and safety standards and there is universal provision for infrastructure and basic services, the exposure differentials between high- and low-income groups to climate-related risk is much reduced. Although low-income groups are often termed vulnerable, having a low income and few assets in many of these cities does not necessarily imply greater vulnerability to climate change. In low- and middle-income countries, typically the larger the deficit in infrastructure and service provision, the larger the differentials in exposure to most climate change impacts by income group. This means a disproportionate climate impact on low-income groups, who are often made more vulnerable because of poor quality and insecure housing, inadequate infrastructure and lack of provision for health care, emergency services and measures for disaster risk reduction.

Where provision for adequate housing, infrastructure and services is most lacking, the capacity of individuals, households and community organizations to anticipate, cope and recover from the direct and indirect losses and impact of disasters (of which climate-related events are a sub-set) becomes increasingly important (see 8.4.2.2 and 8.4.2.3). Here too, the speed of response and effectiveness of post-disaster response is especially important to the vulnerable (who are more susceptible and have less coping capacity). Their effectiveness depends on understanding the specific vulnerabilities, needs and priorities of different income-groups, age groups and groups that face discrimination, including that faced by women and by particular social or ethnic groups.

Additionally, a growing literature on successful urban adaptation interventions shows that they recognize the interrelations and interdependence between multiple sectors, levels and risks in a dynamic physical, economic, institutional and socio-political environment (Gasper et al., 2011, Kirshen et al., 2008). Therefore, climate policies may need to be embedded in responses to multiple risks and stresses (Reid and Vogel 2006).

8.1.4.2. Understanding Resilience for Urban Centres in Relation to Climate Change

The IPCC has long had an interest in resilience but what is new is a literature discussing resilience to climate change for urban centres and what contributes to this - and this section draws on this literature (Miller 2007, Satterthwaite et al. 2009, Leichenko 2011, da Silva et al. 2012, Tyler and Moench 2012, Brown et al. 2012).

Although resilience is usually considered to be the opposite of vulnerability, vulnerability is often discussed in relation to particular groups of people within the population whereas resilience is more often discussed in relation to what helps protect them such as infrastructure or climate-risk sensitive land-use management. Addressing resilience for cities is also more than identifying and acting on specific climate change impacts as it looks to the performance of each city's complex and interconnected infrastructure and institutional systems and includes a capacity to withstand unexpected or unpredicted changes. When considered for cities, it is common for certain characteristics of resilience to be identified – for instance flexibility, redundancy, responsiveness, capacity to learn and safe failure (Tyler and Moench 2012, Tyler et al. 2012, da Silva et al. 2012, Brown et al. 2012). There is also a recognition of the complexities of urban systems and the multiple inter-dependencies between different sectors that were noted above.

But when considering a specific city, the level and forms of resilience are often related to specific local factors, services, and institutions – for instance for each district in a city, will the storm and surface water drains cope with the next storm (a particularly pressing issue for cities that have particularly heavy rainfall in particular seasons). During heat waves, will measures to help those most at risk from high temperatures work and reach all high-risk groups? Here, resilience is not only the ability to recover from the impact (bouncing back) but the ability to avoid the need to recover (United Nations 2011). Thus, a considerable part of resilience is the functioning of institutions to provide the above and the knowledge base needed to do so (da Silva et al. 2012). The emerging literature on the resilience of cities to climate change also highlights the need to focus on resource availabilities and sinks beyond the urban boundaries and it may also require coordinated actions by institutions from other jurisdictions (for instance watershed management upstream of a city to reduce flood risks (see Brown et al. 2012, Ramachandraiah 2011).

Cities in high-income nations and many in middle-income nations have become more resilient to extreme weather (and most other potential catalysts for disasters) through a range of measures that have responded to risks and to the political processes that demanded such responses. This resilience has been built over many decades and often required intense political negotiation. The resilience accumulated through this in what was built and in the capacity of institutions provides resilience to some climate change impacts, even though these were not in response to climate change impacts (see for instance Hardoy and Ruete 2013 on Rosario). What strongly influences resilience to extreme weather for urban dwellers is the quality of buildings (homes and workplaces), the quality and coverage for key infrastructure and services, early warning systems for extreme weather and adequate public response measures, whether their incomes are sufficient to invest part in resilience (living in healthy homes, life insurance, insurance for possessions and home, savings, pensions, asset ownership…), what safety nets are available if income is insufficient and the regulatory framework for ensuring the application of the above. Urban governments have importance for most or all of these, although their provision usually depended on changes at national level – for instance in legislation and in financial support (although political change at national level was also in part driven by political pressure from urban dwellers and innovation by city governments). Private companies or non-profit institutions may provide some of the key services and private companies have key roles in provision and often maintenance of infrastructure - but the framework for provision and quality control is provided by local government or local offices or national or provincial government.

A city's accumulated resilience can be assessed for the extent to which it has reduced hazards, reduced risk and reduced exposure, with particular attention to how this serves or protects vulnerable groups and at-risk areas. Also by the measures in place needed to enhance capacity to cope and adapt. Such an assessment can move to considering how well this 'accumulated resilience' serves or will serve climate change adaptation.

Although the components of accumulated resilience were not in response to risks from climate change, the web of institutions and finances that produced these and maintain them provide a base for climate change adaptation (and more broadly for resilience). Building and infrastructure standards can be adjusted if needed (there is infrastructure in place that can be adjusted - for instance increasing capacity for storm and surface water drainage systems), existing service provision can be adjusted for new risks or risk levels (measures to reach populations vulnerable to heat stress during heat waves and within heat islands) and city planning and land-use management can be adjusted to any new or heightened risk (keeping building and city expansion away from areas facing new risk levels). This can be supported by changes in private sector investments (over time shifting from high-risk areas) and changes in insurance premiums and coverage. So the web of institutions and the buildings, infrastructure and services that have developed in response to non-climate change risks provide a foundation for developing resilience to climate change. These provide the ability to absorb climate-change related direct and indirect disturbances while retaining the same basic structure and ways of functioning. Whether they will do so depends on whether urban governments take this on – and whether the demands of their inhabitants and these inhabitants' capacity to organize and get change promote this; also whether the institutions and their complex inter-relationships have the capacity to learn. Obviously, the extent to which these provide or can provide resilience in the future also depends on slowing and stopping the increases in risk from GHG emissions and other drivers of climate change.

Many cities that have accumulated resilience may not act on the changes in hazards and risks that climate change is bringing or will bring. So here, the issue is whether the institutions and political pressures that built the accumulated resilience shift now to resilience as a process – responding dynamically and effectively to evolving and changing climate change-related risks (and evolving and changing knowledge bases for this). For cities with accumulated resilience, there may be climate change impacts that such accumulated resilience does not serve - for instance potential disruption to resource flows. Or the actions needed for resilience are outside their jurisdiction.

For urban centres with little accumulated resilience, *resilience as a process* has importance, both to help reduce over time the (often very large) deficiencies in most or all the infrastructure, services and regulatory frameworks that provide resilience in high-income nations and to build resilience to climate change impacts. For around a third of the world's urban population, this has to be done in a context of limited incomes and assets and poor living conditions and little resilience to any stress or shock. Just an increase in prices of food staples or a drop in income (an income earner being ill or injured) or a new cost (medicines needed for a sick family member) can quickly mean inadequate food and thus hunger and thus reduced capacity to work and to resist infections.

The above also implies a different perspective on how climate change adaptation (and resilience) needs to be supported. It emphasizes how resilience to climate change impacts is intimately tied into the quality of governance (in which local governance has particular importance) and in the government capacity and willingness to listen to, work with, support and serve those who lack resilience. Here too, the idea of resilience as 'bouncing forward' has importance – as shown by the successful partnerships between government and grassroots organizations formed by residents of informal settlements that have built or improved homes and neighbourhoods. This would also be part of the shift from resilience to transformation (see Pelling 2011a).

Thus, resilience can be considered in relation to individuals/households, communities and urban centres. In each, it includes the capacity to take action that avoids a climate change impact (live in safe location, have safe house, have risk reducing infrastructure), to take action before it happens to reduce its impact (especially relevant for extreme weather events), to cope with the impact and to bounce back (either to the previous state or to a more resilient state) For urban centres, bounce back includes a government capacity to get the key services up and running and repair infrastructure.

8.1.5. Conclusions from the Fourth Assessment (AR4) and What this Chapter does Beyond this Assessment

AR4's chapter on Industries, Settlements and Human Society noted that these are accustomed to variability in environmental conditions but more at risk if change is more extreme (for instance beyond what had been experienced in the past), persistent or rapid, especially if not foreseen and where capacities for adaptation are limited.

Except for abrupt extreme events, climate change impacts are not dominant issues for urban centres but their importance is in their interaction with other stressors including rapid population growth, political instability, poverty and inequality, ineffective local governments and jurisdictional fragmentation and aging or inadequate infrastructure. Key challenges to getting attention to adaptation include the difficulties of estimating and projecting the magnitudes of climate risk in particular places and sectors with precision and a weak knowledge base on the costs of adaptation.

AR4 described how the interactions between climate change and global urbanization has led to concentrations of urban populations in low-income nations with weak adaptive capacity. It also described the interactions between climate change and a globalized economy that include long supply chains and impacts spreading from directly impacted areas and sectors to other areas and sectors through complex linkages. Many impacts will be unanticipated and total impacts are also poorly estimated by considering only direct impacts. Key global vulnerabilities include interregional trade and migration patterns.

AR4's Chapter 7 also described how climate change impacts and most key vulnerabilities are influenced by local contexts including geographic location, the sensitivity to climate of enterprises located there, development pathways and population groups unable to avoid dangerous sites and homes.

Key vulnerabilities are most often related to climate phenomena that exceed thresholds for adaptation (eg extreme weather or abrupt changes) and limited resources or institutional capacities to cope (development context). Climate change will increase demands on water and energy supplies and often on health care and emergency response systems.

Individual adaptation may not produce systemic adaptation. In addition adaptation of systems may not benefit all because of differential vulnerability of particular groups and places. Adaptation will require a greater awareness of threats and alternatives beyond historical experience and current access to finance.

Technological innovation for climate adaptation comes largely from industry and services motivated by market signals and these may not be well matched with climate change adaptation needs and residual uncertainties. Many are incremental adjustments to current business activities. Planning guidance and risk management by insurers will have role for instance in locational choice for industry.

Certain types of infrastructure are more at risk – including most transport, drainage and electricity transmission systems and many water supply abstraction and treatment works. There is a need to increase reserve margins and develop back up capacity. Adaptation of infrastructure and building stock is often dependent on changes in the institutions and governance framework e.g. in planning regulations and building codes. Climate change has become one of many changes to be understood and planned by for by local managers and decision makers.

8.1.5.1. Key Uncertainties and Research Priorities

A range of key uncertainties and research priorities emerge from recent literature:

- Inadequate knowledge on the vulnerabilities of human systems and on adaptation potentials from direct impacts of climate change, from second and third order impacts and from interconnections between systems
- Understanding and predicting impacts of climate change at a fine grained geographic and sectoral scale
- Uncertainties about potential impact, costs and limits of adaptation
- Uncertainties about trends in societal, economic and technological change with or without climate change.
- Serious limitations on data availability on nature-society links and fine-scale contexts

8.1.5.2. What has Changed since AR4

A much larger and more diverse literature on current and potential climate change vulnerabilities of different urban centres and their structure and functioning. The volume of relevant literature and the greater detail in much of it makes a concise and comprehensive summary more difficult. But this has also produced more clarity in what contributes to or builds resilience. Specifically:

- More on adaptation responses being considered or taken by cities and , in high-income nations, national governments and factors that encourage this (this includes a large and important grey literature produced by or for city governments)
- More nuanced understanding of the many ways by which poverty and discrimination exacerbates vulnerability to climate impacts
- More detailed studies going into depth for particular issues of built environment responses to promote adaptation (see for instance the growth in the literature on green and white roofs)
- More case studies of community-based adaptation in its potential contributions and in its limitations
- More consideration of the role of green infrastructure and ecosystem services in adaptation strategies
- More considerations on the financing, enabling and supporting of adaptation for households and enterprises
- More on learning from innovation in disaster risk reduction
- A greater appreciation of the inter-dependencies between different infrastructure networks and of the need for adaptation both in 'hard' infrastructure and in the 'soft' institutions that plan and manage it.

8.2. Urbanization Processes, Sustainable Habitats, and Climate Change Risks

8.2.1. Introduction

This section assesses the connections between ongoing urbanization and climate change in relation to patterns and conditions of climate risk, impact, and vulnerability. The focus is on urbanization and its local, regional and global environmental consequences and the processes that may lead to risk exposure, constrain people in high-risk livelihoods and residences and generate vulnerabilities in critical infrastructure. Understanding urbanization and associated risk and vulnerability distributions is critical for an effective response to threats of climate change and their impacts (Romero Lankao and Qin 2011, Bulkeley 2010, Solnit 2009, Satterthwaite et al. 2007, Vale and Campanella 2005), promotion of sustainable urban habitats and the transition to increased urban resilience. In this section, there is a particular interest in the ability of cities to respond to environmental crises, and the resilience and sustainability of cities (Solecki et al. 2012, Solecki 2012).

The section assesses the direct impacts of climate change on urban populations and urban systems. Together, direct climate impacts and shifts in urbanization change the profile of societal risk and vulnerability and alter transition pathways to greater resilience and sustainability and their management in communities. In this way, connecting climate change with urbanization is presented as crucial to understanding current and future changes in each other.

8.2.2. Urbanization

8.2.2.1. Magnitude and Connections to Climate Change

Section 8.1 emphasized how much conditions in urban centres vary, influenced by the proportion of the population with incomes too low to allow them to afford food and non-food needs; the extent to which the whole population (and vulnerable groups within this population) are served by the basic infrastructure and network of services that should serve as the main reducers of risk; the extent to which their site is at risk from climate change impacts; and the competence, capacity and accountability of its government (Pelling 2003, Moser and Satterthwaite 2008, Hardoy and Pandiella 2009). Variations in these factors have important consequences for the process of climate change, for how climate change contributes to global environmental change, shaping impacts in urban areas, and for how cities might be able to respond to climate change (Rosenzweig et al. 2011, Seto and Satterthwaite 2010, Güneralp and Seto 2008).

Urbanization can be considered in relation to key qualities and parameters (spatial, temporal, and sustainability) to capture the shifting, complex interactions between climate change and urban growth within a global-regional context. Given the significant and rising levels of urbanization (Section 8.1.3 above), more people will be exposed to impacts of climate change in urban areas with a growing proportion exposed in large centres and megacities (de Sherbinin et. al. 2007, Revi 2007). Additionally, many smaller urban centres in Africa, Latin America and Asia are growing rapidly but are "often institutionally weak and unable to promote effective mitigation and adaptation actions" (Romero Lankao and Dodman 2011:114). In aggregate it is in the cities in these regions with less than a million inhabitants where most population growth is expected. But it is largely those cities that have limited institutional and financial capacity to address development challenges and incorporate adaptation and mitigation as elements of urban development.

Urbanization alters local environments via a series of physical phenomena that can result in problems such as heat islands and local flooding and these are likely to be exacerbated by climate change. It is critical to understand the interplay between the urbanization process, current local environmental change and accelerating climate change. For example, the intensity of urban heat island (UHI) has been found to be associated with the intensity of urbanization (Kolokotroni et al. 2010, Chen et al. 2011, Iqbal et al. 2011, Fujibe 2011, Rim 2009, Santos et al. 2009, Tayanc et al. 2009, Sajjad et al. 2009, Jung 2008, He et al. 2007, Stone 2007). The dense nature of many large cities (including megacities) produces pronounced urban influences on anthropogenic heat emissions and surface roughness. Anthropogenic heat fluxes for large cities can be very high: up to 50-500 W m^{-2} has been observed in global analysis (Flanner 2009, Allen et al. 2011) in London (Iamarino et al. 2011) and Singapore (Quah and Roth 2012), with values locally reaching 1500 W m^{-2} in Tokyo (Ichinose et al. 1999). Under clear skies and light wind conditions, large cities can be more than 10°C warmer than surrounding rural environments (Oke 1982).

In London observations have recorded nighttime temperatures up to 7ºC higher in central London than in Wisley, a rural location 32 km southwest of the city (Wilby 2007: 35). Although small urban centres also experience the UHI, urban population has a non-linear relationship with urban-rural temperature differences (Smith and Levermore 2008: 4559). Studies have also linked rates of urbanization with past UHI trends, urban heating, current variability, and projected climate change. For instance, London's annual number of nights with heat islands stronger than 4ºC has increased by 4 days/decade since the late 1950s; meanwhile, the average nocturnal heat island intensity rose by just ~0.1ºC/decade over the same period (Wilby 2007: 35). Projections suggest that by 2050, London's nocturnal UHI in August could rise another 0.5°C, representing a 40 percent increase in the number of nights with intense UHI episodes (*ibid*.: 36). For New York City, climate change is expected to exacerbate the existing UHI conditions via increase of extended heat waves (Rosenzweig et al. 2009). Additionally, extensive research has been done recently which attempts to connect recent climate shifts, extreme 20th century weather events and rates of urbanization with on-going and future climate change (Manton 2010).

In a review of relationships between coastal megacities and environmental change, Grimmond (2013) found increasing evidence that cities can influence weather (e.g. rainfall, lightning) through complex urban land use–weather–climate feedbacks (Ohashi and Kida 2002). Megacity impact on air flows, especially for coastal cities has been modeled, for example for New York and Tokyo (Holt et al. 2009, Holt and Pullen 2007, Thompson et al.

2007,) and found to influence both internal city environmental and regional weather and air quality. Megacity-coastal interactions may also impact the hydrological cycle and pollutant removal processes through the development of fog, clouds and precipitation in and around megacities and coastal areas (Landsberg 1970, Ohashi and Kida 2002, Shepherd et al, 2002). Models show building density and design as well as the scale of urbanization to be the most important local determinants (Oleson et al. 2011, Trusilova et al. 2008).

While there are as yet only few modeling exercises that have been applied at the urban scale, the results indicate an 'urban effect' that leads locally to higher temperatures and reduced humidity while additional warming also marginally increases rainfall over large cities, reduces wind speeds and increases plant productivity. The replacement of vegetation with urban surface outweighs this positive impact to reduce the overall land carbon sink (Grimmond et al. 2012). Jackson et al. (2010) and Oleson et al. (2011) confirm that building material properties are influential in creating different urban climates, which have the potential to alter energy demand for climate control systems in buildings. These results suggest that climate impacts of large cities including the megacities are open to change should they be redesigned, and use of energy-efficient building materials, passive design technologies and appropriate land-use are scaled up.

8.2.2.2. Spatiality, Physical Planning, and Climate Change

The pattern of urban spatial development is a critical factor in the interactions between urbanization, climate-related risks, and vulnerability. While urban form frequently ranges from concentrated to dispersed, most planned urban settlements exhibit declining population density outward from the urban core (Seto et al. 2010, Leichenko and Solecki 2008). In cities with large fringe and unplanned settlements this pattern can be reversed. In both cases urban growth is experienced through horizontal expansion and sprawl (United Nations 2012, Hasse and Lathrop 2003). Rapid urban population growth in the last decade has been increasingly marked by growth in vertical density (high-rise living, and working) in many nations, especially in Asia. Higher density living can offer opportunities for resource conservation but also challenges for planning and urban management (see 8.3.3.7 for more).

Many large cities have developed into extended metropolitan regions across a wide range of settlement conditions from low-, middle and high income nations (Seto et al. 2010, Leichenko and Solecki 2005). As large cities develop, scale makes it difficult for them to perform as an organic whole (Blackburn and da Silva 2013). In mega urban-regions this can force a multiplication of loci for economic activity, industry, educational excellence, and concentrations of poverty. It is often problematic for these multiple centres to interact in planned ways that can benefit from traditional scale economies, creating pressures for geographical, social, administrative and political fragmentation – leading to a transition from uni-polarity to multi-polarity (Laquian 2011).

Urban expansion has fostered extensive networks of critical infrastructure, which are frequently vulnerable to climate change (Solecki et al. 2012, Rosenzweig et al. 2011). For instance, New York City's dispersed communications network faces several climate-related risks: electrical support facilities would be flooded, while cell towers can topple due to strong winds or become corroded as sea levels rise (Zimmerman and Faris 2010). In Alaska, telecommunications towers are already settling due to warming permafrost (Larsen et al. 2008). During the extreme rainfall event in 2005, Mumbai's telecommunications networks ceased to function due to a mix of overload, shut down of the power system and lack of supply of diesel for generators (Revi 2006). Provision for water for cities that are rapidly growing and in water-scarce regions like Delhi and Beijing are increasingly stretched and this can generate increased vulnerability to changes in precipitation patterns associated with climate change.

Settlement patterns strongly shape conditions for climate change adaptation and mitigation (Stone et al. 2010, Biesbroek et al. 2009). For instance, within Toronto, per capita greenhouse gas emissions from housing and transport varied from 1.3 to 13 tCO_2 equivalent when comparing a dense inner-city neighbourhood with good access to public transport with a sprawling outer suburb (OTHER REF Hoornweg et al. 2011). Cities generate challenges for adaptation by concentrating people and assets in ways that increase climate-related risks and vulnerabilities; by the same token, urban areas create advantages to support resilience through the "economies of scale and proximity that they present for key protective infrastructure and services for risk-reducing governance innovations..." (Satterthwaite 2009: 560). Higher-density development with adequate transport links can promote social integration and equity, particularly in cities where low-income households live in peripheral settlements (Dulal et al. 2011). Physical planning interventions can be combined with command-and-control measures (e.g. zoning), land use taxes, price mechanisms, and public education campaigns to promote sustainable transport and settlement patterns (Grazi and van den Bergh 2008).

8.2.2.3. Temporal Dimensions

For any city or region, it is important to understand the connections between climate risk and vulnerability and the rate of change in aspects of urbanization including populations and households, urban spatial expansion, and redevelopment of existing urbanized areas. Urbanization is associated with changing dimensions of migration and materials flows both into and out of cities and within them (Grimm et al. 2008). The level of increase and some cases decrease of these conditions create a dynamic quality in cities. Rapidly changing cities have the challenge of managing this growth via housing and infrastructure development while also attempting to simultaneously understand the relative impact of climate change. The conflation of local environmental change resulting from urbanization with climate change shifts make the identification and implementation of effective adaptation strategies more difficult. For example, water shortages are already a chronic concern for many cities in low and middle income nations and this typically worsens as the population and demand continues to grow (Muller 2007). Overlaying climate change-related reductions in supply or heightened uncertainties facing water managers with this existing instability creates the conditions for greater management and governance crises (*ibid.,* Gober 2010, Milly et al. 2008).

8.2.2.4. Sustainability and Ecological Habitat

The urbanization-climate change connection has important implications for ecological sustainability. Urbanization is one of the key drivers of global environmental change and is directly connected to the question of ecological sustainability, and to the ecological underpinning of urban life (Huang, Yeh, and Chang 2010). In turn, an "important aspect of achieving urban sustainability is strengthening our ability to respond to the changing relation between urbanization and climate" (Grimm et al. 2008: 758). As cities grow and change, the demand for resources expands and transforms, increasing cities' ecological footprint (Rees 1992, Wackenagal et al. 2006) and long distance resource linkages (e.g., teleconnections). In many cases, city-resource supply connections have become more distant and more at risk of interruption (e.g., Seto et al. 2012, Jenerette and Larsen 2006).

Climate change is likely to accelerate ecological pressures, as well as interact with existing urban environmental, economic, and political stresses (Leichenko 2011, Wilbanks and Kates 2010). For example, New Orleans' geophysical vulnerability is shaped by its low-lying location, accelerating subsidence, rising sea levels, and heightened intensity or frequency of hurricanes due to climate change—a combination of natural phenomena exacerbated by "settlement decisions, canal development, loss of barrier wetlands, extraction of oil and natural gas, and the design, construction, and failure of protective structures and rainfall storage" (Wilbanks and Kates 2010: 726, Ernston et al. 2010). Cities in arid regions already struggle with water shortages often in the context of rising demand, but for many such cities, climate change will likely further reduce water availability because of shifts in precipitation and/or evaporation (Gober 2010).

8.2.2.5. Regional Differences

Case studies and regional reviews assessing urban vulnerabilities to climate change have revealed diverse challenges and large differences in levels of adaptive capacity (Rosenzweig et al. 2011, Hunt and Watkiss 2011). For instance, discussions in African cities (Simon 2010, Kithiia 2011) have highlighted the lack of capacity and awareness of climate change, as well as often extremely high levels of vulnerability among the continent's large and rapidly growing urban poor populations. Other reviews have considered cities in Latin America (Hardoy and Romero-Lankao 2011), North America (Zimmerman and Faris 2011), Europe (Carter 2011), and China (Liu and Deng 2011).

Studies have analyzed Asian cities' health risks due to climate change (Kovats and Akhtar 2008) and other urban vulnerabilities in South and Southeast Asia (Birkmann et al. 2010, Alam and Rabbani 2009, Revi 2009).

The global distribution of urban risks is highly context-specific, dynamic, and uneven between and within regions. Absolute exposure to extreme events over the next few decades will be concentrated in large cities and countries with urban populations in low-lying coastal areas, as in many Asian nations (McGranahan, Balk, and Anderson 2007). Urban populations' exposure to climate change related risks is obviously influenced by the scale of the population concentration in cities and the proportion of the population in urban areas. However, recent improvements in urban governance and rising wealth in Latin America (one of the world's most urbanized regions) have helped to strengthen adaptive capacity (Hardoy and Romero-Lankao 2011). Urban risks are not static and will continue to change in the future: in sub-Saharan Africa, the combination of relatively high population growth rates and increasing levels of urbanization (projected to reach 46 percent by 2030) will bring a corresponding rise in exposure to climate change impacts.

Studies from different cities confirm how much the scale and nature of climate change risks will differ; Section 8.1 and Table 8-2 also emphasized the very large differences between cities in their current resilience to such risks, in the capacity to adapt and in the proportion of their population in informal settlements. Most such settlements lack risk-reducing infrastructure; many are on dangerous sites including steep slopes and low lands adjacent to unprotected river banks, ocean shorelines and have structures built on unconsolidated soil materials, where building codes are not applied (Hardoy et al 2001, Pelling, 2003). But those who are generally most vulnerable to climate change impacts are the women, children, health compromised and the elderly among this population in informal settlements – due to the fact that either they are less mobile (e.g., women with child care responsibilities), have less resources or are physically weak. Here, the combination of a lack of infrastructure access, low incomes and limited assets puts them at high risk from disasters (Moser and Satterthwaite 2008).

8.2.3. Climate Variability and Change Impacts

Climate change is likely to lead to increased occurrences and intensity of extreme weather events such as heavy rainfall, warm spells and heat events, drought, intense storm surges and sea-level rise (see Hunt and Watkiss 2011, Romero-Lankao and Dodman 2011, Rosenzweig et al., 2011.). Physical factors such as topography and geo-hydrological conditions typically differentiate variations in the distribution of impacts within an urban area. So too do social (e.g. equity and justice issues), geographic (e.g. high density locations, suburban, exurban locations) and temporal (e.g. short, medium, and long term shifts) contexts.

8.2.3.1. Inland Flooding

Heavy rainfall and storms surges would impact urban areas through flooding which in turn could lead to the destruction of properties and public infrastructure, contamination of water sources, water logging, loss of business and livelihood options and increase in water borne diseases as noted in wide range of studies (Revi 2007, Dossou and Glehouenou-Dossou 2007, Kovats and Akhtar 2008, Sharma and Tomar 2010, Adelekan 2010, Hardoy and Pandiella 2009, de Sherbinin et. al. 2007, Douglas et al. 2008, Roberts 2008, Nie et al. 2009). Case studies of inland cities have considered the elevated risk of flooding due to climate change, such as in Kampala (Lwasa 2010) and travel disruptions in Portland (Chang et al. 2010). Extensive studies have attempted to better model the frequency and condition of extreme precipitation events and associated flooding (Ranger et al. 2011, Onof and Arnbjerg-Nielsen 2009, Nelson et al. 2009, Olsson et al. 2009, Sen 2009).

8.2.3.2. Coastal Flooding, Sea Level Rise, and Storm Surge

Sea-level rise represents one of the primary shifts in urban climate change risk, given the increasing concentration of urban centres and populations in coastal locations (McGranahan, Balk, and Anderson 2007). Rising sea levels, the associated coastal and riverbank erosion, or flooding with storm surge could all lead to widespread impacts on populations, property and coastal vegetation and ecosystems, and threats to commerce, business, and livelihoods (Hanson et al. 2011, Carbognin et al. 2010, Pavri et al. 2010, El Banna and Frihy 2009, Zanchetting 2007, Dossou and Glehouenou-Dossou 2009). It is the lowland areas in coastal cities such as Lagos, Mombasa, or Mumbai that are usually more at risk of flooding, especially if these also have less provision for drainage (Adelekan 2010, Awuor et al. 2008, Revi 2009). Structures constructed on in-filled soils in the lowlands of Lagos, Mumbai and Shanghai are more exposed to risks of flood hazards than similar structures built on consolidated materials (*ibid.*). Many coastal cities have sites at risk from both a riverine and coastal storm surge (Mehrotra et al. 2011).

Hanson et al. (2011) estimate the change in exposure of large global port cities to coastal flooding in the 2070s compared to today with scenarios of socio-economic growth, sea level rise, storm surge and subsidence. They find that population at risk could more than triple while asset exposure is expected to increase more than ten-fold with a 0.5 metre rise in sea-level. The study identifies the “top-20” cities for both population and asset exposure to coastal flooding. The high risk cities in both the current and 2070 rankings are spread across low- middle and high income nations but concentrated in Asian deltaic cities. They include Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, New York, Osaka-Kobe, Alexandria, Tokyo, Tianjin, Bangkok, Dhaka and Hai Phong. Using asset exposure as the metric, cities in high-income nations and in China figure prominently - Miami, New York City, Tokyo and New Orleans as well as Guangzhou, Shanghai, Tianjin). This type of analysis underscores the urgent need for urban risk reduction measures.

8.2.3.3. Urban Heat and Cold

Heat waves and warm spells could exacerbate urban heat island effects, including increased air pollution (Campbell-Lendrum and Corvalán 2007) and heat-related health problems (Hajat et al., 2010), increased salinity of shallow aquifers in drylands due increased evapo-transpiration **(refs)** and the spread to new areas of some diseases including malaria and dengue fever (Kovats and Akhtar 2008). Conversely, widespread reduction in cold waves will induce shifts in heating demands (Mideksa and Kallbekken 2010). Occasional more intense cold waves resulting from increased climate variation could also have intense localized impacts. Increased warming is predicted in a wide variety of cities including sub-tropical, semi-arid, and temperate sites (Thorsson et. al. 2011).

8.2.3.4. Drought and Water Scarcity

Drought can lead to food insecurity, increase in fuel wood prices, water shortages, electricity power shortages for urban areas that depend mostly on hydropower, increased food prices and an increase in water related diseases; these may also lead to increased rural to urban migration (Farley et al. 2011, Herrfahrdt-Pahle 2010, Vairavamoorthy et al. 2008). Averaging across all climate change scenarios, recent findings suggest that nearly 100 million more city-dwellers “will live under perennial shortage under climate change conditions than under current climate” (McDonald *et al*. 2011: 6312). The study also notes the role of demographic growth: “Modelled results show that currently 150 million people live in cities with perennial water shortage, defined as having less than 100 L per person per day of sustainable surface and groundwater flow within their urban extent” and by 2050, this figure could increase to almost 1 billion (ibid.).

8.2.3.5. Air Pollution and Public Health

The burden of allergies and asthma will rise as existing urban air pollution will be exacerbated through climate change-related mechanisms (O'Neill and Ebie 2009, Reid et al 2009 and Gamble 2009b, Kinney 2008). Increased temperatures will promote the production of pollutants, with tropospheric ozone and particulate matter of especial concern as city -dwellers are often more affected by air pollution than rural residents (D’Amato and Cecchi 2008: 1268). Climate change may affect the distribution, quantity, and quality of pollen, as well as altering the timing and duration of pollen seasons; the burden of asthma and allergies could also rise as a result of interactions between heavier pollen loads and increased air pollution, or as climate change promotes more frequent wildfires (Shea et al. 2008). Furthermore, climate change may contribute to long-distance transport of pollen, pollutants or heavy precipitation events such as thunderstorms, which are often linked to asthma epidemics (ibid., D'Amato et al. 2011). These shifts have obvious implications for urban health policy.

8.2.3.6. Geo-Hydrological Hazards

The exposure to climate related hazards will vary due to differences in the geomorphologic characteristics of the city (Luino and Castaldini 2010). Climate change will increase the risk and vulnerability of urban populations to a range of geohydrological hazards including groundwater and aquifer quality reduction (e.g. Praskievicz and Chang 2009, Taylor and Stefan 2009) and subsidence and increased salinity intrusion. Subsidence caused by groundwater extraction has led some land in cities like Singapore and Jakarta to sink by a meter or more, this is compounded when groundwater is saline (eroding structures) or rainfall increases in intensity and duration (Ref.). As an example, urban areas located in lowlands could have a high risk to flooding while urban centers located in hilly areas will be exposed to landslides.

8.2.4. Exposure and Sensitivity of Urban Sectors

This section assesses how the observed and forecasted direct impacts of climate change influence the exposure and sensitivity of city residents, infrastructure, and systems by considering key affected sectors and possible interrelations.[2] The section examines both the temporal and spatial scale of the shifts in climate risk across cities and urbanizing sites in the next few decades. The focus is on how the scale and character of risks change and grow in cities as shifts in climate extremes, means and long-term trends (e.g. sea-level rise) take place.

[FOOTNOTE 2: Direct impacts, following the UN-ECLAC methodology, include all costs and losses attributed to the impact of hazard events, but exclude systemic impacts for example on urban economies through price fluctuations following disaster or the impact of disaster losses on production chains.]

We know that climate change will have profound impacts on a broad spectrum of city functions, infrastructure, and services and that it will interact with and potentially exacerbate many existing stresses. These impacts can occur both *in situ* and through long-distance connections between cities and rural locations, such as sites of resource production and extraction (Seto et al. 2012, Satterthwaite et al., 2010). The interaction between climate change and existing environmental stresses can lead to a range of synergies, challenges, and opportunities for adaptation with complex interlinkages and often highly uncertain processes (Ernston et al. 2010). The 2007 floods in the city of Villahermosa also covered two thirds of Tabasco State with serious consequences for the city's economic base. Regional damages and asset and infrastructure losses amounted to US$ 3.1 billion, equivalent to 30 percent of the state GDP (CEPAL 2008). Urban centres serving prosperous agricultural regions are particularly sensitive to climate change as water supply or particular crops may be at risk. In Naivasha, Kenya, drought threatens high-value export-oriented horticulture (Simon 2010). Urban centres that are tourist centres or serving tourism in locations where the weather becomes less attractive are also at risk.

Similarly, infrastructure will be impacted by systematic and cascading climate risks (Hunt and Watkiss 2011). Climate stresses, particularly extreme events, will have effects across interconnected urban systems – both within and across multiple sectors (Gasper, Blohm and Ruth 2011). The cascading effects of climate change are especially likely in the water, sanitation, energy and transportation sectors, due to the often tightly-coupled character of urban infrastructure systems (see Rosenzweig and Solecki 2010 for a discussion of New York City's infrastructure). These systematic cascades can have both direct as well as indirect economic impacts (Hallegatte et al. 2011, Ranger et al. 2011) which can extend from the built environment to urban public health (Frumkin et al. 2008, Keim 2008).

A critical element of climate impacts is that they will affect infrastructure investments that have long operational lives - in some cases up to 100 years or more (Hallegatte 2009). In low- and middle-income cities additional investment is needed to address deficits in infrastructure and services since without this, making the short to long-term trade-off to improve resilience is difficult (Dodman and Satterthwaite 2009). This deficit provides an opportunity for smart climate smart infrastructure planning that consider the combined needs of pro-poor development and climate change adaptation and mitigation. This is a more difficult task for cities such as New York with dense aging infrastructure, materials that "may not be able to withstand the projected strains and stresses from a changing climate" (Zimmerman and Faris 2010: 63).

Recent assessments have projected the rising population and asset exposure in large port cities (Hanson et al. 2011, also Munich Re 2004)), alongside case studies in Copenhagen (Hallegatte *et al*. 2011) and Mumbai (Ranger et al. 2011). By 2070, the exposed assets in cities such as Ningbo (China), Dhaka (Bangladesh) and Kolkata (India) may increase by more than 60-fold (Hanson et al. 2011: 100-1.

8.2.4.1. Water, Sanitation, and Drainage

Water and sanitation systems strongly shape household well-being and health, while exerting a wider influence upon urban economic activities, energy demands and the rural-urban water balance (Gober 2010). Among the projected impacts of climate change on water are altered precipitation and runoff patterns in cities; changes in sea level and resulting saline ingress; constraints in water availability and quality; and heightened uncertainty in the assumptions that underpin long-term planning and investment in water systems (Muller 2007, Fane and Turner 2010). Local government departments responsible for water supply and management must confront these new climatic patterns, major uncertainties in availabilities and learn to respond to a dynamics and evolving sets of constraints (Milly et al. 2008).

In many rapidly-developing cities, climate change's impacts on water supplies will interact with growing population, growing demand and economic pressures. This will often heighten water stress and increase negative impacts on the natural resource base with impacts on water quality and quantity. Caribbean nations are urbanising with an expanding middle class, sharply raising the demand for water and increasing the associated challenges of managing runoff, storm water, and solid wastes (Cashman et al. 2010). Aggravating such water stresses, climate change could significantly reduce rainfall levels especially during the Caribbean's crucial rainy season (*ibid.,* p. 57).

Emerging water shortages have increasingly forced cities to enhance their supplies by extending their water withdrawal demands from more remote rural places (e.g. Mumbai, Delhi, Mexico City) and huge engineering solutions (e.g. many Andean cities and Mexico City). In Shanghai, climate change is likely to bring decreased water availability, as well as flooding, groundwater salinization and coastal subsidence. The city's population of 17 million is projected to continue expanding, often within areas that are "likely increasingly flood-prone" (de Sherbinin et al. 2007: 60). Groundwater depletion has contributed to land subsidence in these already vulnerable areas, reinforcing the water stresses and risks of erosion, but Shanghai's wealth and correspondingly greater adaptive capacity may help to manage these complex risks *(ibid.)*.

Climate change will most likely have significant impacts on urban water availability and quality. Large-scale critical infrastructure such as sanitation systems for cities (e.g. Cape Town – Ziervogel et al. 2010) and large thermal power stations' water requirements for cooling may also be affected. Climate change will impact residential water demand and supply and its management (O'Hara and Georgakakos 2008). Moreover, it will exacerbate existing tensions and conflicts between the various end-uses (residential, commercial, industrial, agricultural, and infrastructural).

Wastewater and sanitation systems will be increasingly overburdened during extreme precipitation events as a result of poor maintenance, the limited capacity of drainage systems in old cities, or the lack of provision in unplanned settlements (Howard et al. 2010, Wong and Brown 2009). This will be made worse by uncontrolled city development that often causes natural drainage channels to be built over. An analysis of three cities in Washington State sought to assess future stream-flows and the magnitudes of peak discharges, concluding that "concern over present [drainage] design standards is warranted" (Rosenberg et al. 2010: 347). Climate change was identified as one of the key drivers affecting Britain's future sewer systems (Tait et al. 2008). According to a model of urbanisation and climate change impacts in an urban catchment, the volume of sewage released to the environment by combined sewage overflow spills and flooding was projected to increase by 40% (ibid) In the city of La Ceiba in Honduras, stakeholders concluded that addressing urban drainage and improved management of the Rio Cangrejal watershed were top priority for protecting the population against projected climate change impacts; the city lacks a storm-water drainage system but experiences regular flooding from heavy rainfall and storm surges (Smith et al. 2011).

Floods, droughts and heavy rainfall have also impacted agriculture and urban food sources, and climate change can exacerbate food and water scarcity in urban areas (Gasper, Blohm and Ruth 2011).

Some water systems, under some scenarios and short-term time frames, are not projected to experience negative impacts. For instance, Chicago's Metropolitan Water Reclamation District (MWRD) found that reduced precipitation due to climate change would decrease pumping and general operations costs, since sewers will contain less rainwater in drier seasons (Hayhoe et al. 2010). This district is projected to save money until 2100, but as precipitation is likely to increase afterwards as will the costs of water management.

8.2.4.2. Energy

Since energy exerts a major influence on economic development, health, and quality of life, any disruption or unreliability in power or fuel supplies due to climate change can have far-reaching consequences. Most urban businesses (from the largest to many home-based enterprises), infrastructure, services (including health care and emergency services) and residents rely heavily on power supplies (Halsnaes and Garg 2011). So too does water treatment and supply, rail-based public transport, road traffic management and often flood-protection measures (ibid, Jollands et al. 2007).

Past experiences with power outages indicate some of the knock-on effects: New York City's blackout of 2003 lasted 28 hours and halted electricity, mass transport, surface vehicles due to signaling outages, "and water supply for a much longer period" (Rosenzweig and Solecki 2010: 20). Low-income households in Chittagong utilise candles or kerosene lamps during the city's frequent power outages, which was found to disturb children's studies, increase expenses, and overheat homes (Rahman, Haughton and Jonas 2010). A review of climate change impacts on the electricity sector (Mideksa and Kallbekken 2010) suggested projected reductions in the efficiency of cooling for thermal power; changes in hydropower and wind power potential; and changing demand for heating or cooling in the US and Europe.

Less is known of demand-side energy impacts of climate change in low and middle-income nations. In most urban centres in low-income and some middle-income nations, a significant proportion of the population does not have access to electricity, and energy use in low-income households is still dominated by charcoal, firewood, or biomass based fuels (Satterthwaite and Sverdlik 2012). Most of these nations are also likely to experience large increases in mean temperatures or rising frequency of heat-waves due to climate change (IPCC 4AR), which necessitates more vigorous adaptation measures to cope with increased demands for cooling energy.

Climate change will alter the patterns of urban energy consumption, particularly with respect to electricity demand and/or energy needed for cooling or heating (for a review see Mideksa and Kallbekken 2010). In settings with extensive air conditioning use, climate change will bring increases in air conditioning demand and in turn heightened electricity demand (Radhi 2009; see also Hayhoe *et al.* 2010 for a discussion of this in relation to Chicago). Warmer temperatures and more intense heat waves also likely to lead to the rapid increase in the use of air conditioning in cities where extensive air conditioning use is not present, particularly among populations that can afford it (e.g. much of Europe).

Conversely, in temperate and more northern regions winter temperatures increases will bring decreases in energy demand for heating (Mideksa and Kallbekken 2010). In most cases within individual cities, potential increases in summertime energy demand from climate change will exceed reductions in winter energy demand reductions.

Many cities' economies will be impacted if climate change induces water scarcity and variability that interrupt hydropower supplies. Climate change may interrupt Brazil's hydroelectric supplies, with negative knock-on effects on the economies of many urban centres. Cities in sub-Saharan Africa often rely on hydropower for their electricity, and failures in hydropower supplies "can lead to a more general 'urban failure' " (Muller 2007). Discussing supply side concerns, Laube et al. (2006) identify water shortages in Ghana following low precipitation periods and competition with hydropower between energy and water provision including to downstream urban centres as a possible impact at times. Declining water levels in the Hoover Dam have raised the possibility that Los Angeles will lose "a major power source as hydroelectric turbines shut down," and that Las Vegas will experience a severe decline in drinking water availability (Gober 2010: 145).

Summer heatwaves are associated with spikes in demand with extensive use of air conditioning, resulting in brownouts or blackouts (Mideksa and Kallbekken 2010). Temperate cities in Australia are already experiencing regular blackouts on hot summer days, largely due to increased residential air-conditioner use (Maller and Strengers 2011). Research in Boston (Kirshen et al. 2008: 115) suggested that rising energy demands in Boston's hotter summers have a "disproportional impact on [the] elderly and poor; increased energy expenditures; [and] loss of productivity and quality of life" (*ibid*.).

The projected increase in the frequency of snow or ice storms during the next decades in the northeast U.S. for example will disrupt the electricity distribution systems because of the collapse of power lines and other infrastructure (Rosenzweig et al. 2012).

8.2.4.3. Transportation and Telecommunications

Climate change related extreme events and exposure will affect transportation and telecommunication infrastructure including a variety of capital stock such as bridges, roads, railways, pipelines, and port facilities, data sensors, and wire and wireless networks. Assessing the disruption of transport networks outside and inside cities is critical. Extreme climate event disruptions outside cites can impact urban economies.

The literature on transport and climate change focuses more on mitigation than on adaptation and as yet, transport has received limited attention within the urban adaptation literature (Hunt and Watkiss 2011). Existing studies on climate change impacts are often limited to the short-run demand side, particularly in passenger transport (Koetse and Rietveld 2009). But climate change creates several challenges for transport systems. The daily functioning of most transport systems is already sensitive to weather extremes including extreme precipitation, temperature, winds, visibility, and for coastal cities, rising sea levels with the associated risks of flooding and damages (Love et al., 2010). Transport is thus highly vulnerable to climate variability and change, and the economic importance of transport systems has increased with the rise of just-in-time delivery methods, heightening the risk of losses due to extreme weather (*ibid,* also Gasper, Blohm and Ruth 2010). In addition to adapting road transport, it will be necessary to ensure bridges, railway cuttings, and other hard infrastructure are resilient to climate change over their service lifespan (Jaroszweski et al. 2010). For railways, few studies have examined the effects of climate change but weather-related rail system failures may be caused by high temperatures, icing, and storms (Koetse and Rietveld 2009).

The impacts upon transport and communications will be region-specific. Most cities in low- and middle-income nations are still developing their transport systems. This is especially so in the larger, more successful and more rapidly growing cities – for instance, developing transport networks in Asian cities are often at risk from extreme weather events (Regmi and Hanaoka 2011). India's transport and telecommunications networks are still being built, and adaptation as well as mitigation measures "will need to be integrated within the design of these systems" (Revi 2009: 329).

Meanwhile, cities in colder regions will enjoy increased opportunities for developing road networks or ports due to loss of sea ice, although it may be costly to adapt these regions' road, air and water transport networks (Larsen et al 2008). For industries and communities in Northern Canada, reduced freshwater-ice levels creates economic benefits such as longer shipping seasons (Prowse et al. 2009). Lost sea ice could also promote new seaports in marine environments, but inland towns require sizable investments in land-based roads to replace winter ice roads that formerly utilised small lakes and stream networks (ibid.). More generally, thawing of the ground can result in instability and major damage to roads, infrastructure, and buildings (ibid.).

The direct impacts of extreme weather on transport are often more easily assessed than the indirect impacts or possible knock-on effects between systems. Studies have often examined the direct impacts of flooding upon transport infrastructure, but the indirect costs of delays, detours, and trip cancellation "may also be substantial" (Koetse and Rietveld 2009: 209).

During Mumbai's 2005 floods, there were serious direct impacts in terms of injuries, deaths and property damage but also serious indirect impacts as most city services were shut down for 5 days without contact via rail, road or air (Revi 2005). Transport and other urban infrastructure networks are often interdependent and located in close physical proximity to one another (Kirshen et al. 2008). Yet only a few assessments have jointly considered the impacts upon transport and other associated sectors (Hayhoe *et al*. 2010 for Chicago, Kirshen, Ruth, and Anderson 2008 for Boston). Implementing adaptation strategies in the transport sector requires "coordination at national, regional, and local levels", since climate change impacts are widespread and extend across scales (Regmi and Hanaoka 2011: 39).

Transport systems are critical for effective disasters response– for instance where there is an urgent need for evacuating populations prior to an approaching storm or where disaster response requires an urgent need to ensure provision for food, water and emergency services to affected populations.

8.2.4.4. Built Environment, and Recreation and Heritage Sites

The built environment – residential, commercial, industrial, and other structures including heritage sites – will be impacted by climate change (Wilby 2007, Spennemann and Look 1998). Risks to built heritage has led to the Venice Declaration on Building Resilience at the Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies which brings together UNESCO, UNHABITAT, EC and individual city mayors.

Urban housing is "often the major part of the infrastructure affected [by disasters]..." (Jacobs and Williams 2011: 176). Extreme events like cyclones and floods inflict a heavy toll on housing, particularly those structures built with informal building materials and built outside of safety standards (United Nations 2011). Dhaka's 1998 floods damaged 30% of the city's units and of these, 32% were permanent/semi-permanent homes belonging to wealthier households, but 36% were lower-quality owned by the lower-middle classes and 32% by the poorest (Alam and Rabbani 2007: 89). Adelekan 2012 shows how a relatively modest increase in wind speeds during storms caused widespread damage and high costs of rebuilding or repairs in central Ibadan. In addition, increased climate variability, warmer temperatures, precipitation shifts, and increased humidity will accelerate the deterioration and weathering of many stone and metal structures in cities (Stewart et al. 2011, Bonazza et al. 2009, Smith et al. 2008, Thornbush and Viles 2007, Carlota et al. 2007).

Recreational sites such as parks, playgrounds will be affected as well. In New York, recreational sites are defined as critical infrastructure and often located in low elevation areas subject to storm surge flooding (Rosenzweig and Solecki 2010). Although climate change is likely to have significant impacts on traditional tourist destinations, little existing research has examined the effects upon urban tourism in particular (Gasper, Blohm and Ruth 2011).

8.2.4.5. Ecosystem Services and Green Infrastructure

A wide variety of ecosystem services and green infrastructure will be impacted by climate change. Climate change will alter ecosystem functions such as temperature and precipitation regimes, evaporation, humidity, soil moisture levels, vegetation growth rates (and allergen levels), water tables and aquifer levels, and air quality. These can influence the effectiveness of pervious surfaces used in storm water management, green/white/blue roofs, coastal marshes such as flood protection, food and urban agriculture and overall biomass production, shifts in disease vectors (e.g., seasonality and intensity of mosquitoes), and decline in air quality because of increase in secondary air pollutants. Mombasa will likely experience more variable rainfall as a result of climate change, making initiating and expanding green infrastructure more difficult (Kithiia and Lyth 2011). Street trees in British cities will be increasingly prone to heat stress and to attacks by pests, including non-native pathogens and pests that could survive for the first time under warmer or wetter conditions (Tubby and Webber 2010). Urban coastal wetlands will be inundated with sea level rise. In New York city, remnant coastal wetlands will be lost to sea-level rise because the wetlands will not be able to migrate inland due to bulk heading and intensive coastal development (Rosenzweig et al. 2012).

8.2.4.6. Social and Public Services

The effects of climate change will also be evident across several urban social and public services such as health and social care provision, education, firefighting, police and emergency services. Many low- and middle-income cities lack adequate social and public service provision (Bartlett 2008, Satterthwaite *et al*. 2007) while higher-income cities are only beginning to consider climate change in their health or disaster management plans (O'Neil et al. 2010, Brody *et al*. 2010). Although there are few studies on adapting education, police, or other key services, a growing public health literature has discussed multi-sectoral adaptation strategies (Huang et al. 2011). Cities' existing public health measures provide a foundation for adapting to climate change, such as heat warning systems or disease surveillance (Bedsworth 2009, McMichael et al. 2008). Negative climate impacts on some of the most vulnerable in society– the very young and children (Sheffield and Landrigan 2011, Watt and Chamberlain 2011, Ebi and Paulson 2010, the elderly (Oven 2012, White-Newsome et al. 2011) and the severely disadvantaged (Kenny et al. 2010, Ramin and Svoboda 2009) have been highlighted.

8.2.5. Urban Transition to Resilience and Sustainability

Climate change risks also affect the process of transition to resilience and sustainability. By heightening uncertainties and altering longstanding patterns of environmental risks, climate change may strongly influence how urban areas are managed just when many cities continue to face other significant stressors such as rapid population growth, increased pollution, resource demands, and concentrated poverty (Mehrorta et al. 2011, Wilbanks and Kates 2010). This section discusses how climate change increasingly affects municipal decision-making frames and alters local conceptions of cities as vehicles for economic growth, for political change, for meeting livelihoods and basic needs as well as larger-scale goals of resilience and sustainability.

8.2.5.1. Uncertainty and Surprise

Climate change will contribute to more uncertain and dynamic urban conditions, making past environmental responses and baselines less valuable for predicting cities' future environments (Solecki et al. 2010). It has been suggested that "the complexities and uncertainties associated with climate change pose by far the greatest challenges that planners have ever been asked to handle" (Susskind 2010: 2010: 218).. Municipal- and higher-level adaptation plans will need to take into account uncertainty about future climates and extremes. These will need to consider direct and indirect economic costs, the trade-off of with inaction and thus locking in to ill-adapted infrastructure versus investment in adaptation when climate change is less than anticipated (Hallegatte et al. 2007).

Several decision-making settings in urban areas are influenced by shifts in the likelihood of extreme weather events and the need to respond to climate-related surprises. Water resource managers (Fane and Turner 2010, Dessai and Hulme 2007), insurance companies (Crichton 2007, Botzen et al. 2010), public health, disaster, and emergency responders (Keim 2008, Huang et al. 2011, Hess et al. 2009) will need to grapple with heightened climate-related uncertainties. Infrastructure planners need to adopt various strategies to incorporate uncertainty, such as selecting no-regret strategies; favouring reversible and flexible options; buying 'safety margins' in new investments; promoting soft adaptation strategies; and/or reducing decision time horizons (Hallegatte 2009).

8.2.5.2. Extreme Event Probability

Shifts in extreme event probability have impacted how cities are understood by stakeholders and decision-makers. It is important to assess how these changes are integrated back into local decision-making. In New York, the prospect of increased climate variability has spurred an integration of climate resiliency efforts into extreme event planning and actions including increased storm water management during intense precipitation events to forestall or prevent inland and street-level flooding (Rosenzweig and Solecki 2010). Conversely Jakarta has several early-warning disaster systems in place but no adaptation plans have been developed; Jakarta's Spatial Plan does not incorporate climate change and the local government's focus is on disaster management rather than preparing for climate change (Firmana *et al*. 2011).

Urban decision-makers have widely divergent motivations and strategies for incorporating extreme events into local adaptation plans. Cities have implemented adaptation measures in response to "specific local or regional natural disasters, which may or may not be climate-related", such as enhancing preparedness measures in the Greater Mumbai Disaster Management Plan after the city's 2005 floods (Revi, 2006) (Bulkeley 2010: 245). Findings in the UK (Tompkins et al. 2010) and other European cities (Carter 2011) suggest that the primary motives for adaptation measures are rarely climate-related; policymakers instead prioritise biodiversity conservation, energy reduction, or responding to current climate extremes. However, some authors argue that adaptation strategies enjoy greater success by creating synergies with other agendas, such as improving health or enhancing urban competitiveness (Nath and Behera 2011, Carter 2011). Further research is needed to evaluate the merits of stand-alone adaptation plans, as against approaches that seek to mainstream climate change into urban planning (Romero-Lankao and Dodman 2011).

8.2.5.3. Transitions

In recent years, several urban environmental transition models (e.g. McGranahan and Marcotullio 2007) have been introduced to show transitions between health hazards and environmental impacts as cities and neighbourhoods develop, including the use of global and local sinks for wastes that are outside their boundaries . Within these models, key variables have been identified that make cities vulnerable to climate change (e.g., concentrated urban form and extensive infrastructure networks). Established sustainability approaches e.g. compact cities, eco-regions, polycentric new-town planning systems, rural development as a strategy for moderating urbanization (Williams et al. 2012) are among the most common transition strategies.

Climate change has encouraged stakeholders and decision-makers to re-evaluate the environment of their cities as dynamic and connected to several transition contexts, especially with respect to movement toward low-carbon economies (Buckeley et al. 2010, Mdluli and Vogel 2010). Other transition contexts are associated with an understanding of the urban systems and functions that are increasingly under stress so that past approaches are no longer adequate (Pelling and Dill 2010).

Transitions in the context of climate change emerge in two situations. The first is a systems-level perspective where urban systems could reach a tipping point in which a failure or collapse could occur. The second is a broader scale societal transition to enhanced resilience and adaptive capacity (and attention to mitigation) in the face of accelerated climate change (Solecki and Murphy 2012, Ernstson et al. 2010, Mdluli and Vogel 2010, Tompkins et al. 2010, Gusdorf et al. 2008, Pelling 2011a). The latter can often occur without resulting in a broader scale transition (Pelling and Navarrete 2011), with incremental changes also potentially precipitating regime level shifts. Although such shifts can also happen as a result of discrete regime failure (Pelling 2011a) this is less common. Such relevant transformational changes have been observed most often following urban earthquake events (e.g. in Nicaragua, Guatemala, Turkey) but are also associated with flooding in Bangladesh (Pelling 2011a). Disasters can enable regime level change at moments in history where competing approaches to development have political voice, an organizational base that articulates competing analysis of the causes of the disaster and weak systemic counter response.

8.2.5.4. Social Dynamics, Economic Tensions, and Multiple Stressors

Climate change may exacerbate existing social and economic stressors in cities with the potential to affect urban livelihoods, engender political or social upheaval, or generate other negative impacts upon human security (Siddiqi 2011, Simon and Leck 2010, Bunce et al. 2010). Climate change could potentially contribute to violent conflicts and spur migration (de Sherbinin 2011, Adamo 2010, Reuveny 2007), yet there is considerable uncertainty regarding projections. Migration may represent an important household strategy to adapt by diversifying income-sources and livelihoods (Tacoli 2009). Although climate change could significantly disrupt livelihoods, outcomes will depend upon particular social structures, state institutions, and other broader determinants of human security (Barnett and Adger 2007). In sum, “dwindling resources in an uncertain political, economic and social context are capable of generating conflict and instability, but the causal mechanisms are often indirect” between climate and conflict (Beniston 2010: 567).

Specific tensions emerging from climate change impacts have been derived from studies connecting climate impacts with disaster recovery (Solecki et al. 2011). These tensions include temporary or permanent poverty; food insecurity; and shifts in the informal economy. Shifts in social dynamics include the possibility and aspiration that reconstruction and recovery can improve people’s livelihoods, changing the structure of the urban economy through the disaster cycle; changes in city administration; private and public property ownership; lifestyle (Coombes and Jones 2010) and in more dramatic cases change in the urban center’s economic base.

To help understand climate-related tensions in cities, a stronger research focus upon cities, human security, and climate change has been advocated (Simon and Leck 2010). The links between humanitarian work and climate change are increasingly recognized, but further collaborations between climate scientists, researchers, and aid workers is needed (Braman et al., 2010). Holistic strategies help to link development goals with adaptation, so that “multi-dimensional and multi-scale approaches [can] better guide the construction of adaptation responses to climate change and integrate them to development strategies” (Sánchez-Rodriguez 2009: 205).

Climate change also creates implications for equity from different management solutions (Pelling 2012). For example, the privatization of urban water supply and sanitation systems advantages specific groups over others. Conversely, community-based solutions that also build social capital can be a component in generating generic urban resilience. But these too may exacerbate inequality at the city level with those local areas with strong levels of social capital being able to benefit most from local community led action or support for local initiatives from international and national partners (UN HABITAT 2007, Pelling 2012).

8.2.5.5. Historical Analogues

The experience of cities in coping with environmental/resource crises in the past provides a useful analog to understand climate change impacts and shifts in urbanization process (Solecki 2012, Ranger et al. 2011, Ford et al. 2010, McLeman and Hunter 2010, Hallegate et al. 2007, Gibbons et al. 2006).Cities often have been able to respond to localized risks and vulnerabilities such as resource shortages and environmental quality issues by externalizing the problems either through expansion of the resource catchment or by externalising the environmental quality threats (e.g. sewerage, rubbish) to more remote and distant locations (McGranahan 2007, Tarr 1997). This is more complex in the case of climate change is that the source of the risk and vulnerability is external to individual cities and outside their span of control. City governments have dealt with many environmental health problems by reducing or removing the hazard but this they cannot do for climate change.

Urban development and urbanization has been dramatically impacted by past changes associated with large scale exogenous factors which have either been pervasive (e.g., globalization) and/or profound e.g. wartime devastation, civil war (Hewitt 2009), and natural hazards such as earthquakes, cyclones, as well as the application of new technologies (e.g., automobiles, electricity, the internet). Identity is particularly important in this context because the physical fabric can be rebuilt but in so-doing the identity of a city may be changed. From these cases, it is evident that well-governed cities demonstrate a capacity to adapt and to learn from crises (Solecki 2012).

8.3. Adapting Urban Areas

8.3.1. Introduction

The literature on urban climate adaptation has increased significantly since the Fourth Assessment (AR 4) – with an emphasis on particular cities and specific adaptation interventions. The growing interest in urban adaptation is mainly evident in three aspects. The first is a literature examining risks and vulnerabilities for particular cities. The second, overlapping with this, are papers discussing what might constitute resilience. The third is documentation produced by or for particular city governments on adaptation. There is less documentation of local government decisions to include climate change adaptation for urban areas in plans and investment programmes, although some city governments report on this (see Solecki 2012, Roberts 2008a and 2010).

Most national climate change plans and policies give little attention to urban adaptation. Perhaps the main exception to this is where local or regional governments have engaged in disaster risk reduction to extreme weather events – see below.

Urban climate change adaptation planning faces uncertainties about the nature and location of present and future hazard risk and vulnerability at the urban scale – as most climate models function at a lower resolution than most cities. The availability of relevant risk data continues to be challenging as it is often not collected or if it is, rarely quantitative, at the appropriate scale and is often fragmented across city departments (Hardoy and Pandiella 2009). Many suggested adaptation measures are in response to specific local or regional hazard risks, which may not be directly climate-related (Bulkeley 2010). Climate data needs to be integrated geographically, across time-scales, and consider the range of regional benefits and costs of climate policy if it needs to be useful to adaptation and spark local dialogue (Ruth 2010).

There is a growing body of literature on opportunities to strengthen urban climate resilience in household, community and city development plans, infrastructure development investment and the management of ecosystems and of cities' physical expansion. City governments that have developed adaptation policies recognize that their strategies, investments and actions plans have to be part of an iterative process that can change with the availability of new information, analyses or frameworks - as presented in "Iterative Risk Management Approach to Climate Change" (National Research Council 2011). What is important is the recognition by local governments of the need for a unit that has responsibilities for this – drawing together relevant data, often drawn from different departments, keeping key politicians and civil servants informed and consulting with key stakeholders (Roberts 2010, Brown et al. 2012).

8.3.2. Development Plans and Pathways

As AR4 emphasized, many of the forces shaping greenhouse gas emissions are those underlying development pathways – including the scale, nature and location of private and public investment in infrastructure (Wilbanks, Romero Lankao et al. 2007). These also influence the form and spatial distribution of urban development and the scale and location of climate-related risks to urban enterprises and populations. Responsibility for encouraging new investments and migration flows away from high risk sites is often shared between local, provincial and national government through a combination of climate sensitive disaster risk management and urban planning and zoning. But the priority given by national and urban governments to economic growth usually means that this is rarely implemented with vigor.

8.3.2.1. Adaptation and Development Planning

Urban adaptation is becoming important for some national, regional and city governments although the first steps have often come from stakeholders outside the state sector. In high-income countries, interactions between national climate policies and local level and the division of responsibilities have been examined (in Italy, Massetti et al

2007). There is also attention to local adaptation implementation through subsidies and flexible schemes in different city contexts and the transfer of authority and resources to city level (for the Netherlands see Gupta et al. 2007). The design of new decision making strategies for local level governments considers the complexity and dynamics of evolving social-ecological systems (Kennedy et al. 2010). Examples include adaptation plans and local responses in Sydney to cope with sea level rise and storms (Hebert and Taplin 2006) and adaptation planning in California (Bedsworth and Hanak 2010). In China, adaptation programmes are being developed and implemented at national and local level. The debate emphasizes the policy space and the division of responsibility between national and local levels (Teng et al. 2007)

There is a growing literature on urban adaptation from low and middle-income nations (Blanco 2007, Carolini 2007, Martine et al. 2007, McGranahan et al. 2007, Satterthwaite et al. 2007, de Sherbinin et al. 2007, UN-Habitat 2007, United Nations Population Fund 2007, Agrawala and van Aalst 2008, Ayers 2008, Bartlett 2008, Bicknell et al. 2009, Douglas et al. 2008, Kovats and Akhtar 2008, Revi 2008, Roberts 2008a, Tanner et al. 2008, Hardoy and Pandiella 2009,Wong 2009, Manuel-Navarrete et al. 2011). Four relevant issues can be drawn from this - the fact that these nations have most of the world's current and future urban population; the need to consider poverty and social inequality as multidimensional problems that may be aggravated by climate change; the need to consider human agency among low-income inhabitants as an important resource in building local responses to climate change; and the relevance of multilevel governance in adaptation strategies (Sánchez-Rodríguez 2009).

Although few publications suggest specific operational strategies, they stress the importance of the linkage between climate adaptation and development. Manuel-Navarrete et al. (2011) explores the interplay between visions of development, governance structures, and strategies to cope with hurricanes in the Mexican Caribbean where exposure and vulnerability are influenced by political decisions and contingent development paths. Similarly there are few reports on multidimensional approaches to guide operational adapation. There is growing attention to integrating adaptation with development interventions and addressing structural drivers of social and urban vulnerability – see for instance Climate Action Plans of Mexico City, Cartagena and San Andrés de Tumaco (Sánchez-Rodríguez 2009).

Two factors help explain the lack of detailed attention to urban climate change adaptation in low- and middle-income nations. The first is the lack of attention to urban adaptation within national policies and institutions, in comparison with sectors like agriculture. Responsibility for climate change policies are often with ministries or agencies that have little influence on others whose cooperation is essential responsible e.g. for social policies, public works and local government (Ojima 2009, Roberts 2010, Hardoy and Pandiella 2007). Governments' social policies and priorities influence the social and spatial distribution of climate related risk and vulnerability yet few agencies recognize their potential role in reducing risk and vulnerability. Adaptation in informal settlements and the incorporation of individual and group agency in bottom-up adaptation strategies is of particular relevance in low income and most middle-income nations (Sánchez-Rodríguez 2009). Recent experiences of Central American cities like Tegucigalpa and in some cities in the Philippines show the involvement of low-income communities in risk reduction may be first steps towards climate adaptation (Aragón-Durand 2011, Carcellar et al. 2011).

The second is a focus on mitigation rather than adaptation. Local decision-makers frequently view climate change as a marginal issue, with adaptation usually ranked lower than mitigation on the urban policy agenda (Bulkeley 2010, Simon 2010). For instance, Mexico City's climate change agenda focuses on mitigation with adaptation still a vague concept that is not incorporated into concrete actions and decisions (GDF 2006, GDF, 2008, GDF 2011). Adaptation is seen as a capacity to withstand weather-related impacts such as floods through early warning systems rather than comprehensive, long-term adaptation measures such as watershed management to reduce the speed and volume of flood waters. In Sao Paulo, more attention was given to mitigation with adaptation action limited to broad declarations about the needed actions in different sectors (INPE, UNICAMP, USP, 2010). There is little academic and policy literature on climate change adaptation for Brazilian cities (Ojima 2009, Soares de Moura 2009). In addition, the pressure on national and local governments to act is lessened by the absence of public awareness of the importance of addressing climate change adaptation (see Nagy et al. 2007). There is also a "knowledge gap" between policymakers and scientists regarding knowledge needed to enhance adaptation as in the case of Tijuana (see Sanchez-Rodríguez, 2011).

8.3.2.2. Disaster Risk Reduction and its Contribution to Climate Change Adapation

The growing concentration of people and economic activities in urban centres and the increasing number and scale of cities can generate new patterns of disaster hazard, exposure and vulnerability. This trend is visible in the large and rising number of localized disasters in urban areas in many low- and middle-income nations, mainly associated with extreme weather (storms, flooding, fires and landslides) (United Nations 2009, 2011). This has particular relevance for climate change adaptation, given the increase in the frequency and intensity of potentially hazardous weather events that climate change is bringing.

Exposure to disaster risk from weather events in expanding urban areas increases when local governments fail to implement their responsibilities, including needed expansion in infrastructure and services and risk reduction through implementing building standards and appropriate land-use management (ibid). This is typically in countries with low per capita GDPs and weak governance (i.e. in the first two categories of Table 8-2) and may be exacerbated by rapid urban population growth.

The most urbanized nations generally have the lowest mortality to extreme weather events (United Nations 2009). Urbanization accompanied by more capable and accountable local governments can reduce disaster risk as is evident in the declines in mortality from extreme weather (and other) disasters in many middle and all high-income nations (United Nations 2011).

While local government investment usually represents a small proportion of total investment in and around an urban centre, it has particular importance in risk reduction through investments in risk-reducing infrastructure, public services and planning and regulation that ensures buildings and infrastructure meet needed standards and guide development away from high-risk areas. Urban governments have explicit responsibilities for many assets, some of which may be risk prone – for instance schools, hospitals, clinics, water supplies, communications, sanitation, electricity, roads and bridges. Where private provision for infrastructure and services is significant, it usually falls to local government to coordinate such provision and hence, enhance its role and responsibility for urban adaptation.

From the late 1980s, a new approach to reducing disaster risk in urban areas was developed in some Latin American nations that is relevant to climate adaptation. It involved three processes: detailed analyses of local records of disasters that including smaller disaster events than reported in international databases; recognition that most disasters were the result of local failures to assess and act on risk; and the recognition of the central roles of local governments in disaster risk reduction but with support from national and local civil defence organizations working with civil society and community organizations within the settlements most at risk (United Nations 2009, IFRC 2010). These led to institutional and legislative changes at national or regional level to support disaster risk reduction (Gavidia 2006, IFRC 2010). In Colombia, a national law supports disaster risk reduction and a National System for Prevention and Response to Disasters with a shift in the main responsibility for action to municipal administrations. In Nicaragua, the National System for Disaster Prevention, Mitigation and Response (SINAPRED) was set up in 2000 to work with local governments to strengthen disaster preparedness and management by integrating disaster mitigation and risk reduction into local development processes (Von Hesse, et al., 2008). There are other initiatives and action programmes in Central and South America with regard to urban risk management and disaster preparedness, including the influence of La Red (IFRC 2010), the DIPECHO project, “Developing Resilient Cities” and UNDP and GOAL in Central America.

In growing numbers of Asian (Shaw and Sharma, 2011) and African (Pelling and Wisner 2007) cities’ experiences with community-driven ‘slum’ or informal settlement upgrading has led to a recognition of the potential of these to reduce risk and deep rooted vulnerability to extreme weather events. This is most effective when supported by local government and civil defence/emergency response agencies (Boonyabancha 2005, Archer and Boonyabancha 2011, Carcellar et al. 2011).

The Homeless People’s Federation of the Philippines developed a series of effective responses following major disasters, which included: community-rooted data gathering (assessing the severity and scope of destruction and victims’ immediate needs); trust and contact building; support for savings; the registering of community organizations; and identifying needed interventions, including building materials loans for house repairs. The effectiveness of risk reduction is also much enhanced where local governments work to support these (Carcellar et al. 2011) and experiences such as these have helped inform community-based adaptation (see 8.4).

There are also international networks supporting innovation in disaster risk reduction and/or climate change adaptation and inter-city learning. These include la Red in Latin America (IFRC 2010), the Earthquakes and Megacities project which includes multi-hazard risk assessment and the cities programme of the Asian Disaster Preparedness Centre. As donor interest has grown in supporting disaster risk management as a vehicle for climate change adaptation, a number of resilience oriented urban programmes have developed including the Asian Cities Climate Change Resilience Network (Brown et al. 2012), the UN ISDR Resilient City network (Blackburn et al 2012) and ICLEI's city adaptation network.

Despite growing international support for urban disaster risk management, it can be difficult for local governments to access the human and financial resources needed to make real change on the ground (Von Hesse et al. 2008). Local governments do not get recognition for the disasters their programmes prevented – so risk reduction investments are not seen as priorities and have to compete for scarce resources with what are judged to be more pressing needs. Effective policies are often tied to the terms in office of particular mayors or political parties (Mansilla et al. 2008, Hardoy et al. 2011). In most cases, disaster risk reduction is still not integrated into development plans and not drawing in all relevant departments and divisions of local government. Manizales in Colombia is an exception as disaster risk reduction is seen as part of local development and where collective interests overcome individual and party political interests (Hardoy and Velásquez Barreto 2013)

As detailed in the IPCC SREX (2012), disaster risk management is increasingly positioned as a frontline sector for the integration of climate change adaptation into everyday decision-making and practices. This can be seen in the plans of urban municipalities such as Tegucigalpa, Honduras and Montevideo (Aragón-Durand 2011). Where disaster risk management is taken seriously by government or civil society this offers real opportunities for synergy as the long-range nature of climate change concerns and its policy visibility can enhance local support for disaster risk management. The still common disjuncture in international frameworks and national responsibilities mean there is much scope for better coordinated efforts to make urban DRM climate smart (SREX 2012, Aragón-Durand 2008).

8.3.3. Adapting Key Sectors

8.3.3.1. Adapting the Economic Base of Urban Centres

Climate change will bring changes to the comparative advantages of cities and regions – for instance through influencing climate sensitive resources and changes in locations of extreme weather, water availability and flooding. Many case studies show how extreme weather can impede economic activities in cities, such as damaging industrial infrastructure and disrupting coastal ports and supply chains (Gasper et al. 2011).

The importance of effective climate adaptation is that it can help mitigate risks from such changes, deepen resilience and limit disadvantages. For urban centres facing climate-related risks, a failure to adapt is likely to discourage new investments. Over the long term this could lead enterprises moving or expanding to other safer, better adapted locations. Multinational corporations and many national businesses have long been adept at changing the location of their production (and also their headquarters) in response to changing opportunities and risks so they can choose to avoid urban centres facing high risks linked both to climate change and a failure to adapt.

Disasters can change perceptions of risk and discourage new investments. For instance, businesses may move after a disaster impacts other businesses and services that they use (especially basic services like utilities, schools, and hospitals) (Hallegatte et al, 2007). A lack of capacity to reconstruct means increased vulnerability to succeeding extreme weather events and less new investment that in turn weakens the urban economic base (Benson and Clay 2004, Hallegatte et al. 2007, Hallegatte et al. 2011).

Past experience of de-industrialization in cities in the U.S. and Europe show the difficulties of changing economic structures. When the main activity of a city or region weakens, incomes, employment and local authority revenues decrease, making it more difficult to re-invest in new business and reducing attractiveness for new investments. If climate change forces many regions to change their economic structure and business models, transitions may prove difficult to manage (Berger 2003). Specific adaptation policies may be useful to help make the transition more rapid and less painful.

Climate change adaptation is generally cheaper and easier to implement in new urban developments – for instance peri-urban fringes, rather than retrofitting infrastructure and industries already in place (McGranahan, Balk, and Anderson 2007).

Within and around urban centres, local governments may need to utilise several adaptation strategies including selective relocation, land use planning to reduce exposure, shifting development from floodplains, and revised building regulations to retrofit or flood-proof structures (Hanson *et al.* 2011). There may be opportunities for proactive adaptation outside the larger cities where much of the future urban growth is likely to occur although. For instance, in Manizales in Colombia, local government has begun incorporating climate change and environmental management into its local development agenda, including the establishment of city climate monitoring systems, although this is a city that has long had innovative environmental and disaster risk reduction policies (Hardoy and Velásquez Barreto 2013). However, smaller urban centres are often institutionally weaker and often lack critical infrastructure.

Adapting the urban economic base may require short- and long-term strategies to assist vulnerable sectors and households. The consequences of climate change for urban livelihoods may be particularly profound for low-income households who generally lack assets or insurance to help them cope with shocks (Moser and Satterthwaite 2008). The urban informal sector is usually a significant part of a city's economy and provides employment for large sections of the population. But the effects of extreme weather on the informal economy are rarely considered as in the case of 2003 floods in Santa Fe, Argentina (Hardoy and Pandiella 2009). Social protection and safety nets for vulnerable groups, "particularly in the informal economy," may be needed to cope with the short-term impacts of climate change (Sánchez and Poschen 2009).

There is a growing discussion of the importance of support for a 'green economy' combined with green infrastructure to help shift the economic and employment base towards lower carbon, more climate resilient patterns but as yet too little detailed discussion of this in relation to particular cities.

The 'waste economy' in cities in low- and middle-income nations should be an important sector in the green economy as it provides livelihoods to a large number of people (Hasan 1999, Hardoy et al. 2001, Medina 2007) along with contributing to waste reduction and GHG emission reduction (Huq and Ayers 2009). In Brazil's main cities, over 0.5 million people are engaged in waste picking and recycling (Fergutz et al. 2011); an estimated 17,000 people in Lima and 40,000 in Cairo earn their livelihoods from informal recycling (Scheinberg et al. 2011). The mechanisms by which city governments choose to work with those working in this waste economy or ignore them has obvious implications for employment and for resource use.

For some cities, there is documentation of the kinds of adaptation needed to protect or enhance their economic base. For instance, in Mombasa, local authorities may need to redesign and reconstruct the city's ports, protect cement industries and oil refineries and relocate some industries inland, all of which requires major capital investments (Awuor et al. 2008).

There are many parts of Rio de Janeiro's diverse economy (including manufacturing, oil refineries, shipyards and tourism) that adaptation will need to protect along with the urgent need to address the vulnerability of large population living in informal settlements (favelas) on land at risk of landslides that are most at risk (de Sherbinin et al. 2007). Defences needed to help safeguard coastal industries and residential areas could threaten the city's beach tourist industry. It is also difficult to focus the attention of politicians and civil servants on adaptation when their planning for city development is focuses on hosting the World Cup and the Olympics. As in most cities, making

Rio's economic base more resilient to climate change will need to resolve such tensions and trade-offs, necessitating dialogue amongst local stakeholders (Ruth 2010).

As yet, there is little evidence that climate-change related risks or cities adaptive capacities have an influence on the location of private sector investments. They are however, influenced by the availability of infrastructure and services that are an essential part of adaptive capacity. Many cities in Asian high growth economies are located on low-lying coastal areas[3], which are undergoing rapid urbanisation and economic transformation (McGranahan, Balk and Anderson 2007). Many of these coastal settlements are also within areas where cyclones are common. Without adaptive measures and with rising concentrations of population, infrastructure, and industries along India's coasts, there could be a non-linear increase in coastal vulnerability over the next two decades (Revi 2009). The same is true for China (McGranahan et al. 2007).

[FOOTNOTE 3: These 'low-elevation coastal zones' (LECZ) are defined as the contiguous area along the coast that is less than 10 metres above sea level (McGranahan, Balk, and Anderson 2007).]

Few economic assessments of climate change risks have been completed in West African coastal cities. National and city governments will face difficulties protecting many cities or particular districts and their industries, infrastructure and tourism is in the case of Cotonou (Doussou and Gléhouenou-Doussou 2009) **.** Lagos, Dakar, and other important economic centres in the Gulf of Guinea have large areas on the coast that are close to mean sea level, leaving them highly vulnerable to erosion and rising sea levels (Simon 2010). Compounding the climate change-induced flooding risks are the cities' rapid coastal construction, destruction of mangrove swamps, and inadequate refuse collection (ibid.).

8.3.3.2. Adapting Food and Biomass for Urban Populations

Large sections of the urban population in low- and middle-income countries suffer hunger while a larger number face food and nutrition insecurity (Montgomery et al. 2004, Ahmed et al. 2007, Cohen and Garrett 2010). This is due more to their low incomes and limited capacities to access food than to overall food shortages (Cohen and Garrett 2010). Among low-income urban households in such nations, food expenditures generally represent more than half of total expenditures (Cohen and Garrett 2011). This makes low income urban populations particularly at risk to food price inflation.

Climate change is likely to have far-reaching influence on food security, but its impact "will crucially depend on the future policy environment for the poor" (Schmidhuber and Tubiello 2007: 708, see also Douglas 2009). Globally, agriculture has managed to keep up with rising demands worldwide, including the rapid growth in the population, the rapid increase in the proportion of non-agricultural workers to agricultural workers that accompanies urbanisation and consumer dietary shifts that are far more meat and carbon intensive and often land intensive (Satterthwaite et al. 2010). However, food security may be eroded by competing pressures for water or bio-fuels (Godfray *et al,* 2010). Although adjustments in farming practices are essential, adapting urban food systems represents a major challenge and will necessitate radical changes in food production, storage, processing, distribution, and access (ibid).

Urban food-related adaptation needs to consider both supply and demand side constraints. Climate-change related constraints on agricultural production and the food supply chain can impact urban consumers through reduced supplies or higher prices. Falling agricultural production or farmer incomes also reduces their demand for the urban producer and consumer goods and services they use. Disruption to urban centres may also mean disruption to the markets, services or remittance flows on which agricultural producers rely (Tacoli 2003).

Urban centres that are seriously impacted by extreme weather also face serious challenges in ensuring that the affected population have access to adequate food supplies. Flooding, drought, or other extreme events often lead to food price shocks in cities (Bartlett 2008) as well as spoiling or destroying food supplies for many households. After the 2004 floods in Bangladesh, Dhaka's rice prices increased by 30 percent and vegetable prices more than doubled

(Douglas 2009**).** Bangladesh's urban slum-dwellers and rural landless poor were the groups worst-affected by food insecurity (*ibid*.).

When facing increased food prices, the urban poor in low and most middle income nations adopt a range of coping strategies such as reduced consumption, fewer meals, purchasing less nutritious foods, or increasing labour particularly by women and children (Cohen and Garrett 2011: 473-5). But these erode nutrition and health status, especially of the most vulnerable and fail to strengthen resilience, particularly in the context of more frequent disasters.

Adaptive local responses have included support for urban or peri-agriculture, local markets and enhanced safety nets. Food price increases may be moderated by improving the efficiency of urban markets, regulations to promote farmers' markets, or investing in infrastructure and production technologies (Cohen and Garrett 2011). Food security may be enhanced by government support for urban agriculture and street food vendors (ibid., Lee-Smith 2011**).** Food security for urban dwellers with low incomes is also increased if they have access to cheaper food or to social incomes – for instance conditional credit or cash transfers (e.g. Brazil' Bolsa familia programme) or, for older groups pensions (Soares et al. 2010). The need to consider complex rural-urban linkages may be decisive in shaping food policies that can address climate change (Revi 2009). Thus, a portfolio of responses that can bridge rural and urban boundaries, as well as action at the household, local, national, and international levels, is needed to strengthen urban food security.

8.3.3.3. Adapting Housing and Settlement

Urban adaptation will be built on the bedrock of good quality and affordable housing that conforms to appropriate health and safety and climate-resilient building standards and has sufficient residual structural integrity over its service life to protect its occupants against extreme weather (United Nations 2009, 2011). Good quality housing should provide its occupants with a comfortable, healthy and secure living environment and protect them from injuries, losses and damage (Haines et al. 2012). As such, it has a key role in protecting urban populations and their assets – and has particular importance for protecting vulnerable groups including infants and young children (Bartlett 2008), older residents or those with chronic health conditions. This also means protection against displacement since low-income urban dwellers are particularly at risk from disruptions to household income.

Section 8.2.4.4 noted how poor quality housing is often at risk from extreme weather. Its resilience can be enhanced via a range of structural interventions (for instance retrofitting existing buildings and revising standards for new-build), interventions that reduce risks to housing (for instance expanding drainage capacity to limit and mitigate flood risks) and non-structural interventions (including insurance). The need for attention to all three of these strategies are obviously greatest where housing quality is low, where settlements have developed on high-risk sites and for cities or city locations in geographic locations where climate change impacts are greatest.

Most of the city governments that have developed climate change adaptation strategies include measures to adapt the building stock. But even in the cities with such discussions, there is still a need to act on the risks and vulnerabilities identified. The range of actors in the housing sector, the myriad connections to other sectors, the potential to promote mitigation, adaptation, and development goals all suggest the need for well-coordinated strategies that can support resilience (Maller and Strengers 2011).

An increasing number of cities have undertaken or commissioned studies to identify measures needed to adapt housing (and other buildings) although there is less evidence of the detailed action plans, budget commitments and regulation changes needed to implement them. A climate change assessment for Bangkok Metropolitan Administration identified a range of measures including a need to flood-proof homes, build elevated basements, and relocate power-supply boxes upstairs; also for households to maintain sufficient food, water, fuel, and other supplies to ensure 72 hours of self-sufficiency (BMA and UNEP 2009). It also pointed to regulatory changes that may be needed to bolster resilience including land use restrictions in floodplains and other at risk sites and revised safety and fire codes for buildings and other structures (ibid). Cape Town's climate change framework (2006) proposed housing interventions including improving construction and regulations for building informal housing, in part to reduce the need for emergency response and anticipate projected climate change. Regulations in New York and Boston are being updated to address climate-related risks to the built environment (see Boston 2011, PlaNYC 2011). London and Melbourne's adaptation plans discuss climate-related impacts on the housing sector, as well as detailing extensive adaptation measures. London's draft plan considers management strategies at city level, neighbourhood, and building scale, which combine green infrastructure and housing interventions (GLA 2010). Approved in 2009, Melbourne's plan similarly combines housing, water, and green infrastructure strategies to promote cooling and long-term adaptation (Melbourne 2009).

Housing and extreme heat: Attention is needed to buildings that provide protection from heat waves, especially in urban heat islands. This includes upgrading homes with low thermal mass and limited ventilation. Interventions that reduce heat gain are also needed including passive cooling and other design measures (Roberts 2008a, Hacker and Holmes 2007) as well as modifications in areas that are heat islands. Chicago's 2008 Climate Action Plan discussed the need to "pursue innovative cooling," which will "seek out innovative ideas for cooling the city and encourage property owners to make green landscape and energy efficiency improvements" (Chicago 2008: 52). Air conditioning and other forms of mechanical cooling can provide relief but these are too expensive for many households and potentially mal-adaptive as they rely on electricity (whose generation may be contributing to greenhouse gas emissions). They may exacerbate residents' vulnerabilities if electricity supplies are unreliable and "if blackouts occur on the hottest days when peak demand is at its worst" (Maller and Strengers 2011: 3). Cities also need heat-wave plans to ensure adequate water provision, back-up electricity supplies, emergency healthcare, and other public services that focus on vulnerable residents. This includes special attention to infants and to the elderly in hospitals, residential facilities (Hajat et al. 2010, Brown and Walker 2008) or living alone.

Passive cooling can be used in both new-build and retrofitted structures to reduce solar gain and internal heat gains, while enhancing natural ventilation or improving insulation (Roberts 2008b and 2008c). Although developments such as the Beddington Zero Energy Development (BedZED) in London (Chance 2009) or Germany's PassiveHaus standard (Rees 2009) have set precedents for mitigating household emissions, these passive designs can simultaneously contribute to adaptation. The designers of BedZED sought to reduce energy demand for heating, cooling and ventilation while also utilising super-insulation, ventilation, and other measures to ensure energy is not required for most of the year (Chance 2009: 532). Thermal mass can used for residential cooling, "because it introduces a time-delay between changes in the outside temperature and the building's thermal response necessary to deal with the high daytime temperatures" (Hacker and Holmes 2007: 103). Structures in southern Europe have already utilised solar shading, ventilation, and thermal mass in the building fabric to promote cooling (ibid.). Simulations for London buildings (under UKCIP02 Medium-High emissions scenarios) suggested that utilising shade, thermal mass, control of ventilation and other advanced passive designs was an "eminently viable option for the UK, at least over the next 50 years or so" (*ibid.,* : 111). Nevertheless, several obstacles may complicate the incorporation of passive designs. Opening windows may be hampered by security concerns or noise pollution in cities (Hacker and Holmes 2007). Additionally, modern windows "often do not ventilate well," and site restrictions, cost, or other constraints may impede the use of passive cooling "particularly in the refurbishment of existing buildings" (Roberts 2008b: 4554).

Housing and disaster-preparedness measures: If populations are displaced or require temporary evacuation, provision for emergency shelters and services need to be able to support vulnerable residents. For instance, housing agencies established shelters and recovery centres after Cyclone Larry in Queensland (in 2006) and New South Wales' coastal flooding (in 2007). Interviews with officials recalled the strains facing 24-hour providers in the shelters and coordination difficulties with emergency health workers, police, insurance, and other agencies (Jacobs and Williams 2011). While not addressing climate change explicitly, the study helps illuminate the range of social support, structural strategies, and interagency efforts that local authorities may need to develop in order to adapt to climate change.

8.3.3.4. Water, Sanitation, Drainage, and the Larger Systems of which They are Part

The challenge of this section (and this chapter), is summarizing key adaptation issues drawn from examples that come from a highly heterogenous mix of urban areas across the globe with order of magnitude variations in the quality and extent of provision for water, sanitation and drainage. In high-income and some middle-income nations, virtually all the urban population is served by drinking quality water piped to the home 24 hours a day, by sewers or other systems of sanitation that minimize risks of faecal contamination and by storm and surface drainage. There are many urban centres in such nations that face serious climate change-related challenges for water. But their plans do not have to address the fact that a significant proportion of their population do not have piped water supplies, sewers or storm drains. They also have in place billing and rent collection systems that generate a substantial proportion of the funds needed for water provision and management.

At the other extreme are a very large number of urban centres in low-income and middle-income nations with very large deficits in provision for water, sanitation and drainage and with weak, under-resourced institutions (UN Habitat 2003, WHO and UNICEF 2012). There is also the billion or so people living in informal settlements where authorities or companies responsible for water and sanitation provision are often unwilling to invest or not allowed to do so. So in considering how to adapt water and waste water systems to climate change, there are not only large differences between nations and cities in the scale and nature of likely impacts – but also very large differences in the quality and extent of provision for water, sanitation and drainage and the quality and resources available to local water and sanitation providers. New York city can develop a ten billion dollar plan to assure it receives adequate water supplies (Solecki 2012) while many cities in sub-Saharan Africa not only have very large deficits in infrastructure but very limited investment capacities.

A few studies have sought to estimate the costs of adapting urban water and sanitation systems. In sub-Saharan African cities, perhaps US$2-5 billion may be required <u>annually</u> to adapt water, wastewater, and drainage systems (Muller 2007). Other research also suggests significant investments needed in low- and middle-income regions to overcome current shortfalls in water and sanitation as well as to cope with climate change (Arnell et al. 2009).

8.3.3.4.1. Adaptation strategies for water

Major et al (2011) listed a range of cities that have begun to plan for and adapt water systems and other infrastructure including Boston, London, Halifax (Canada), New York, Seattle and Toronto (Rosenzweig et al., 2011). But developing such measures is not commonplace and such measures do not necessarily lead to appropriate action.

Supply-side approaches to water shortages such as increasing reservoirs are frequently advocated. To expand its reservoir capacity, Rotterdam developed plans that combine the goals of adaptation and urban renewal (van der Brugge and de Graaf 2010). Floods in 1998 exposed the inadequacies of existing water infrastructure, particularly in the context of climate change, and municipal water authorities committed to expand retention capacity by mixing economic activities with water-based adaptive designs, including ‘water retention squares’ and green roofs; floating houses; and networks of channels. An analysis of 21 draft Water Resources Management Plans in the UK found that agencies usually favoured reservoirs and other supply-side measures to adapt to climate change (Charlton and Arnell 2011). The authors suggest that additional demand-side interventions may be needed to cope with reductions in water availability. Although based upon draft plans from 2008 rather than implemented strategies, the study indicates some key trade-offs and portfolio of responses currently under consideration.

Seattle has utilised demand-side strategies to curtail water consumption including aggressive conservation measures, system savings and price increases linked to consumption levels (Vano et al. 2010). A simulation exercise suggested the system can withstand climate change-induced alterations in reservoir inflows, and the authors note that the “primary reason” for such robustness is the successful reductions in demand (ibid. p. 283).

In Mexico City, government programmes on climate change have suggested actions regarding the water sector although some of these have been proposed but not acted on many times since the 1950s, including measures to decrease water use and the restoration and management of urban and rural micro-basins (Romero-Lankao 2010). Since these programmes prioritize mitigation over adaptation, adaptation measures for the water sector have been conceived as too general and with a lack of institutional commitment. In Durban, the importance of getting climate change adaptation within the water sector was recognized as a priority – and the water sector is influential within the city government because of its importance in delivering development benefits and also it is revenue-earning, well-resourced and retains skilled staff (Roberts 2010). The water sector has also shown an interest in developing its municipal adaptation programme (ibid).

Cape Town has utilised water restrictions and tariffs, although it faces profound challenges in ensuring future supplies (Mukheibir and Ziervogel 2009). The city has responded by commissioning water management studies, which identified the need to consider stresses including climate change as well as effects of population and economic growth (*ibid.*). During the 2005 drought, the local authority substantially increased water tariffs, and such tariff mechanisms may represent "one of the most effective ways" to promote efficient water usage (Mukheibir 2008: 1271). Additional measures may include water restrictions; reuse of grey water; consumer education; or technological solutions such as low-flow systems or dual flush toilets (*ibid:*1271-2).

Research in Phoenix, Arizona, has sought to improve water forecasting data and inform adaptation interventions (Gober et al. 2010). The rapidly-expanding desert city is projected to reach 11 million people by 2050, with most growth in peripheral areas that depend on groundwater (Bolin et al. 2010: 261). Simulations explored how water usage may be reduced to achieve safe yield while accommodating future growth (ibid). Reducing the current high per capita water use may be achieved through urban densification, increased water prices and water conservation measures (ibid.: 277). Gober et al 2010 agreed that stringent demand and supply policies can forestall "even the worst climate conditions and accommodate future population growth, but would require dramatic changes to the Phoenix water supply system" (ibid: 370).

Quito's local government has formulated a range of adaptation plans to address water shortages (Hardoy and Pandiella 2009). Quito is projected to experience reduced freshwater supplies as a result of glacier retreat and other impacts of climate change. Among the municipality's responses are developing dams; encouraging a culture of rational water use; reducing water losses; and developing mechanisms to reduce water conflicts (ibid.). However, Quito has not sought to incorporate community participation in planning and implementation (ibid.). Participatory water planning has occurred elsewhere in Latin America: stakeholders in Hermosillo, Mexico, identified and prioritized specific adaptations such as rainwater harvesting and water-saving technologies (Eakin et al. 2007).

Several cities are considering the potential of rainwater harvesting to enhance water supplies, particularly in low-income areas, but scaling-up may be a challenge. In Sydney, new houses are required under a 2004 law to save 40% of reticulated water for use in gardens and toilets and subsidies were available to install household roof tanks (Warner 2009: 235). Many low-income Caribbean households rely on rainwater collection systems for domestic use, yet upper-income groups in Barbados have voiced resistance to the practice (Cashman et al. 2010: 60). Extending the existing communal collection and distribution systems would require community financing or governmental interventions, as well as overcoming such resistance *(ibid.)*.

Water and energy sectors are frequently linked and problems may ensue if they are considered separately, such as utilizing water from distant, low-quality sources that require high levels of energy for conveyance or treatment. Adaptation in the water sector will requiring identifying such trade-offs, as well as working with multi-partner networks, adopting low-regret anticipatory solutions. Water adaptation planning will need to be developed in concert with green infrastructure strategies. Integrated strategies can minimize possible conflicts between water-intensive parks or gardens, support local industries, and ensure equitable access to water in cities confronting Climate Change.

8.3.3.4.2. Waste and storm water management

Most of the above adaptations are to help ensure sufficient water supplies. Less attention has been given to the adaptations needed to adapt sewer and drainage systems. In St. Maarten, Netherlands Antilles, the government initiated a storm water modelling study and is developing a flood warning system (Vojinovic and Van Teeffelen 2007). Other options under consideration include institutional adaptations such as a new decision-support framework, centralised GIS to enhance all infrastructure planning measures, and public education, alongside structural measures each (improving the channel network and draining of areas with a high groundwater table (ibid)).

City management in Toronto, Canada has prioritised an upgrade of storm water and wastewater systems to circumvent the direct and indirect stresses from climate change (Kessler 2011). Deak and Bucht (2011) analyse past hydrological structures in the city of Lund, Sweden and use the concept of indigenous blue infrastructure to raise questions concerning current storm water management of the urban core.

Cities in California have a range of flood management methods but will need to augment these with forward-looking reservoir operation planning and floodplain mapping, less restrictive rules for raising local funds, and improved public information on flood risks (Hanak and Lund 2012).

The linkages between provisions for water, sanitation and drainage and other sectors means that water adaptation plans will need to work with a range of partners, consider broader development goals, and identify tensions or trade-offs. The urban water and energy sectors are frequently linked (by processes such as pumping) and problems may ensue if they are considered separately, such as utilizing water from distant, low-quality sources that require high levels of energy for conveyance or treatment. Adaptation in the water sector will requiring identifying such trade-offs, as well as working with multi-partner networks, adopting low-regret anticipatory solutions. Water adaptation planning will need to be developed in concert with green infrastructure strategies. Integrated strategies can minimize possible conflicts between water-intensive parks or gardens, support local industries, and ensure equitable access to water in cities confronting climate change.

8.3.3.5. Electricity and Other Energy Sources

Section 8.2.4.2 discussed the heavy dependence of urban economies' infrastructure and residents on power supplies and the far-reaching consequences of unreliable supplies. It also noted the greater focus on mitigation in discussions on urban energy policy. In part, this is because key issues relating to adaptation for electricity generation and distribution systems and for the rest of the energy sector are usually national or regional and are discussed in Chapter 10.

The interrelations between energy and other sectors suggests the need for an integrated approach in understanding vulnerability, energy poverty and shaping appropriate responses (Gasper et al. 2011). One issue of relevance to urban households, businesses and institutions is the extent to which will need to pay for autonomous provision or back-up generating capacity, if grid supplies become unreliable. This represents a high additional cost and less efficient electricity production.

There is also the adaptation agenda needed for the industries related to the supply of other fuels. For instance, in the State of Veracruz, Gulf of Mexico, cities such as Coatzacoalcos and Minatitlan are surrounded by oil, gas and petrochemical plants and that can be affected by the impact of weather-related events. Even though there is a growing concern about the potential impact that climate change and extreme weather events will have in the oil industry in Canada, US and Mexico and how floods and the sea level rise will disrupt oil, gas and petrochemical installations, few climate change adaptation studies on this theme have been undertaken. Huang (2008) explores the differential impact climate change will have on the various petroleum sector activities: exploration, production processing, transportation and storage and states that adaptation measures.There are also important potential co-benefits between mitigation and reduced air pollution from thermal power stations, motorized transport and other industries.

The role of distributed urban energy production as related to adaptation and mitigation also needs to be assessed. With the energy literature overshadowed by mitigation concerns, "relatively few assessments in the energy sector focus on adaptation issues" (Mdluli and Vogel 2010: 206) and "research on the impacts of climate change on the energy sector has been surprisingly scant" (Mideksa and Kallbekken 2010: 3580). The UNFCCC did not estimate the costs of adapting the energy sector (Fankhauser 2009), and research has suggested that "private autonomous measures will dominate the adaptation response as people adjust their buildings, [or] change space-cooling and -heating preferences...” (ibid., 27).

8.3.3.6. Adapting Transport and Telecommunications

Adapting transport and telecommunications systems to climate change poses many challenges. Urban centres depend on road and often rail, air and waterway transport systems for daily functioning – including the movement in and out of the city by commuters and consumers and daily deliveries. Many cities depend on underground electric traction rail systems which may be at considerable risk from flooding

The development of reliable low-cost transport has also increased the dependence of prosperous cities and businesses on regional, national and international supply chains; for instance, 80 percent of the food consumed in London is imported (Bioregional and London Sustainable Development Commission 2010). Most large and successful cities have also spread spatially with the expansion of transport systems supporting a decentralization of the workforce and businesses, most of which depend on a well-functioning transport system. The importance of adapting transport infrastructure to climate change is highlighted by the 60,000 jobs and US$ 3 billion worth annual movement of goods in the Great Lakes–St. Lawrence route in the USA (Ruth 2010). This includes a need to adapt to lower water levels. The study also notes the scale of indirect and direct job losses that could result from decreased connectivity of the shipping network (Ruth 2010).

Transport systems: Cities that have developed climate change adaptation plans usually include attention to making transport systems more resilient to climate change (UN Habitat 2011). Melbourne’s adaptation plan notes that intense storms and wind may lead to blocked roads and disrupted traffic lights, trains, and trams (Melbourne 2009: 60) and how the extent of the disruption may be “further exacerbated by any additional compounding factors such as large-scale events, power disruptions or emergency situations, such as multiple deaths or injuries” *(ibid.)*.

Adaptation will require transport planners to account for climate uncertainties, utilise a whole-of-life approach to managing infrastructure, and constantly update risk assessments (Love et al. 2010: 144). An interdisciplinary approach can incorporate not only changing meteorological hazards but also consider the social and political values and governance framework that can shape more resilient transportation systems (Jaroszweski et al. 2010).

Adapting roads: Climate change may increase the costs of maintaining and repairing road transport networks e.g. for a discussion of this for Chicago due to rising average temperatures and more severe rainfall Hayhoe et al. 2010). To adapt road networks, transport planners are beginning to reassess maintenance costs and traditional materials – for instance stiffer bituminous binding materials to help cope with rising temperatures, but softer bitumen may be appropriate in colder regions (Regmi and Hanaoka 2011: 28). However, current cost considerations may impede their use. The Chicago Department of Transportation decided not to use more permeable, adaptive road materials instead of asphalt and concrete because of higher cost, although it recognised costs may fall with greater economies of scale as demand rises for such materials (Hayhoe *et al*. 2010: 104).

Road maintenance costs vary widely, depending upon the season, local context, and future climate scenarios. In Hamilton, New Zealand, changes in rainfall were projected to increase repair costs in spring and winter, but reduced rainfall in spring and autumn partly balanced out the cost; results depend upon the scenario and further investigation was recommended (Jollands et al. 2007).

Adapting surface and underground railways: Underground transport systems are specific to urban areas and may have “particular vulnerabilities related to extreme events, with uniquely fashioned adaptation responses” (Hunt and Watkiss 2011: 14). Heat impacts are often significant in underground railways, as these systems may be gradually warming due to engine heat, braking systems, and increased passenger loads (Love, Soares, and Püempel 2010). To cope with increasing frequency of hot days due to climate change, “substantial investment” in ventilation or cooling may be necessary (ibid.). Some of New York City’s subways are located in coastal or river floodplains, and the system’s age, fragmented ownership, and current overcapacity may augment the challenge of adaptation

(Zimmerman and Faris 2010: 69-70). Pumps have been installed throughout the subway system and these helped to cope with severe floods in August 2007 during the morning commute (ibid.).

Rail systems that have struggled to cope with existing climate variability may need considerable investment to withstand changes in extreme events and higher temperatures. Railway systems may also be more vulnerable to climate variability and change than the road system, as the latter can more easily redirect traffic during extreme weather events (Lindgren et al. 2009). The costs of delays and lost trips due to extreme weather events were analysed in Boston (Kirshen et al. 2008) and Portland (Chang et al. 2010) and were found to be small relative to the damages upon infrastructure and other property. Portland's nuisance flooding is still likely to increase, although floodplain restoration, use of porous pavements, or detention ponds may all help address this (ibid).

In flood-prone cities, more stringent construction standards, design parameters, or relocation may be needed to adapt transport systems. In Durban, "it may be necessary to revise road construction standards and avoid routes at high risk of flooding" (Roberts 2008a: 531). Coastal road adaptation may require strengthening barriers, increasing design parameters to cope with sea-level rise, or realigning existing roads to a higher location (Regmi and Hanaoka 2011). Much of central Mumbai is built on landfill (as the area was originally seven islands); the landfill areas are prone to flooding, but they contain the main train stations and train lines as well as large populations and a large part of the city's economy (de Sherbinin et al. 2007). Rising sea levels may cause shifts at the sub-surface level of landfill areas and structural instabilities (ibid., 49-50).

Informal settlements frequently lack all weather roads and pathways within the settlement and connection to the wider road system for emergency vehicle access and rapid evacuation. For instance, informal settlements in Chittagong have extremely narrow roads so that " ambulance and fire services cannot enter most of these neighbourhoods, thus exacerbating the existing health and fire risks at household level" (Rahman et al.,2010: 572). Roads in Lagos's informal settlements are often poorly maintained and lack all-weather surfaces, so that a 2006 resident survey ranked roads second to drainage in terms of needed facilities (Adelekan 2010). Evacuations in low-income areas may also be hampered by hazardous locations, prevailing insecurity, and inadequate governance and infrastructure. Following the 2003 and 2006 floods in Santa Fe, Argentina, the lack of information and official evacuation mechanisms prevented a timely response while some low-income residents chose to stay in their homes in order to protect these and their possessions from looters (Hardoy and Pandiella 2009).

Low-income residents can also be profoundly affected by transport disruptions during and after extreme weather events, which can damage critical public transit links, prevent access to work, and heighten exposure to health risks. Interviews in Georgetown, Guyana, found that poorer households mainly rely on public transport and their limited transport access during floods made them more likely to lose time from work or school, as compared to wealthier households (Linnekamp et al. 2011). Better-off households were more likely to possess their own vehicles, while poorer households rarely owned cars, waded through floodwaters in bare feet, and were thereby exposed to waterborne pathogens (*ibid.*). Past studies have also suggested that urban women are more likely than men to walk or utilise public transport (World Bank 2010a), so that the gendered impacts of transport disruptions may merit greater consideration.

Telecommunications: Section 8.2.2.2 noted how key elements in cities' communications systems may be at risk from climate change impacts – so they may need to be strengthened to avoid toppling due to strong winds and electrical support facilities may need to be moved or protected against flooding (see Zimmerman and Faris 2010: 74).

8.3.3.7. Green Infrastructure and Ecosystem Services within Urban Adaptation

'Green infrastructure' denotes ecological features, ranging from wetlands to forests , that provide critical services to urban areas such as purifying water, cleansing air, and moderating climate (Newman 2010). The recognition of the dependence of urban areas on productive and protective ecosystem services has led to considerations of their role in climate change adaptation – and the use of green infrastructure. This includes ecosystem based adaptation that uses opportunities for the management, conservation and restoration of ecosystems to provide needed services and increase resilience. Box 8-1 gives an example of how ecosystem based adaptation is being developed in Durban.

_____ START BOX 8-1 HERE _____

Box 8-1. Ecosystem-based Adaptation in Durban

In Durban, ecosystem based adaptation is part of its climate change adaptation strategy. This seeks to move beyond a focus on street trees and parks to a more detailed understanding of the ecology of indigenous ecosystems. From this can be identified the ways in which biodiversity and ecosystem services can help reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Strategies to achieve biodiversity goals such as developing corridors to facilitate species migration, enlarging core conservation areas and identifying areas for improved matrix management to enhance ecological viability of these core areas can also have adaptation co-benefits. There is also a recognition that the adaptation deficit is both in the lack of conventional infrastructure and the loss of green infrastructure (wetlands, forests, grasslands, soil). It includes an interest in how ecosystem restoration and conservation can contribute to food security, urban development, water purification, waste water treatment climate change adaptation and mitigation.

The development of ecosystem based adaptation in Durban requires a series of steps that include:

1) A better understanding of the impacts of climate change on local biodiversity and how to manage Durban's open space system of 75,000 hectares. The projected warmer and wetter conditions seem to favour invasive and woody plant species.
2) A local research capacity that includes generating needed local data
3) Reducing the vulnerability of indigenous ecosystems as a short term precautionary measure
4) Enhancing protected areas already owned by local government and developing land-use management interventions and agreements with landowners to protect privately-owned land areas critical to biodiversity and ecosystem services.

This needs government incentives and regulation to stop development on environmentally sensitive properties, the removal of perverse incentives and support for landowners affected by this.
5: The promotion of local initiatives that contribute jobs, promote business and life skills development and environmental education with ecosystem management and restoration programmes. Durban has initiated a large scale Community Reforestation Programme where community level 'tree-preneurs' produce indigenous seedlings and are involved in the planting and managing of the restored forest areas. This is part of a larger strategy to enhance biodiversity refuges and water quality, river flow regulation, flood mitigation, sediment controland improved visual amenity. Local level advantages include employment creation and improved food security and educational opportunities.

Source: Roberts et al. (2012).

_____ END BOX 8-1 HERE _____

Green infrastructure refers to interventions that seek to preserve the functionality of existing green landscapes as well as transforming the built environment through the use of photo-remediation techniques and by introducing productive landscapes (La Greca et al. 2011, Zhang, Jeng and Sui 2011). Much of the early innovation in green infrastructure was in response to the need for cost effective and sustainable mechanisms for addressing water shortages or flooding and not directly linked to climate change adaptation. Case studies of green infrastructure aim to measure the impact and assess the potential of urban planning and environmental conservation policies, to create cityscapes that can adapt to a changing climate. One example of this is addressing flood risk through catchment management that includes community-based partnerships supported by full cost accounting and payment for ecosystem services – rather than the more conventional canalisation of rivers (Kithiia and Lyth 2011, Roberts et al. 2012).

Green spaces in cities are considered beneficial for absorbing rainfall and moderating temperatures (Wilson et al. 2011, Oliveira, Andrade and Vaz 2011); also in the reduction of atmospheric particulate pollution (Tallis et al 2011). However, dedicated green areas within urban environments compete for space with other city-based needs and developer priorities. The role of strategic urban planning in mediating among competing demands for land use is highlighted as potentially useful for the governance of adaptation as presented in planning forerunners London, Toronto, and Rotterdam (Wilson et al. 2011).

Some cities have made investments in green infrastructure, linked both to regeneration and to climate change adaptation. For instance, the Green Grid for East London seeks to create "a network of interlinked, multi-purpose open spaces in east London to support the wider regeneration of the sub-region. The Green Grid is being delivered to enhance the potential of existing and new green spaces to connect people and places, to absorb and store water, to cool the vicinity, and to provide a diverse mosaic of habitats for wildlife (GLA, 2010). New York has a well-established programme to protect and enhance its water supply through watershed protection. This includes city ownership of land that allows crucial natural areas to remain undeveloped and work with land owners and communities to balance protecting drinking water quality with and facilitating local economic development and improving waste water treatment. The city government suggests that while the Watershed Protection Program is costly, compared to the costs of constructing and operating a filtration plant, as well as the environmental impacts of the additional energy and chemicals required by filtration, it is the most cost-effective choice for New York." (New York date: 81).

The coastal city of QuyNhon in Vietnam is seeking to reduce flood risks by restoring a 150 hectare zone of mangroves (Brown et al. 2012). Singapore has used several anticipatory plans and projects to enhance green infrastructure including its Streetscape Greenery Master Plan, constructed wetlands or drains and community gardens (Newman 2010). Authorities in England and the Netherlands are recognising the linkages between spatial planning and biodiversity, though "there is less evidence of direct response to the needs of climate change adaptation" (Wilson and Piper 2008: 143). Barriers to action included short-term planning horizons, uncertainty of climate change impacts, and problems of creating habitats due to inadequate resources, ecological challenges, or limited authority and data (ibid., 145).

In Mombasa, the Bamburi Cement Company has rehabilitated 220 hectares of quarry land now known as Haller Park (Kithiia and Lyth 2011: 258). The park currently attracts over 150,000 visitors per year, with "the potential to create adaptation co-benefits despite this not being the original intent" (ibid., 260). Cape Town has initiated community partnerships to conserve biodiversity, including the Cape Flats Nature project with the para-statal South African National Biodiversity Institute (Ernstson *et al*. 2010: 539). The participating schools and local organisations explore ecosystem services (such as flood mitigation and wetland restoration), and the project facilitates "champion forums" to support conservation efforts *(ibid.)*.

The experience in Durban discussed in Box 8-1 also faces many challenges (Roberts et al. 2012). These include an assumption that ecosystem based adaptation is an easy answer to the technological, financial, institutional and skill constraints that limit the implementation and effectiveness of "hard engineering" solutions" (Kithiia and Lyth, 2011:252). Experience in Durban shows that implementing an ecologically functional and well-managed, diverse network of bio-infrastructure needs knowledge, new data collection, expertise and resources. It needs to have direct and immediate developmental co-benefits for local communities and ensure integration across institutional and political boundaries. Substantial knowledge gaps need to be addressed, such as the need to determine where the limits or thresholds lie; many ecosystems have been degraded to the point where their capacity to provide useful services may be drastically reduced." (TEEB 2010b: 7). Burley et al's (2011) review of the wetlands of South East Queensland, Australia indicates that adaptations focused on wetland and biodiversity conservation may impact urban form in coastal areas. A study of the change in tree species composition, diversity and distribution across old and newly established urban parks in Bangalore, India aims to find ways to increase ecological benefits from these biodiversity hotspots (Nagendra and Gopal 2011).

A new methodology seeks to evaluate the impacts on local climate of current land uses and proposed planning policies (Schwarz, Bauer and Haase 2011). In a case study of Leipzig, green areas and water surfaces had cooling effects, as expected but several policies were found to increase local temperatures.

It is generally accepted that mitigating climate change will require a dense urban form but favouring green infrastructure requires provision of open space for storm water management, species migration, and urban cooling (Hamin and Garrun, 2009:242). This suggests that there is a "density conundrum" in that higher densities can prevent the maintenance of ecologically viable and biodiverse systems and exacerbate the urban heat island which in turn generates the need for more cooling and increases energy use, thereby further escalating the urban heat island effect. Mitigating climate change requires a dense urban form (to maximize economies of scale in more efficient resource use and waste reduction, reduce urban expansion, reduce need for motorized transport and reduce building energy use). Adaptation requires an urban form that favours green infrastructure including open space for storm water management, species migration, and urban cooling (Hamin and Garrun 2009, Heleen-Lydeke et al. 2011). But at which point will densities be too high to maintain ecologically viable and biodiverse systems, especially given that urbanization has already compromised the ability of ecosystems to buffer urban development from hazards? This situation will be further exacerbated by the new hazards (e.g. floods, fires) to which systems are and will be exposed as the result of climate change (Depietri et al. 2012:95).

Green and white roofs: Green and white roofs have been introduced in a range of cities, with the potential to create synergies between mitigation and adaptation. Rooftop vegetation helps decrease solar heat gain (reducing the cooling demand and emissions from air conditioning) while cooling the air above the building (Gill *et al*. 2007). They can also retain water during storms, promote local biodiversity and food production (adaptation) while increasing energy efficiency of buildings (mitigation) (Heleen-Lydeke et al. 2011). Durban has a pilot green roof project on a municipal building; indigenous plants are also being identified for the project and rooftop food production is being investigated (Roberts 2010: 411). New York's lack of space for street-level planting helped encourage the adoption of living roofs, which can provide additional area for cooling vegetation (Corburn 2009). Under its Skyrise Greenery project, Singapore has provided subsidies and handbooks for rooftop and wall greening initiatives (Newman 2010).

Green roofs can employ extensive greening (grass) or intensive greening (shrubs) techniques. The cooling effect of extensive and intensive green roofs can work in multiple ways – by harnessing solar radiation, it improves the energy performance of buildings (Parizotto and Lamberts 2012) and contributes to mitigation of urban heat island effect (Zinzi and Agnoli 2011, Jo et al. 2010). Further climate change adaptation benefits from green roofs for the built and urban environment include reduction in storm water run-off generation (see studies conducted by Palla et al 2011, Schroll et al 2011, Voyde et al. 2010). Studies which measure the thermal and hydrological responses of green roofs have compared the performance of living roofs across different plant cover types, levels of soil water, and climatic conditions (see e. g. Jim 2011, Simmons et al. 2008). Hodo-Abalo et al. (2012) confirmed that a dense foliage green roof has a greater cooling effect on buildings in Togolese hot-humid climate conditions. Several field experiments combined with simulated modelling of impacts in the US also confirmed the positive thermal behaviour of green roofs when compared to alternative roof coverings (for example Getter et al. (2011) compared green roofs with a traditional gravel inverted roof, Scherba et al. (2011) compared the heat flux into the urban environment of vegetated roofs, white roofs and black membrane roofs, with PV panels elevated above various roofs, Susca et al. (2010) compared black, green and white roofs, in four areas of New York City and assessed the positive effects of vegetation at both urban and building level.

Based on field tests in the UK, Castleton et al. (2010) suggests that older buildings with poor existing insulation stand to benefit most from green roofs compared to newer structures built to higher insulation standards. Wilkinson and Reed (2009) suggest that the physical property of buildings in city centres causes significant overshadowing, which may mean lower potential for green roof retrofits when compared to installations in suburban areas and smaller towns with lower rise buildings. Benvenuti et al. (2010) highlight the availability of water as the most limiting factor in the realisation of green roofs.

However, a recent meta-analysis suggests that green roofs and parks may have limited effects on cooling (Bowler *et al*. 2010). Findings on green roofs were "mixed, with some evidence of lower air temperatures above green sections in some studies, but not in others" (ibid., 153). Additionally, an urban park was found to be "around 1 ◦C cooler than a non-green site" (ibid.) and larger parks had a greater cooling effect. Yet studies were mainly observational, lacking rigorous experimental designs, and "it is not clear if there is a minimum size threshold or if there is a simple linear relationship" between the park's size and cooling impact (ibid.). While different types of vegetation have stronger effects, the analysis could not demonstrate "exactly how green infrastructure should be designed in terms of the abundance, type, and distribution of greening" *(ibid)*

Cool roofs or white reflective roofs use bright surfaces to reflect short-wave solar radiation, which lowers the surface temperature of buildings compared to conventional (black) roofs with bituminous membrane (Saber et al 2012). Quantification of the cooling benefits from white roofs in various urban settings has been undertaken - for instance the study in Hyderabad Xu et al. 2012), comparison of white and black roofs in the North American climate by (Saber et al. 2012) and a Sicilian case study by (Romeo and Xinzi 2011)). Comparisons between green and white roofs have been undertaken in various climatic zones: Ismail et al. (2011) investigated their cooling potential on a single-storey building in Malaysia and Zinzi and Agnoli (2011) explored the comparative applicability of the two roof treatments in a Mediterranean climate. Results suggest that local conditions play a dominant role in determining which treatment is best for improving internal conditions as well as moderating the urban heat-island phenomenon. For instance, Hamdan et al. (2011) found a layer of clay on top of the roof as the most efficient for passive cooling purposes in the Jordanian climate, compared to two different types of reflective roofs.

8.3.3.8. Adapting Public Services and Other Public Responses

It will fall to the public services network and public policy to ensure that climate change adaptation addressed the needs of those most at risk and most vulnerable. Many aspects of this have already been covered – for instance ensuring adequate provision for water, sanitation, drainage and solid waste collection and provision for rapid response to disasters. Health care services and emergency services (including ambulance, police and fire fighting) are likely to have their workload increased while also needing to ensure that their systems can themselves adapt. They also need good working relationships with other key government sectors and with civil protection services – including the armed forces and Red Cross and Red Crescent societies.

As city risk and vulnerability assessments become more common and detailed, these provide a basis for assessing how public policies and services need to change and adapt – for instance, the levels of risk exposure of key health care facilities from flooding. Availability of data on and the personnel to reach vulnerable urban populations with effective responses e.g. protecting groups particularly vulnerable to heat waves which will be challenging in many cities. There is little evidence of consideration being given to needed changes in public services in response to climate change e.g. the risk of fires is likely to increase in and around many urban centres because of increased drought and rising temperatures.

Enhanced emergency medical services may help cope with extreme events while health officials can also improve surveillance, forecast the health risks and benefits of adaptation strategies, and support public education campaigns. Public health systems may need to increase attention to disease vector control (e.g. screening windows, eliminating breeding grounds for the mosquitoes that are vectors for malaria and dengue) and bolster food hygiene measures linking to increased flooding and temperatures.

The costs of adapting health care systems may be considerable – for instance comprehensive surveillance and monitoring systems, regional centres and programs, and modelling software that can capture the health risks of Climate Change.

Risk and vulnerability assessments also need to look at the complete range of schools and daycare centres to assess their vulnerability to climate change. School buildings can be designed and built to serve as safe centres during floods or storms to which those at risk can move temporarily – although it is also important after a disaster to quickly re-establish functioning schools both for the benefits for children and for their parents (Bartlett 2008).

For cities without a robust emergency response network, adapting to Climate Change may require significant improvements in staffing, resources, and preparedness plans. This will include particular attention to providing emergency services in informal settlements lacking adequate roads or infrastructure.

Section 8.2.3.6 noted how the burden of allergies and asthma will rise where existing urban air pollution is exacerbated by climate change. A range of adaptation strategies have recently been identified, including monitoring aeroallergens; improving access to health care and asthma medications; and revised planting practices or urban planning strategies (Beggs 2010). However, additional research is still needed to understand the complex links between weather and pollutants in the context of climate change (Harlan and Ruddell 2011). Furthermore, important synergies can be achieved through combining mitigation and adaptation strategies to improve air quality, reduce private transport, and promote healthier lifestyles (*ibid.,* also Bloomberg and Aggarwala 2008).

8.4. Urban Planning, Management, and Governance

This section discusses what we have learnt about introducing adaptation strategies into the core of urban government investment and management with a buy-in from key sectors and directorates within local government and support from non-state actors. This includes experiences with integrating development, disaster risk reduction and climate change adaptation. It includes consideration of household and community based adaptation and of where local processes are or can be supported by higher levels of government and for low- and middle-income nations, by international agencies.

Much of what is needed for effective urban adaptation falls within the responsibilities of municipal governments. Many aspects of adaptation can only implemented at the urban level through what local governments do, encourage, allow, support and control. This requires support from regional (sub-national) and national institutions and policies, suggesting that urban adaptation will necessarily be nested and policy-centric, with overlapping responsibilities and authority operating across relevant sectors and themes (Ostrom 2009, Dietz et al., 2003)

Approaches to adaptation include new urban policies and incentives for action but also measures to “climate proof” or audit existing policies to ensure that they do not lead to greater vulnerability and risk (Urwin and Jordan 2008). Capacity constraints, including limited technical expertise and ill-designed institutional mechanisms, will limit the ability of local authorities to work more effectively with other local, regional and national authorities on the adaptation agenda. Similarly, many national governments still do not recognize the importance of local governments in climate change adaptation (OECD 2010a).

8.4.1. Urban Governance and Enabling Frameworks, Conditions, and Tools for Learning

Enabling conditions and frameworks to support urban adaptation are grounded in local-national institutional structures and local competences and interests. Key dimensions of adaptation include awareness, analytical capacity (e.g. vulnerability assessment and assessment of policy options) and action (Moser and Luers 2008). Each dimension presents a different set of challenges and requires specific types of capacity and enabling conditions at city level.

As stressed in 8.1, the context for adaptation decisions will inevitably vary by country and location but preconditions for sound urban decision-making and accumulated resilience can be generalised from the literature and experience to date. These relate to principles of good urban government (what government does) and governance (how they work with other institutions and actors including the private sector and civil society). These generally include science-policy deliberative practice and vulnerability assessment to support adaptation (Adger et al. 2009, NRC 2007, 2008, 2009, Renn 2008, Moser 2009, Corfee-Morlot et al. 2011). Civil society -- including non-governmental and community-based organizations -- has an important role in good urban governance and environmental management including community risk assessment and contribution to adaptation, incorporation of local knowledge and understanding local preferences and norms (e.g. Krishnamurthy et al. 2011, Fazey et al. 2010, Shaw et al. 2009, Tompkins et al. 2008, Van Aalst et al. 2008). It is important to note that human behaviour and social norms are not static but that these evolve through dialogue and understanding (Moser 2006, Dietz et al.2003, Ostrom 2009). Furthermore, the capacity to act at urban levels varies with organisational form and problem complexity (Habermas 98, Corfee-Morlot et al. 2011), which in turn relates to levels of development and the context for development (Bicknell et al. 2009).

Section 8.3 made clear how building local adaptation capacity also means enabling disaster risk reduction to limit vulnerability to current and future hazards such as floods, water shortage or heatwaves (e.g. Satterthwaite et al. 2009, Schipper and Pelling 2006, UNISDR 2008). It includes the capacity to address the physical drivers of vulnerability, such as through upgrading and implementing infrastructure standards and zoning laws, urban planning or early warning systems as well as through better education or information provision (Adger et al. 2007, 2009). The high vulnerability of often-large numbers of the urban poor to extreme weather events and their limited adaptive capacity makes the design and implementation of anticipatory adaptation action, including disaster risk management a key function of urban policy.

8.4.1.1. Multi-Level Governance and the Unique Role of Urban Governance and Governments

A framework for urban governance emerges from the challenges climate change brings to multilevel risk governance. In this framework, urban governments are one of the central players with authority for relevant policy decisions but they often lack scientific information and expertise essential to understanding the nature of the problem (see Figure 8-1; Corfee-Morlot et al. 2011). “Semi-autonomous” institutions such as local water authorities or insurance regulators (in the “inner circle”) have importance although these may be operating at a larger, regional level. Ideally there is also engagement of other local stakeholders such as businesses, communities and expert advisors in adaptation decisions, referred to here as part of the “outer circle”. Media and other forms of civil-social infrastructure act as filters of substantive knowledge and help to join expert information with local knowledge to build understanding and engagement on climate change (Carvalho and Burgess 2005; Leiserowitz 2006). Good practice hinges in part upon the credibility, legitimacy and salience of science-policy and other interactions with expert advisors (Cash 2001, Cash et al. 2006, NRC 2007, Preston et al. 2011). Communication efforts are also essential (Moser and Dilling 2006, Moser and Luers 2008, Moser 2006). Good governance depends in part on how well policy and decision processes mediate across these different actors, spheres of influence, sources of information and resources to co-produce knowledge, support learning and action over time.

[INSERT FIGURE 8-1 HERE
Figure 8-1: Circulation of power for public decision-making on climate change. Source: adapted from Corfee-Morlot, Cochran, Teasdale, and Hallegatte (2011).]

From an institutional and policy perspective, urban governments have some authority in relevant domains for adaptation decisions but many of their decisions will be enabled, bounded or constrained by national or sub-national regional policies, land use and infrastructure planning decisions (ARUP/ C40 report, OECD 2010). In addition, it may be ineffective for a single urban government to act in isolation of neighbouring governments e.g. to implement flood protection of contiguous land areas or evacuation planning in the event of a disaster.

8.4.1.2. Aligning Policies across Vertical and Horizontal Governance Processes

Adaptive capacity in cities depends upon the alignment of policies and incentives such that they work coherently across multiple levels of government to deliver effective urban adaptation (Corfee-Morlot et al. 2011, Mukheibir and Ziervogel 2007, Urwin and Jordan 2008, Cash et al. 2006, Young 2002, Bulkele and Kern 2006, Kern and Gotelind 2009). In many instances national institutions may have the direct authority for key decisions or overlapping jurisdictional authority in relevant urban adaptation sectors (e.g. coastal zone management, buildings and water sector). There is therefore a need to audit (pre)existing policies and screen new policies across levels of government to ensure the consistent integration of climate change risk and vulnerability considerations. Failing to do so can lead to mal-adaptation even where pro-active adaptation policies exist. For example, if long-standing sector policies do not take climate change into account, business-as-usual development trends will continue to lock-in outcomes that raise the vulnerability of urban populations, infrastructure and natural systems to climate change (OECD 2009, Urwin, Jordan 2008). Some of the relevant institutions for adaptation (e.g. water authorities) are nested in that they represent both national and local interests but may operate independently of urban authorities. Thus raising urban adaptive capacity requires institutions that facilitate coordination across multiple, nested and poly-centric authorities that make decisions to address urban vulnerability and which have potential to mainstream adaptation measures.

Opportunities for accelerating learning and action may stem from horizontal coordination and networking across actors and institutions in different municipalities and wider metropolitan areas – many of which will face similar challenges (Lowe et al., 2009, Aall et al., 2007, Schroeder and Bulkeley 2008). Local contexts and implementation agendas also underscore the need for tailoring of national goals and policies to local circumstances and preferences. Consultation and awareness raising is essential to avoid the kind of public backlash in response to the French government's attempt to ban urban development and strategic retreat in areas of current and increasing risk to coastal flooding following the storm Xynthia in 2010 (Laurent 2010). This points to another key challenge for urban adaptation, which is to address vested interests and trade-offs, where near-term development may appear to conflict with longer-term adaptation and resilience goals.

8.4.1.3. Unique Role of Urban Governments

Although adaptation requires coherence across multiple levels of government, there are many tasks that require local governments since these are uniquely situated to understand local contexts, raise awareness, respond to citizens and civil society pressures, strengthen planning and build capacity to take actions in some areas. Notably, they can work closely with local stakeholders through an analytic-deliberative process to build a "policy space" (Brunner 1996, Brunner et al. 2005, Cash and Moser 2000, Grindle and Thomas 1991, Healy 1997). Within this, it is possible to generate a good understanding of local contextual factors that will matter to decisions about how to manage climate change (Healy 1997, Ostrom 2009). Local governments can also raise awareness and promote understanding of climate change risk and drivers of vulnerability for adaptation and help to create a common vision for the future (Corfee-Morlot et al. 2011, Moser 2006, Moser and Dilling 2006, Ostrom 2009).

Local governments can also integrate climate change and disaster risk management and resilience into urban development decisions and urban land use planning. They can identify opportunities to integrate adaptation into territorial development planning and infrastructure investments even where funding comes from national or even international donor sources (Vigue and Hallegatte 2012, Hall et al. 2012). Urban governments are central to the interface between climate change and development, including the provisioning of essential services (water, sanitation, waste, shelter, mobility services as well as education and health services) (Bulkeley 2010; Bulkeley and Kern 2006) and they often operate an important share of urban infrastructure to provide these services through municipal operations (ARUP/C40 2012). Further the fact that preferences of actors tend to be more homogenous across smaller than larger units (Ostrom 2009) provides opportunities for leadership and flexibility to innovate that may not exist at higher levels of governance. Thus, some evidence suggests that urban governments may be unique in their ability to provide leadership, to innovate and to promote learning-by-doing (OECD 2010).

However, local government decisions are often driven by short-term priorities of economic growth and competitiveness (Carmin and Dodman 2012, Moser and Luers 2008). Addressing climate change requires taking a longer term perspective and reconciling this with near-term priorities (Leichencko 2011, Pelling 2010, Romero-Lankao and Quin 2011). There is also tension between urban governments focusing on economic growth and the large (and in many nations growing) numbers of the urban poor ill-served or unserved by the infrastructure and services on which resilience to climate change depends (Bicknell et al. 2009). This issue is exacerbated by inattention by international donors to local policy and development concerns, where they work almost uniquely with national governments. Thus while there is evidence of growing awareness and analytical capacity (i.e. in the form of adaptation planning) within many urban governments and governance processes, there is much less evidence of action in the form of implementation and influence on key sectors (Roberts 2010). This may be due to parallel processes where adaptation planning is done separately from urban and territorial development planning. This raises additional barriers to action, where an essential step is to integrate and mainstream adaptation plans and risk management into urban and development planning from local to national levels with a clear time frame, mandate and resources for implementation (Brugmann 2012, OECD 2008, Satterthwaite et al. 2009)

8.4.1.4. Mainstreaming Adaptation into Municipal Planning

The extent to which a consideration of climate change adaption by municipal governments is being mainstreamed into municipal planning systems and development investments has particular importance in the Global South where much of the risk from climate change comes from the inadequacies in provision for infrastructure and services and it makes little sense to introduce an additional layer of climate change planning to already complex (and often fragmented) planning systems (Kithiia 2010, Roberts 2008a).

Integrating climate change adaptation into municipal development planning faces significant challenges such as lack of information, institutional compartmentalization and fragmentation and resource constraints (Wilson, et al, 2011). The planning agenda is usually full in most authorities and it is hard to find institutional space for climate change adaptation (Measham et al. 2010: 4, 19). Climate change may also be seen merely as "add-ons to the overall strategies driven by economic and spatial concerns" (Kithiia and Dowling 2010: 474).

A solution would be to mainstream adaptation within municipal plans and regulatory frameworks so local level investments funds in development are planned "with adaptation needs in mind" (Lowe *et al,* 2009: 6). Integrating climate change adaptation in urban development could help planners rethink the traditional approach of designing infrastructure based on past weather patterns and changes in sea level and move towards a new approach of forward looking risk-based design for a range of future climate conditions (Kithiia 2010).

One way to mainstream adaptation within government agencies is to focus on how it protects economic development, promotes innovation, improves service delivery and builds a city's resilience to shocks. Other mainstreaming tools include encouraging pilot projects and sectoral rather than cross-sectoral adaptation action. A sectoral approach makes the climate message easier to understand by departmentalised local government agencies and the associated responsibilities and actions clearer and simpler to identify and assign (Roberts 2010, UN-Habitat 2011). Pilot projects root the (often vague) concept of adaptation in reality and allow a practical demonstration of gains (Roberts 2010, Tyler et al. 2010. Brown et al. 2012). Municipal authorities in India can see climate change adaptation as a priority if they see co-benefits between adaptation and measures to address development and environmental health concerns (Sharma and Tomar 2010).

For municipal authorities focused on mitigation, bringing potential mitigation-adaptation synergies to notice can help get their attention to adaptation. Local governments may be able to address both adaptation and mitigation using the same "policy levers" such as building standards, transport infrastructure, and other urban planning tools (Hallegate, Henriet and Corfee-Morlot 2011: 72). This can also avoid tradeoffs when designing policies for mitigation or adaptation and enhancing response capacity developing institutional links (Swart and Raes, 2007). A further challenge is to develop methods to evaluate emerging adaptation measures (Hedger et al. 2008, Preston et al. 2011).

Assessments of risk and vulnerability to climate change's direct and indirect impacts are often the first step in getting the attention of municipal governments, especially where these are assessed in the context of general development policy objectives. The approach is based on the application of a limited set of indicators, representatives of focal development policy objectives, and a stepwise approach to address climate change impacts, development linkages, and the economic, social and environmental dimensions (Halsnaes and Traerup 2009).

8.4.1.5. Engaging Stakeholders and Processes for Learning

The advantages of working at local levels that include building a "policy space" that links local stakeholders and the experts was noted above. If the goal is a resilient, safe, and healthy city, having a common understanding or vision of what such a future might comprise at urban scale is a first step to achieving it (Corfee-Morlot et al. 2011, Moser 2006, Moser and Dilling 2006).

Participatory processes figure prominently across cities that have demonstrated leadership on urban adaptation (Carmin et al. 2012, Brown et al. 2012, see also below). This experiences is consistent with the conceptual literature that suggests that participatory decision-making is essential where uncertainty and complexity characterise scientific understanding of the policy problem as is the case for climate change (Funtowicz and Ravetz 1993, Liberatore and Funtowicz 2003). Further, many have argued that while managing risk, reducing urban vulnerability and climate impacts is the goal of urban adaptation action, the legitimacy and effectiveness of action is likely to be determined by the institutional features of the decision-making process, notably by participatory inclusiveness, equity, awareness raising, deliberation, argument, and persuasion (Dietz 2003, Corfee-Morlot et al. 2011,Lim et al. 2005, Mukheibir and Ziervogel 2007). A review of 45 vulnerability mapping exercises found that only 40 percent included stakeholder participation, which in turn raises questions about procedural justice, legitimacy and salience of such exercises to support adaptation investments and other adaptation decisions (Preston et al. 2011).

In many urban settings, civil society already has a significant role to support adaptation planning and decisions. For example, some studies show that despite limited information, some action is moving ahead on adaptation at urban scale particularly through initial planning and awareness raising (Hunt, Watkiss 2011, Anguelovski, Carmin 2011, Lowe, Foster and Winkelman 2009, Carmin, Anguelovski 2009). Experience in a handful of cities – e.g. Capetown, London, New York -- demonstrate that engaging a wide number and variety of stakeholders at early stages in the risk assessment helps to create political support and momentum for follow-on research and ultimately adaptation planning (Hunt and Watkiss 2011, Anguelovski and Carmin 2011). In informal settlements where there is little or no formal infrastructures and services, stakeholder engagement provides a means for participatory community risk assessment, where local capacity to adapt is built in part through accessing local knowledge. Overtime, it is possible to establish institutional mechanisms that support innovation; collaboration and learning within and across sectors to advance urban adaptation action but this will take time and resources (Mukheibir, Ziervogel 2007, Burch 2010, Anguelovski Ref, Carmin 2011, Roberts 2010).

8.4.1.6. Delivering Co-Benefits

We noted earlier the difficulties of getting government attention to climate change adaptation when their priorities are economic growth and competitiveness. This suggests a need not only for local leadership but also for understanding and championing development and environmental co-benefits. Such benefits connect to the overarching goals of urban policy, poverty reduction and development, such as delivering safer, more comfortable and healthier urban environments and reducing the vulnerability of low-income groups (Burch 2010, Clapp et al., 2010, Hallegatte et al., 2011, Kousky and Schneider 2003, Carmin and Anguelovski 2009, Roberts 2010).

Numerous examples exist of ecosystem-based adaptation to better manage scarce water resources or limit flood risk (BMU 2011) or renovation of housing to provide basic weather resistance (Gilingham et al. 2009, IEA 2005). These are receiving increased attention in development finance portfolios as "adaptation" programmes, as they build resilience to climate extremes but these can also deliver multiple development co-benefits to urbanites. A growing number of cities are recognizing the importance ecosystem services to protect people and the resources on which they depend (e.g. flood control, preventing coastal erosion) and to meet basic needs (e.g. assisting with energy and food security) (GLA 2011, Roberts 2010, City of New York 2011, Institute for Sustainable Communities, undated). An ecosystem services based approach is particularly important in the global South where the livelihoods of the peri-urban and urban population are heavily dependent on natural resources.

Co-benefits may be particularly important in the global South, where climate change adaptation planning and implementation suffer from low political priority as they are not perceived to be central to urban development priorities. A UN-Habitat report states (undated b: 18); "*People in the developing world take advantage of the resources at their disposal (labour, capital, entitlements) and are willing to accept a necessary level of risk. Adaptation strategies need to recognize and accept this reality rather than propose ideal courses of action that cannot be realized*." There is also escalating 'urbanization of poverty', where the current climate change challenges appear marginal when compared with the deficits in infrastructure and service provision outlined earlier and other socio-economic problems faced by authorities responsible for urban development and security (Kithiia and Dowling 2010, Roberts 2008).

Development and climate change adaptation are often seen as separate challenges in a sub-national, regional planning context. A review in OECD countries revealed that only Japan and South Korea are championing climate action as an integral part of development policy at sub-national levels, while Finland and Sweden have innovative sub-national climate policies and action programmes, which are incentivised and funded by the central government (OECD 2010, Ch. 8). For most OECD countries, however, the two issues are tackled separately. Policy research argues that successful adaptation has to be rooted within development context of the city or country and harmonised with its development priorities, such as poverty reduction, food security and disaster management (Moser and Luers 2008, UN-Habitat, undated b, Satterthwaite et al. 2009, Lwasa, 2010). As concluded by Kithiia (2010) "…*without combating urban poverty and providing alternative sources of livelihood, little will be achieved towards climate change mitigation and adaptation*…" (page 4). The need to integrate climate and disaster risk management more fully into urban development planning holds across low-, middle- and high-income nations yet the approaches to do so will undoubted vary considerably.

8.4.1.7. Vulnerability and Risk Assessment Practices: Understanding Science, Socio-Economics, and Policy Interactions

Principles of good practice in public decision-making and climate risk governance include an important component of science – policy exchange and deliberation where good adaptation decisions will necessarily be based on credible scientific information (Corfee-Morlot et al. 2011, Rosenzweig and Solecki 2010). Understanding climate risks and vulnerabilities demands a continuous re-assessment of the scientific knowledge about local climate conditions and translating this into useable local knowledge. This will depend upon local capacity to access and use climate change information as it becomes available and processes for local stakeholder engagement on climate change, risk and adaptation .

Climate science refers to the ability to understand past climate conditions, monitor and attribute historical and present climate change to anthropogenic forcings, and project future changes in temperature, sea level and precipitation sufficiently well that people and governments can plan for and adapt to these changes (McCarthy et al. 2010).

The paths by which climate change alters local climatic conditions and who is exposed and impacted, will vary with local contextual factors (such as local physical and socio-economic conditions e.g. the size of the local population and its distribution across the land; age, thermal characteristics and location of the built environment; and altitude, soil and vegetation conditions, proximity to the sea or river basins of the area).

Credibility, legitimacy and salience are seen as key characteristics to increase the usability of science and other expert knowledge in policy assessments (from local to global) (NRC 2007, Preston et al. 2011). Research has shown the key role of boundary organisations to interpret and shape scientific inputs such that they become more useable in a political context (Cash 2001, Jasanoff 1990, Gieryn 1999, Guston 2001). A variety of institutional forms (NRC 2009) and funding sources for such organisations and activities are possible (i.e. national or sub-national public and in some cases private funding). Boundary activities may be based in a nearby academic community and designed to work with a single urban location (e.g. such as in the case of New York City and Columbia University), operating with a regional focus (e.g. at state or provincial level such as the case of Ouranos in Quebec) or as part of a nationwide effort to provide decision support for urban decision-makers (Corfee-Morlot et al. 2011, Vogel et al. 2007, Moser and Tribbia 2006).

Useful information about climate change at urban spatial scales is still lacking (Hunt and Watkiss 2011). Only a small number of cities largely in high-income countries have quantified risks in local contexts and even fewer have quantified possible costs of climate change risks under different climate and/or socio-economic scenarios. Sea level rise and coastal flood risk and health and water resources are among the most studied sectors, while energy, transport and built infrastructure receive far less attention (ibid). While science and climate change information is increasingly available, socio-economic drivers of vulnerability and impacts are less well studied or understood (Romero-Lankao and Qin 2011).

Even where detailed quantitative and technical assessments exist, the influence of these may be limited if the timing is mis-matched with major policy decisions or if decision-makers do not access and use this information or. For example, 10-year urban master plans have the potential to incorporate climate risks and vulnerabilities, but timely assessments need to be made available to match with their creation. Moser and Tribbia (2006) explore how decision makers access or use scientific information and the sources they rely on. Resource managers are more likely to rely upon informal sources such as maps or in-house experts, media and internet rather than scientific journals. This emphasises the need to work closely with decision makers in the production and communication of scientific information (ibid, Moser 2006). This demonstrates a need for two-way communication between producers and consumers of information early in any assessment process if the information is to have influence (Carmin et al. 2012, McCarthy et al. 2010

8.4.1.8. Planning Tools: Risk Screening, Vulnerability Mapping, and Urban Integrated Assessment

Policies in all urban infrastructure and planning sectors are key entry points for integration of climate change (e.g. water, wastewater, natural resource management, building regulations, land-use management, transport planning, and disaster management). Including climate risk management in infrastructure at the planning or design phase can avoid higher costs of retrofit at a later date (Bigio and Hallegatte, forthcoming). This can be assisted through a variety of planning and assessment tools including environmental impact assessment, vulnerability mapping and urban integrated assessment.

Urban governments also typically own and operate some share of urban infrastructure directly (e.g. schools, drainage systems, roads and parking facilities) and thus have opportunities to integrate climate change considerations into these investment decisions. For the private sector, governments can ensure that up to date climate information is available to support adaptation through their decisions (Agrawala et al. 2011; see also section below).

A wide range of tools have been developed and used to assess the environmental performance of urban areas including environmental impact assessment tools, environmental audits, strategic environmental assessments and local agenda 21s (Haughton 1999) . While these have tools and methods that have relevance and utility to adaptation planning, including those relating to participatory engagement, these often gave little or no consideration to adaptation.

Local climate change risk assessments, vulnerability and risk mapping can identify priority “most vulnerable” populations and locations at risk and provide a tool for urban adaptation decision makers (Ranger et al 2009, Hallegatte et al. 2010, Bigio and Hallegatte forthcoming, Livengood and Kunte 2012). One example is the LOCATE methodology (Local Options for Communities to Adapt and Technologies to Enhance Capacity) that is being tested in eight African countries; in each country a non-governmental organisation is working with one or more communities to test it. The methodology identifies local “hot spots” and a “project owner”, before moving into project design and implementation, as well as monitoring, evaluation and learning phases. It includes hazard and vulnerability mapping, where overlaying the two informs choices about which populations, infrastructure and areas to prioritise for action (Annecke 2010).

Tools that organize and rank information on vulnerability in different locations often aim to identify relative and absolute differences in risk and resilience capacity (Manuel-Navarrete et al. 2011, Hahna et al. 2009, Posey 2009, Milman and Short 2008). A review of risk screening and assessment tools, and of experience with their use by different donors and their partner countries (Hammil and Tanner 2011) show how these vary from a quick screening to identify risks to a fuller risk analysis and evaluation of adaptation options. In another review, Preston et al. (2011) consider 45 vulnerability mapping studies highlighting two broad functions: problem orientation (i.e. assessing and understanding the problem) and decision support. Noting the wide variety of functions and methods in the mapping exercises, the review suggests that effectiveness is guided by: identifying clear goals; framing vulnerability in a way that is meaningful to users; choice of robust technical methods; and ensuring engagement of the appropriate stakeholder (user) communities.

But most urban environments are complex systems and understanding these in a dynamic context can assist decision-makers to make good policy choices. Rapid socio-economic change in urban areas over time raises the complexity and uncertainty of local climate change impacts (see Figure 8-1). It is important to understand how the socio-economic and physical drivers of vulnerability interact with climate change to impact local population, economies and infrastructure. Earlier sections have highlighted the large range and complex mix of factors that influence these drivers. Adaptation will inevitably impact a range of urban policy goals e.g. those aiming to improve local air quality; to boost the local economy and jobs in the near term; to build resilience to economic shocks as well as shocks from disasters and environmental stresses that will be exacerbated by climate change; and to extend basic infrastructure and public services to under-served urban populations.

Downscaling climate scenarios, systems models and conducting urban integrated assessment modelling at local scales integrate different types of information in a forward-looking framework to support policy assessment in an urban context (e.g. Dawson et al. 2009, Hall et al. 2010, Hallegatte et al., 2011, Van Vuuren 2007, Viguie and Hallegatte 2012, Walsh et al. 2009, 2011). Integrated assessment modelling considers the driving forces of urban vulnerability and climate change impacts alongside possible policy responses and their outcomes. By integrating knowledge, this modelling provides a tool for use in urban areas by policy-makers to examine and better understand synergies and trade-offs across policy strategies. From this, policies can be identified that will deliver benefits across multiple criteria (Viguie and Hallegatte 2012, Dawson et al. 2009). These modelling frameworks take time to build and to be integrated into decision maker processes but early results are promising (e.g. Viguie and Hallegatte 2012, Dawson et al. 2009, Walsh 2011).

8.4.2. Private Sector, Civil Society, and Other Actors and Partnerships

8.4.2.1. Private Sector Engagement and the Insurance Sector

The very large range in the scale and nature of private enterprises – from informal street vendors to global corporations – makes any summary of measures needed to support adaptation difficult. But almost all private enterprises are concerned about the costs and availabilities of supplies, of needed infrastructure and services and of access to markets.

Some analysts argue that most of the investment required for sound adaptation will come from a multitude of small-scale private decisions spanning individuals, households and firms (Bowen, Fankhauser et al. 2008, OECD 2008). Yet international discussions often assume that the public goods nature of adaptation will require a major public investment to cover the principal adaptation needs in low- and middle-income countries (AGF 2010a and b). The need for adaptation investments will far exceed available funds from public budgets (Hedger 2011OECD 2008, World Bank 2010b), pointing to the need for both public and private investment to address adaptation. Brugmann (2012) notes how cities concentrate a high proportion of global investment and value added and a high proportion of total adaptation costs - and effective adaptation depends on catalysing market-based investments in adaptation and financial instruments that reward investors who contribute to resilience.

For markets to work in favour of urban adaptation, the private sector will need to see financial value in getting involved. In a 2011 survey of the most serious risks that companies face (Aon 2011), the top ranked risks were economic slowdown, regulatory/legislative change, increasing competition and damage to reputation. Weather and natural disasters came 16th and climate change 44th – even if some risks that were ranked higher may be associated with climate change impacts (business interruption was 5th, commodity price risk 8th and distribution or supply chain failure 12th). It is not clear that private sector actors are well positioned to consider the big questions of urban development that climate change is increasingly requiring (Redclift et al. 2011). In Cancun, Mexico close relationships between government and the corporate private sector have not led to a significant reflection on the urban development model and its part in generating risk through hazard exposure of capital intensive and large-scale coastal development. Private sector investments are limited to superficial changes, for example in building design to withstand hurricanes with most investment in risk management coming from the state sector through for example beach replenishment and a focus on rapid disaster recovery (Manuel-Navarrete et al. 2011).

More reliable, specific and downscaled projections of climate change and tools for risk screening and management can help engage the interest of businesses and consumers (AGF 2010, UNEP-FI 2011). Both public and private actors can have a role in providing regional and local climate predictions and hazard mapping e.g. data and projections on socio-economic trends, climate change, urban water supply and management practices and land use and building trends (UNEP-FI, 2011). A review of private sector engagement in adaptation shows anecdotal evidence of large businesses with assets at risk to climate change beginning to invest in vulnerability assessments, yet few have begun to invest in adaptation (Agrawala et al. 2011). While some private sector actors may be proactive in taking action against climate change risks, many more will postpone upfront investments for longer term benefits against uncertain risks. Eakin et al. (2010) and Chu and Schroeder (2010) suggest that the private sector may become more prominent when local governments and/civil society are limited but if there is limited capacity to pay and to reduce risk, it is difficult to see how this will happen.

Insurance markets can play a unique role in adaptation by sharing and spreading financial risk from climate change. This could directly reduce the damage costs that go beyond the financial by sending market signals to individuals, households and firms about the nature of climate change risks and how to better manage them (Fankhauser et al. 2008, Mills 2007). For example, a variety of mechanisms can help limit damages and manage risks of climate change in urban flood prone areas (Rosenzweig and Solecki 2010) including provision of health and life insurance to individuals; property and possessions insurance for home and commercial property owners and micro insurance mechanisms to support those that may not otherwise be covered by insurance. By providing risk-differentiated property insurance premiums, insurers can incentivise individuals and businesses to invest in adaption or to avoid building in high-risk areas (e.g. flood prone or fire hazard areas) and retro-fit property to reduce risk.

Innovative insurance mechanisms are being explored and may support adaptation on a regional scale in the future (Brugmann 2012). On example is the Caribbean Catastrophe Risk Insurance Facility (CCRIF) operating across the Caribbean as a risk management mechanism (Germanwatch 2010). While insurance pools are designed to give governments quick access to funds should a disaster strike, a shortcoming is that they do not provide funds for actual reconstruction. Catastrophe bonds are another mechanism that could be used to finance disaster responses, with potential to use the proceeds of the bond as a "positive" source of funding to reduce hazard exposure and risk e.g. to finance the weather proofing of buildings (Brugmann 2012). Experience to date suggests that these catastrophe bonds are written quite narrowly for specific events in specific locations and thus may may not provide the broad protection necessary to limit catastrophic risk as warranted in a changing climate (Keogh et al. 2010). More research is needed on the role of different insurance or private market risk-spreading instruments for urban risk management and their wider social implications.

Where risk levels exceed certain thresholds, insurers will abandon coverage or charge excessive amounts for coverage. Private investment or standard insurance markets will not protect low-income urban dwellers, many of whom live in informal settlements where insurance is often inappropriate (few assets are legally owned), inaccessible (they are unable to get bank accounts that are required) or unaffordable (premiums set too high so that the up-front costs of insurance prevent its take up) (Ranger et al., 2009, Hallegatte et al. 2010). For example, around half of Mumbai's population currently live in informal settlements most of which have inadequate provision of basic infrastructure and are at risk to floods today (Hallegatte et al. 2010, Ranger et al. 2011). The risk profile for this informal settlement population is set to increase under most scenarios of climate change. This population will not be served insurance mechanisms but will rely instead upon government assistance and local solidarity, such as family and community support, to respond when disaster hits (Hallegatte et al. 2010). So insurance while reducing net risk and loss potential in urban areas can increase inequality in security across the city and within neighbourhoods or across regions (da Silva 2010).

In many informal settlements, informal savings groups are active and provide members with quick access to funds. Most savers and most savings managers are women and these groups have particular importance for providing their members with rapid access to emergency loans (Mitlin 2008). In many nations in Africa and Asia, slum or shack dwellers have pooled their savings and used these for collective investments that reduce risk within their existing settlement or reduce risk by allowing them to negotiate land and support where they can build new homes (Manda 2007, Mitlin and Muller 2004).

Microfinance schemes may contribute to pro-poor, urban adaptation through a variety of different instruments including micro-credit, micro-insurance and micro-savings. To date, these have been applied mostly in rural areas. These also generally benefit those with some property status and amongst the less poor. As Hammill et al. (2008: 117) state: "*The value of MFS holds for climate change adaptation is in its outreach to vulnerable populations through a combination of direct and in-direct financial support, and through the long-term nature of its services that help families build assets and coping mechanisms over time, especially through savings and increasingly through microinsurance – products and sharing of knowledge and information to influence behaviours*."

Micro-insurance may be a critical, formal means to share risk in low-income areas at high risk to weather events. Although typically more costly than commercial bank loans, this can support entrepreneurial undertakings by those unable to get bank loans, help diversify local economies and empower women in particular, which can in turn contribute to adaptive capacity in a local context (World Bank 2010b, Agrawala and Carraro 2010). But micro-finance may focus on short-term gains by encouraging growth in risk-prone areas and sustaining livelihoods with little resilience to climate change (Agrawala and Carraro 2010). This suggests a need for "climate-proofing" microfinance practices and targeting its use to priority tasks that will deliver adaptation and development benefits in the nearer term including disaster risk reduction and community based technical training and education (ibid.). Microfinance also provides a means for donors to deliver support to low-income groups without creating an ongoing dependence on aid (ibid., Hammill et al. 2008). But one limitation of micro-finance for adaptation is that it provides credit to individuals for their use so it is not easily used to help finance collective investments - for instance to improve drainage - and can be a route into indebtedness especially during disaster recovery. There has been some experience in low-income communities setting up City Development Funds in Asia in which they pool their savings and from which they can draw loans for, among other things, disaster rehabilitation (Archer 2012).

Public policy needs to establish enabling conditions for markets to allocate scarce resources most efficiently to adaptation options and to overcome persistent market barriers. For example, in the urban context, policies can target provision of ecosystem services that fall outside of the market system to provide adaptation benefits, such as storm buffering and flood protection through mangrove protection in coastal zones or urban green space protection along river-ways (Fankhauser et al., 2008, Roberts et al. 2012). In the buildings sector, well-documented examples of market failure exist where optimal investment in weather proofing new construction and retrofitting existing stock is less likely without regulatory intervention [add cites]. Public policy and funding is also needed to protect the poorest and most vulnerable populations, who are least able to protect themselves through private action. More generally, where information is highly uncertain or not consistent with past experience, as is the case for the prediction of extreme weather events and potential losses, public policy has a role to ensure action e.g. to fill gaps in insurance markets where insurers are unable or unwilling to act (Fankhauser et al., 2008, Mills 2007, SREX 2012, UN-Habitat 2011). Regulations may have a key role to engage the private sector, as in the UK where vulnerability assessment is required for infrastructure investments (Agrawala et al., 2011). Other examples exist where governments lead by example by requiring the integration of adaptation considerations into public operations and infrastructure investments which in turn affects private sector providers of services and products in the supply chain of these operations. Thus even where markets exist and are well-functioning, public intervention to advance adaptation action is warranted as a means to engage the private sector in adaptation.

8.4.2.2. Household-based Adaptation in Urban Areas

Urban residents in high-income nations typically do not need to form community organizations and take direct action to build the roads, drains, good quality buildings and other infrastructure and services that will underpin their resilience to climate change. But these basic services are not available to hundreds of millions of urban dwellers in low and middle-income nations. The last decade has brought a much greater appreciation of the importance of household and community action to mitigate disaster risk, to make post-disaster recovery more effective and eventually build resilience to climate change. The contribution of household and community based action to resilience becomes important, where governments lack the capacity or the willingness to act. But the scale and scope of household and community based adaptation is constrained by the absence of local government support.

Individuals and households in informal settlements take multiple measures to mitigate the impact of extreme weather, especially where there is a history of floods, heat waves or high winds (Wamsler 2007, Adelekan 2010, Jabeen et al. 2010, Livengood and Kunte 2012, Kiunsi 2012). Some seek to modify the hazard itself e.g. ventilation and roof covering to reduce high temperatures during heat waves or barriers built to prevent floodwater entering homes) or reduce their exposure e.g. by sleeping and keeping food stores on top of high furniture and moving temporarily to safer locations. Exposure reduction measures are the most common. One informal settlement resident in Freetown reported that "w*hen we see very dark clouds up the hills, we expect heavy rains to come. So we get ourselves prepared by transferring our valuable things and our children on our very high beds reached by climbing ladders" (*Douglas et al 2008).

Some of these studies show the wide range of measures that household take. A study in Korail, one of the largest informal settlements in Dhaka, showed that diverse response to flood risk – barriers across door fronts, increasing the height of furniture, making floors or shelves to store goods above the flood line. Provision for ventilation, creepers or other material on roofs and false ceilings helped to keep down temperatures (see Figure 8-2). Households also used portable cookers that can be used on shelves or furniture (Jabeen et al. 2010). But the protection provided by such pragmatic measures are limited in much of Korail and most other informal settlements by the higher risks their inhabitants face because they live in high risk locations.

[INSERT FIGURE 8-2 HERE
Figure 8-2: Household adaptation - a cross section of a shelter in an informal settlement in Dhaka (Korail) showing measures to cope with flooding and high temperatures. Source: Jabeen et al (2010).]

When Korail was first settled, the higher ground was build on but as it expanded, houses were built closer to the adjacent lake and reservoir. Here as in most cities in low- and middle-income nations, large concentrations of low-income groups live on land at high risk from extreme weather because these are the only locations where they can build or afford to rent accommodation that is close to income-earning opportunities (Hardoy et al. 2001, Aragón, 2007). The risks from not finding paid work are greater than the risks from extreme weather. A study of risks faced by the residents of four informal settlements in Lagos to flooding showed community initiatives to clear blocked drainage channels but most responses were by individuals or households such as constructing drains, trenches or walls to try to protect houses. Food and household items were stored on shelves or cupboards above anticipated flood levels (Adelekan 2010). Here and in Korail, those interviewed highlighted the loss of income or assets as one of the most critical impacts from extreme weather – especially missed working hours or days.

There are also constraints on the capacity of low-income households to act. For instance, in Korail, many inhabitants do not move to safer locations when floods are anticipated because this risked loss of assets and disrupting livelihoods (Jabeen et al. 2010). They also worried about looting and whether they would be allowed to return to their original location. Similar concerns were expressed by the inhabitants of informal settlements in Santa Fe, Argentina who were also reluctant to move to safer locations for comparable reasons (Hardoy et al. 2011). There is some recognition that strengthening and supporting the asset base of low-income households helps increase their resilience to stresses and shocks, including those related to climate change (Moser and Satterthwaite 2008.).

8.4.2.3. Community-based Adaptation

Community-based adaptation implies that a group of residents in a particular settlement agree to work together to address a perceived risk they face that the city government is not addressing (Boyd et al. 2009, Dodman and Mitlin 2011). It can be action autonomous of government or action with other groups to engage with local governments. There is typically far less need for community action on this in high-income nations, as shown in Table 8-2. In low and most middle-income nations enabling community based adaptation and building resilience is more relevant because of the limited capacity of governments to provide much needed risk-reducing infrastructure and services or their unwillingness to work in informal settlements. A range of studies have documented how local populations have a depth of knowledge and capacities to mitigate their vulnerabilities (Dodman and Mitlin 2011, Anguelovski and Carmin 2011). Close to a billion people live in informal settlements in urban areas across the world and community-based adaptation is their only means of response.

Community-based adaptation can be autonomous as residents within a particular settlement work together to install or repair infrastructure or provide services or action to engage local government and if possible work with it. There are many precedents for this engagement with local governments, including many 'slum' or 'squatter' upgrading programmes that have improved housing quality and infrastructure provision. Most upgrading programmes also mean that those living in these settlements became incorporated into 'the formal' city and this often means other measures by the state to reduce their risks – for instance though access to schools, health care and safety nets (Almansi 2009, Boonyabancha 2005, Fernandes 2007, Ferguson and Navarrete 2003, Imparato and Ruster 2003, Some, Hafidz and Sauter 2009, UN Millennium Project 2005). In many informal settlements, the issue of land tenure is difficult to resolve and this impede upgrading programmes and local level adaptation action although upgrading programmes have resolved such issues (Boonyabancha 2005, 2009, Almansi 2009).

The studies noted above highlight the willingness of individuals to invest in collective action influenced by their tenure status and how secure they feel from eviction. Tenants are usually unwilling to invest in improving housing they live in and less willing to invest in community initiatives. But the contribution of community-level organization, DRR and climate change adaptation can be greatly enhanced where local governments and other agencies like civil defence organizations recognize their role and support them.

It has become more common for local governments to work with community-based organizations not only in upgrading but also in disaster risk reduction (Pelling 2011b, United Nations 2009, 2011, IFRC 2010). Community-based adaptation will probably be preceded by community-based actions to reduce risks and vulnerabilities to flooding, storms and heat waves in the past (Archer and Boonyabancha 2011).

Interest in community-based adaptation has grown among researchers and international agencies but mostly for rural populations and their livelihoods (Dodman and Mitlin 2011). There are obvious limits to what community action can do in urban areas. For instance it may be able to help construct or improve drainage and collect solid waste within settlements, but it will not be able to provide network infrastructure (e.g. piped water or drainage networks) or city-region management (Satterthwaite et al. 2009). Most informal settlements are embedded in a larger built up area so there is no space in their periphery to which to channel flood waters or dispose of household wastes.

Urban resilience to climate change impacts requires actions, investments and governance frameworks that only local governments can provide, even though private sector and community-based action may support this. A focus on community-action may mean a lack of attention to the structural inequalities that underpin local vulnerabilities and to the failure of local governments and agencies to address these (Dodman and Mitlin 2011). Low-income communities may not see urban climate change adaptation as a priority, especially if confronted with pressing daily issues such as generating sufficient income and a threat of eviction (Banks et al. 2011).

The effectiveness of community-based action is also dependent on how representative and inclusive the community leaders and organizations are. There are examples of its effectiveness where there are representative organizations formed by those living in informal settlements (Appadurai 2004, Mitlin 2012) but also examples of local political structures that inhibit this (Banks 2008 and Houtzager and Acharya 2011). There are also wider constraints on the capacity of community organizations to act. For instance, discussions in El Salvador with the inhabitants of 15 disaster-prone "slum" communities and with local organizations showed many making individual and household responses – but difficulties in getting community action as there were no representative community organizations through which to design and implement settlement-measures. In addition, there was a lack of support from government agencies and from civil society organizations (Wamsler 2007).

The effectiveness of community-based adaptation in urban areas depends on the extent to which community organization (and the larger networks or federations they form) can generate pressure for larger changes within government and for relations between community organizations and government (Boonyabancha and Mitlin 2012). Community-based adaptation can engage with key development agendas that reduce poverty and vulnerability (Sabates-Wheeler et al. 2008) and potentially be effective in light of local inequalities and adverse power relations at district, city, national and transnational levels (Mohan and Stokke 2000).

There are new methods of documenting and mapping risks and vulnerabilities in informal settlements that serve and support community based adaptation. Even though it is common for a third or more of the inhabitants of cities in low- and middle-income nations to live in informal settlements, these are often not included in official government records and maps. In a growing number of cities, the mapping and enumeration of informal settlements has been undertaken by residents organizations supported by grassroots leaders and local NGOs – with city governments coming to support these and recognizing the validity of the data and maps produced (Patel and Baptist 2012). These provide the household and settlement data and maps needed to plan the installation or upgrading of infrastructure and services that reduce risks from extreme weather. Some of these community-driven enumerations also collect data for each informal settlement on risks and vulnerabilities to extreme weather and other hazards (Pelling 2011b, Carcellar et al. 2011, Livengood and Kunte 2012). For instance, community surveys in the Philippines identified at risk communities under bridges, near cliffs and other landslide-prone areas, on coastal shorelines and river banks, in public cemeteries near open dumpsites, and on those in flood-prone locations (Carcellar et al. 2012). This mapping also helps raise awareness among the inhabitants of informal settlements of the risks they face, as well as getting their engagement in planning risk reduction and making early warning systems and when needed emergency evacuation effective (Pelling 2011b).

8.4.2.4. Philanthropic and Other Civil Society Support for Urban Adaptation

Many have suggested that the authority of state actors is considerably weaker today than it has been in the past on issues of public concern, giving rise to increased influence of non-state actors and institutions (Corfee-Morlot et al. 2007, Levy and Newell 2005, Sathaye et al. 2007, Social Learning Group 2001). While the balance of influence between state and non-state actors in urban areas depends much on local and national historical context, civil society actors from neighbourhood groups to rights coalitions and urban social movements have come to play an important role in the shaping, delivery and critique of urban development and especially in the provision and accessibility of critical infrastructure and services.

Some civil society initiatives have developed models of infrastructure delivery that have relevance for adaptation. For instance, the installation of community-managed sewers and drains supported by the Orangi Pilot Project Research and Training Institute in urban areas in Pakistan provided much needed infrastructure in informal settlements although the impact of this work was much increased where government provided the trunk infrastructure into which these integrated (Hasan 2006). Elsewhere ad hoc coalitions of civil society actors, or in many other cities uncoordinated activity provide a de facto delivery mechanism for accessing basic infrastructure and rights as part of development and disaster response (Pelling 2003). Adding to the argument for enhanced civil society coordination is the recognition that many disaster events are small, local but have a widespread and cumulative impact on the development prospects of poor households and communities (United Nations 2009). The range of recent disaster events in Asian cities suggest a growing need for a new support mechanism to and among local stakeholders – one that should include local government as well as local civil society organisations (Shaw and Izumi 2011: 263). One experiment in this regard, though not exclusively focused on urban contexts is the Global Network of Civil Society Organizations for disaster risk reduction. This has organised community groups at national and then regional and global levels in a structured assessment of the local delivery for disaster risk reduction goals as set out in the Hyogo Framework as a means of verifying claims made by national government submissions to the ISDR.

Civil society has had a large and usually growing role in shaping practices on environmental policy and outcomes by championing ideas and providing platforms for dialogue and debate (Bramwell 1989, Brulle 2000, Carpenter 2001, Gough and Shackley 2001, Hall and Taplin 2006, Yearley 1994). This includes engagement spanning national to local levels of adaptation decision-making (Moser 2009, McKenzie Hedger et al. 2006, UKCIP 2008). Aside from their direct influence in shaping policy, non-governmental actors also play a “watchdog” role to assess how well policies are performing with respect to the stated goals (Brown and Jacobson 1998, Levy and Newell 2005, Gough and Shackley 2001). Where urban based civil society is particularly well coordinated and has high degrees of legitimacy it can reach beyond this to offer alternative models for urban governance and for adapting to climate change as part of the development struggle (Pelling et al. 2011, Mitlin 2011). These are alternatives that need not be in confrontation with local government. Evidence from Santo Domingo, the Dominican Republic has shown the importance of partnerships between local urban government and local civil society actors in achieving longevity, in options for upscaling local disaster risk reduction initiatives and for building on trust generated by such projects to deliver other gains, in this case improved policing and reduction in gang related violence (Pelling 2011). In the Philippines, many local governments now work with the Philippines Homeless People's Federation in identifying those most at risk and acting to address this (Carcellar et al., 2011)

The coming together of grassroots civil society organisations to form international collaborations strengthens the framing role of civil society while retaining its local accountability and focus. The local situatedness of adaptation and the need to both address local conditions and structural root causes of vulnerability makes such organisations well placed. Amongst the most active with a dedicated urban focus is Shack/Slum Dwellers International (SDI), a network of community-based organizations and federations of the urban poor in 33 countries in Africa, Asia, and Latin America. Its member federations share experiences, lobby and undertake practical upgrading and risk reduction initiatives as well as seeking to influence the policies of development assistance agencies. Regional networks of organisations also contribute to the emerging international architecture of civil society movements working on risk reduction - for example, the Asian Coalition for Community Action Program managed by the Asian Coalition for Housing Rights is supporting community-driven upgrading initiatives in 150 cities and supporting improved relations between community organizations and local governments. Other civil society networks have broader interests but include urban risk reduction, for example the Asian Disaster Reduction and Response Network (ADRRN) which aims to strengthen local civil society groups in the region.

Another expression of international civil society as an enabling framework is the role played by philanthropic organizations. One example of this is the Rockefeller Foundation's support for the Asian Cities Climate Change Resilience Network (ACCCRN). This is supporting partners in ten cities in India, Indonesia, Thailand and Vietnam to build local knowledge, capacity and strategies to institutionalise climate change adaptation and resilience in local planning and development. This includes prioritising proposals for interventions to guide future investments to build resilience into the measures to meet the diverse needs of residents, businesses and the urban economy (Moench et al. 2011, Brown et al 2012). While not working explicitly on urban adaptation others, such as the Bill and Melinda Gates Foundation have deep interests, in both poverty and disaster response. The growth in philanthropic foundation spending has as yet largely unresearched implications for the direction of research and capacity building on urban adaptation (Buchner et al. 2001).

8.4.2.5. Research Institutions, including Universities

A number of international initiatives led by research oriented institutions and networks have added visibility and begun to strengthen research capacity on issues of urban climate change adaptation. For example, START has organized two Cities at Risk international workshops (2009 and 2011). As interest in urban aspects of adaptation amongst researchers and universities and associated national research funding agencies is growing but also changing from an orientation based principally in an engineering and technology domains to one that recognizes also the contributions to be made from social and economic sciences and the humanities in understanding urbanization experiences and processes in risk management and adaptation to climate change.

The Urban Global Environmental Change Programme (UGEC) of the International Human Dimensions Programme of the Earth Systems Science Partnership (ESSP) has built a set of international networks in adaptation, mitigation and relationships between these two. Urbanization and adaptation has become a thematic issue dealt with by the Land-Ocean Interface at the Coastal Zone (LOICZ) programme through its interest on megacities and costal urban regions. The role of adaptation and its interaction with disaster risk reduction is also highlighted by the International Scientific Union project, Integrated Research on Disaster Risk (IRDR). There is also the IDRC funded research on urban adaptation in Africa.

Individual academic institutes have also begun to champion urban adaptation. For example the Urban Observatory in Manila has become a regional hub for climate change science and including urban adaptation, though interests in mitigation and in rural contexts for adaptation are much more developed. Elsewhere in Asia, in Malaysia the Universiti Kebangsaan Malaysia hosts a Malaysian Network for Research on Climate, Environment and

Development (MyCLIMATE) and has focused on building awareness and capacity amongst industry and civil society (Izumi and Shaw, 2011), and the Climate and Disaster Resilience Initiative (Kyoto University, CITYNET and UNISDR) has focused on working with city managers and practitioners (Shaw and IEDM Team 2009). Centres for capacity building are also emerging such as the International Centre for Climate Change and Development, Bangladesh which offers short course on urban adaptation planning (Mehotra et al. 2009, Anguelovski and Carmin 2011).

8.4.2.6. City Networks – Sharing Experiences with Spreading Learning between Urban Centers

There is increasing evidence of multilevel urban climate risk governance operating horizontally through transnational networks, where urban actors work across organisational boundaries to influence outcomes (Bulkeley and Betsill 2005, Bulkeley and Moser 2007). At the sub-national level, some of these horizontal relationships have been created through formalised information networks and coalitions acting both nationally and internationally, including ICLEI's Cities for Climate Protection, the Climate Alliance, the C-40 Large Cities Climate Leadership Group, and the Urban Leaders Adaptation Initiative in the US. The United Cities and Local Governments that represents local governments within the United Nations have a growing interest in climate change adaptation. The Asian Cities Climate Change Resilience Network (ACCCRN) mentioned above also encourages inter-city learning for officials and local researchers (Brown et al. 2012). There is also the Making Cities Resilient network supported by the UN International Strategy for Disaster Risk Reduction which seeks to catalyse city governments to take action based on a ten-point priority agenda (Blackburn et al., 2012).

These networks have received increasing attention in social research on climate policy. For example, ICLEI's Cities for Climate Protection network has been extensively analyzed in the literature (Aall et al. 2007, Betsill and Bulkeley 2004, 2006, Lindseth 2004). The focus of some of these networks was initially on mitigation but attention to adaptation is growing. as in US Urban Leaders Adaptation Initiative Foster et al. 2011. These groups have given an institutional foundation to concerted effort and collaboration on climate change at city level (Aall et al. 2007, Kern and Gotelind 2009, Romero Lankao 2007).

8.4.3. Resources for Urban Adaptation and their Management

Resources for urban adaptation action comes from the public sector – both domestic and international sources – as well as from the private sector, e.g. in the form of market based finance for infrastructure investment.

8.4.3.1. Domestic Financing: Local and National Sources of Funding and Support

Domestic public funding is likely to be one of the most significant and sustainable source of funding for adaptation in many countries, including locally levied revenues as well as revenue transfers or grants from sub-national regional and central governments (OECD 2010: Ch 9, Hedger and Bird 2011).

Table 8-3 summarizes the main financial instruments that can help fund adaptation. In countries where property markets are well-functioning and some fiscal authority exists at local levels of government, revenue sources that might be used to support adaptation and include taxes, fees and charges. For high-income countries, estimates show that local governments are responsible for about 70 percent of public spending and for roughly 50 percent of the public spending that occurs on the environment, often operating in partnership with other levels of government (OECD 2010). The scale and source of funds that might contribute to adaptation varies widely by city and location. The balance of local revenue sources available to a city depends upon the national institutional and legislative framework that devolves some authority to tax or imposes other fiscal policies on local residents, property owners and businesses. Some of the environmental innovation shown in cities in Latin America over the last 20 years is associated with decentralization that has strengthened fiscal bases for cities, as well as elected mayors and more accountable city governments (Campbell 2003, Cabannes 2004). Much less is known about urban fiscal policies in Africa and Asia except that a high proportion of urban governments in many nations have very limited investment capacities as most of their revenues go on salaries and other recurrent expenditures (United Cities and Local Governments 2011).

[INSERT TABLE 8-3 HERE
Table 8-3: Main financial instruments to green urban development and infrastructure investment.]

In recent years, there have been more examples of green local fiscal policies. These include congestion charges or value-capture land taxes that make visible the cost of environmental externalities and/or the benefits of infrastructure and services provided to property owners (e.g. transportation, wastewater or water services). Such measures promote private investment in risk management while also mobilising local revenue sources (where a portion could be targeted to support urban adaptation). Local fiscal incentives for mal-adaptation may also exist, e.g. in China urban government budgets and actions are financed by land sales, which in turn promote urban sprawl (Merk, 2012). Greening local fiscal policies will also need to identify and address mal-adaptation.

Another important source of funding for local adaptation action is national or regional (sub-national) grants, loans and other forms of revenue transfer. OECD (2010) states: "In cases where environmental policies with large spillovers are assigned to local governments, intergovernmental grants could make sense in order to compensate local governments for the external benefits of its expenditures." One example of this is municipal funding in Brazil that is influenced by ecosystem management quality (see Box 8-2).

_____ START BOX 8-2 HERE _____

Box 8-2. Environmental Indicators in Allocating Tax Shares to Local Governments in Brazil

In Brazil, part of the revenues from a value-added tax (ICMS) collected by state governments must be redistributed among municipalities. Three-quarters of this is defined by the federal constitution, but the remaining 25% is allocated by each state government. The state of Paraná introduced the ecological ICMS (ICMS-E) in 1992, followed by several other states. It was introduced against the background of state-induced land-use restrictions (protected areas) for several municipalities, which prevented them from developing land but provided no compensation. For example, 90 percent of the municipality of Piraquara is designated as a protected area for conserving a watershed to supply the Curitiba metropolitan region with water (May et al. 2002).

Although the states have different systems in place, there are many commonalities in the allocation mechanism. Revenues are allocated according to an ecological index based on the proportion of a municipality's area set aside for protection. Protected areas are weighted according to different categories of conservation management ranging from 1.0 (for ecological research centres and biological reserves) to 0.1 (for special local areas of tourist interest, and buffer zones). Paraná and some other states include an evaluation of the quality of the protected areas in the calculation of the index based on physical quality, biological quality (fauna and flora), quality of water resources, physical representativeness and quality of planning, implementation and maintenance.

Evaluations in Paraná and Minas Gerais show that the introduction of the ICMS-E has been associated with improved environmental management and the creation of new protected areas (May et al. 2002). The ICMS-E has also improved relations between protected areas and the surrounding inhabitants, as they start to see these as an opportunity to generate revenue, rather than an obstacle to development. The ICMS-E has built on existing institutions and administrative procedures, and thus has had very low transaction costs (Ring 2008).

_____ END BOX 8-2 HERE _____

A number of other innovative financial mechanisms may be drawn upon to support urban adaptation action. These include revolving funds and the energy services company (or the "ESCO") model (OECD 2010:Ch. 8 and Ch 9). Revolving funds can be developed from a variety of different revenue streams, say from a CDM project (Puppim de Oliveira 2009) or financial savings from an energy efficiency investment in municipal buildings, to feed an ongoing public fund that can support public investments that yield adaptation benefits. Cities and other governments in high and some middle income countries may also have direct access to debt instruments such as bond markets or loans from national (or regional) development banks or financial institutions (OECD 2010, EIB 2011). Local access to capital markets to fund adaptation investments can also be facilitated through risk-sharing mechanisms or financial guarantees instruments provided by external or domestic development banks e.g. Kfw provides low-interest loans to local banks which in turn finance energy efficiency renovations in residential and commercial building) (OECD 2010, Kfw 2011).

The very high costs brought by extreme weather events in urban areas described in earlier sections and the fact that climate change increases risk of weather-related disasters in urban areas indicates the need for increased funding and attention from national budgets for disaster risk reduction, early warning and evacuation procedures within urban areas, alongside other adaptation measures (World Bank 2010b, World Bank 2010a, Hallegatte and Corfee-Morlot 2011).

8.4.3.2. International Financing: Multilateral and Bilateral Development Assistance

While more international funding for adaptation and mitigation has been committed (see for instance the Cancun Agreements) and there are some indications that governments are broadly on track to deliver on these commitments (Clapp et al. 2012 , Buchner et al. 2011) what is less in evidence is the institutional arrangements by which support is available to urban governments for adaptation. This is also the case for new dedicated climate change funds. In addition, international public funding for adaptation may be difficult to discern from development finance (Tirpak et al. 2010, Buchner et al. 2011)

Recent data suggest that a notable share of development finance targets climate adaptation (UNEP 2010, OECD 2012).The extent to which urban adaptation is covered with this is largely unknown. Conventional delivery institutions – through multilateral and bilateral channels – appear to have the biggest role in adaptation financing, though new vertical funds are also emerging. The proliferation of multiple, single purpose funding mechanisms runs contrary to long-standing principles of sound development cooperation notably harmonisation and alignment (McKenzie Hedger 2011).

One detailed study looking across five development cooperation agencies suggests that just under one-third of their climate change funding was committed to adaptation, representing close to USD four billion in 2009. Some 95 percent was estimated to be concessional – mostly low-interest loans with only 14 percent being grants (UNEP 2010, Atteridge et al. 2009). The study covers three bilateral agencies: Japan's JICA, French AFD, German KFW; and two multilateral or regional development agencies: the European Union's European Investment Bank and the Nordic Environmental Finance Corporation (NEFCO). Adaptation funding in 2009 was an estimated 30% more than that in 2008. About three-quarters of adaptation funding by these donors is in the water supply and treatment sector and another 20 percent directed to other urban relevant sectors (i.e. transport, policy loans, disaster risk reduction (UNEP 2010). Interestingly health and energy are overlooked despite the fact that these sectors are also vulnerable to climate change.

Recent research underscores the need for more proactive planning, strategies and project preparation in recipient or partner countries. Typically partner countries lack defined priorities for the use of funds and, when combined with donor tendency to "control" funds to ensure short-term results and a large variety of different funding instruments, the result are highly fragmented delivery systems that lead to unclear outcomes (Peskett and Brown 2011). Even where national climate strategies exist to guide action – as in the case of Bangladesh which is an "early mover" on adaptation planning – the plan is not yet costed nor is it sequenced, which makes it difficult to use as a framework for delivery of international climate finance (Hedger 2011). This raises fundamental questions about the capacity in either the donor or the partner countries to effectively manage the magnitude of the funds currently available for adaptation, yet alone scaled up funds. Reconciling top-down resources with bottom-up, locally based planning and project preparation could provide a means to better target development assistance (i.e. to urban planning processes that take climate risks into account), while also ensuring that limited funding is directed to programmes that aim to be mainstreamed into urban development processes over time (Brugmann 2012).

A key to improving effectiveness of international public finance will be country-led planning processes that identify priority projects and programmes for the targeting of adaptation funds that include urban adaptation . A further challenge is to raise the profile and the attention to urban or local adaptation within national adaptation planning. To date, the National Adaptation Programmes of Action developed by forty five LDCs (Oxfam 2011) and the support of the UNFCCC for the formulation of National Action Plans have shown little interest in urban adaptation. These remain essentially “top down” and are led by the national government. Urban governments typically only have access to international public finance through their national governments. Routine institutional mechanisms for supporting the needed multilevel urban adaptation planning and risk governance do not exist yet (Corfee-Morlot et al. 2011, Carmin and Dodman forthcoming).

Some authors conclude that development finance has largely failed in the past to tackle urban development problems, including those of the urban poor, which in turn increases the vulnerability of urban populations to climate change (Satterthwaite et al. 2009). In some middle income countries, such as Indonesia, rather than focusing on large amounts of new external funding to support climate action, a more effective and sustaining strategy may be national fiscal policy reforms and incentives to steer investment (Peskett and Brown, 2011). Beyond better delivery and use of development finance, there is also a need to mobilise domestic public and private investment to ensure delivery of adaptation at national and urban levels (Hedger 2011a & b, Hedger and Bird 2011, OECD 2012).

8.4.3.3. Multilateral Humanitarian and Disaster Management Assistance

The systematic programming of adaptation into multilateral humanitarian and disaster response and management funding is in its infancy with urban dimensions still largely undeveloped – although this is changing (see United Nations 2009, 2011). The World Bank’s Global Facility for Disaster Reduction and Recovery (GFDRR) explicitly includes adaptation to climate change, its Country Programmes for Disaster Risk Management and Climate Change Adaptation 2009-2011 also seek to deepen engagement in selected priority countries (GFDRR 2009). The GFDRR has also worked with UNISDR to advocate for more joined up policy at the technical level (see Mitchell et al. 2010).

There have been some changes in disaster risk reduction that have relevance for climate change adaptation. Drawing on reports between 2009 and 2011 from 82 governments on how they were addressing disaster risk reduction, there is recognition by national governments of key role of local government in disaster risk reduction. Many such governments also recognize their failure to strengthen local government and support community participation. Almost 60 percent of countries and almost 80 percent of lower-middle income countries reported that local governments have legal responsibility for disaster risk management, only 26 confirmed dedicated budget allocations. With the exception of upper middle income countries, very few report dedicated budget allocations to local government for disaster risk management. Figure 8-3 highlights how little attention is being given to urban and land-use planning and also needed investments in drainage infrastructure, especially in low and lower-middle income nations. However, it is also worth noting that in more than half the upper middle and lower middle income nations, climate change policies were reported to be being integrated into disaster risk reduction.

[INSERT FIGURE 8-3 HERE
Figure 8-3: Progress reported by 82 governments in addressing some key aspects of disaster risk reduction by countries’ per capita income. Source: United Nations (2011).]

8.4.3.4. Institutional Capacity and Leadership, Staffing, and Skill Development

A critical factor of success in urban adaptation efforts is leadership, for example from the Mayor’s office or from entrepreneurial staff that understand the challenge and champion awareness raising and institutional change to bring action (Anguelovski, Carmin 2011, Carmin et al. 2012). Creation of a climate change and environmental focal point or office in a city can help to champion and coordinate climate action across government departments or line management agencies (Anguelovski, Carmin 2011, Hunt and Watkiss 2011, OECD 2011, Brown et al. 2012). Yet there may be downsides when the urban climate change function is housed by the environmental line department (e.g. Durban - Roberts, 2008 :523, Boston see Boston 2010, Sydney see Measham et al. 2010). Roberts (2010) notes that environment line management or departments are typically among the weakest parts of government. This in turn can marginalise the climate change coordination function to the low or lower priority and limited resources are usually assigned to environmental departments within government structures, which results in limited institutional influence.

Although there is growing evidence of adaptation leadership in urban contexts (Anguelovski and Carmin 2011, Lowe, Foster and Winkelman 2009, Carmin and Anguelovski 2009, Foster et al., 2011), there are also important political constraints to making adaptation decisions at the local level. Local government decisions are often driven by short term priorities and nearer term concerns about economic growth and competitiveness, making it difficult for them to focus on the more distant implications of climate change (OECD 2009, Romero Lankao and Qin 2011, Pelling 2010). Vested interests fight against such change and often promote development on sites at risk (e.g. coastal or river-side real estate developments). A key step forward is to work towards institutionalising different types of behaviour and norms to recognise and act upon climate and disaster risk (Figure 8-4).

[INSERT FIGURE 8-4 HERE
Figure 8-4: The basic challenge of effective climate change communication to change behavior and norms. Source: Moser and Luers (2008).]

Beyond goal setting and planning for adaptation and disaster risk management, governments also need to regulate, create job descriptions that require actions and provide incentives to act (e.g. for line managers and sector policymakers), and provide training for staff and clear guidance on what to do (Moser 2006). Establishing budgetary transparency and metrics to measure progress on adaptation will also help to institutionalised changes in planning and policy practice (OECD 2012).

8.4.3.5. Monitoring and Evaluation to Assess Progress

Tools for monitoring and evaluation of adaptation actions are needed to assist adaptation leaders and funding institutions to justify investments. Monitoring is particularly challenging for adaptation given that there are no standard metrics to assess progress (Lamhauge et al. 2011, GIZ et al. 2012). Monitoring and evaluation of aid effectiveness of climate finance is a particularly active research (Chaum et al. 2011), in part because donors are asked to justify their investments by reporting on results.

Steps for consistent and internationally harmonised data collection are urgently needed to support monitoring, reporting and verification of both delivery and use of international climate finance to ensure that lessons are learnt and funds are being directed in an effective manner (Hedger 2011, Buchner et al. 2011). Where international finance is flowing, both donors and partners countries will need to assess outcomes and effects of climate finance. There is some evidence of an increasing burden of reporting falling on partner organizations and countries, and even city authorities who receive international support, where partners have to devote significant time and human capacity to reporting on progress, which in turn detracts from further programme design and implementation.

In reviewing the development of urban adaptation interventions and strategies by climate hazard type and their linkage with core policy and practical concerns, certain key questions will need to be addressed:

- Does it reduce mortality?
- Does it help reduce illness and injury and/or their impacts especially on low-income and vulnerable groups?
- Does it make livelihoods more resilient and improve choices on employment and livelihoods?
- Does it reduce negative impacts on economic output and the urban centre's capital stock?
- Does it increase the resilience of lifeline physical and social infrastructure and services?
- Does it increase the resilience of housing, especially for those with limited incomes and assets?
- Does it mitigate impact and improve the productivity and resilience of ecosystem services?
- Does it have potential co-benefits with poverty reduction and mitigation interventions and prepare the base for transformatory adaptation?

8.5. Conclusions

8.5.1. Introduction

The key role of urban governments in climate change adaptation has become more widely recognized. One example of this is the signing of the Durban Adaptation Charter in December 2011 by 114 mayors representing over 950 local governments at COP17. This signaled their intention to begin addressing climate change adaptation in a more concerted and structured way. But as this chapter has described, the way forward is not simple, with both climate change and climate change adaptation being acknowledged as highly complex or "wicked" problems in the urban context (Martins and Ferreira 2011, Fünfgeld and McEvoy 2011). As yet, only a small proportion of urban governments have begun to act on adaptation.

Because of the complexities and uncertainties involved, most action to date has focused on 'no-risk' and 'low cost' interventions where climate change adaptation is a co-benefit of existing work streams, rather than a new, stand alone work area (Roberts 2008, Toronto Environment Office 2008). In many cases this local level action has been initiated with some form of risk and vulnerability assessment, linked to down-scaled climate change projections (e.g. GLA 2011, MWH 2008, Boston 2011, Roberts 2008, UN-Habitat, undated a). This early focus on risk assessment and business-as-usual (but with climate benefits) means a greater focus on interventionist and reactive infrastructure or asset-oriented adaptation (e.g. LCCP 2006, Awuor, et al., 2008, Mehrotra et al. 2011, Heleen-Lydeke et al. 2011) than on the 'soft' or process (i.e. human, institutional and ecological) elements of adaptation, such as resilient development, governance, poverty reduction and livelihood security, social cohesion and ecosystem based adaptation (Lwasa 2010, Jones et al. 2010). This bias is also a product of the aging urban infrastructure of the global North and the large infrastructure and basic service deficits in urban areas in the Global South (UN-Habitat 2011).

A focus on adaptation measures rather than building adaptive capacity or resilience is especially problematic in the urban areas of the global South. Here, "adaptive capacity is limited by resources, weak institutions, poor/inadequate infrastructure and poor governance" (Kithiia , 2009:19). There is a real need to shift from looking at "what a system *has* that enables it to adapt, to recognising what a system *does* to enable it to adapt" (Jones, et al. 2010:1). This suggests a need for more open-ended and flexible concepts such as adapting well, climate smart and resilience (Wilson and Termeer 2011, Brown et al. 2012).

This socio-institutional emphasis also encourages a move away from adaptation is a tool of last resort, an 'end-of-the-pipe' intervention responsive to a narrow range of outcomes and probabilities (Roberts, et al. 2012:2) that supports the prioritisation of existing coping strategies (Heindrichs et al, 2011:216). Instead it prioritises the need for "bouncing forward" (Shaw and Theobald, 2011:2) to greater resilience and the departure from the norm. Adaptation becomes more than an incremental reaction to the climate change problem (Foster et al. 2011) and shifts to what in Table 8-2 is characterized as tranformatory adaptive capacity and climate resilience (Pelling 2011). This is especially important in a world where transgressions of key planetary boundaries such as climate change and biodiversity will take humanity out of the globe's "safe operating" space (Rockström et al. 2009: 1) into an unsafe and unpredictable future where dangerous climate change can induce mean temperature increases of over 2 deg Celsius. If effective adaptation is good development conceived and implemented with adaptation in mind, transformation is good development with adaptation and mitigation in mind. This means that adaptation requires alterations of the "fundamental attributes" of existing technological, governance, and value systems, especially where vulnerability is high and adaptive capacity low, as in most urban areas of the global South (IPCC 2011).

It is this concept of transformative action (IPCC 2011, Roberts et al. 2012) that distinguishes adaptation from good or resilient development. Bouncing back, recovery, return to a previous state or capacity level, retaining identity or functional persistence is implicit in many of the current resilience-focused climate change debates. This can produce climate change resilience in the short term but it does not help address the need for ecologically sustainable patterns of urbanization including the contribution that urban centres must make to reductions in greenhouse gas emissions (Roberts et al. 2012, Pelling 2011, Fünfgeld and McEvoy 2011, Leichenko 2011). As more national and city governments and firms enter into this debate and begin to adapt, so increased attention is being paid to the factors that contribute to or hinder effective transformative action.

8.5.2. What Contributes to Cities Developing Effective Transformative Adaptation Plans?

Opportunities from future urbanisation: United Nations projections suggest that in the next 40 years, the world's urban population will nearly double (United Nations 2012) so this means a need to build the same scale of urban infrastructure in these 40 years as in the past 4000 years (ICLEI, 2011a). Indeed, the next 40 years has to do more than this as it has to address the very large deficits in urban infrastructure in the global south. Much of this growth is likely to be outside the largest cities and city-regions. This provides a transformative opportunity at a global level to break away from unsustainably lifestyles and patterns of development and ensure that urban areas develop in ways that delink a high quality of life from high resource use and greenhouse gas emissions. This represents a significant opportunity to urbanise the adaptation agenda, and converge climate mitigation and adaptation actions.

Water as an early focal point for action: Many urban adaptation plans focus strongly on water management as it is one of the primary media through which climate change impacts are be felt by people, ecosystem and economies (Schutze 2011, Heleen-Lydeke et al. 2011). Issues of quantity and quality, runoff and waste water management under climate change conditions are being incorporated into the adaptation thinking and planning of diverse range of cities (e.g. Toronto, Seattle, New York, London, Durban, Semerang, Indore and Copenhagen) (Kazmierczak and Carter, 2010, US EPA 2011, GLA 2011, Roberts 2010, Tyler et al. 2010, TARU 2010, City of Copenhagen 2011). While issues of water scarcity and flood management provide an obvious institutional and conceptual hook to draw local authorities into adaptation agendas and to encourage early, low risk action, other issues such as the emerging 'green economy' may provide equally useful anchors – highlighting the job creation and investment promotion advantages of adaptation.

Leading with ecosystem based adaptation: Section 8.4 noted how a growing number of cities are recognizing that biodiversity and ecological integrity can be used to protect people and the resources on which they depend. Ecosystem-based adaptation is regarded as one of the more cost effective and sustainable approaches to adaptation given what needs to be spent to manage and preserve ecosystems and the climate adaptation value derived from that spend (TNC 2009, Heleen-Lydeke et al. 2011). Ecosystem conservation and restoration can be regarded as a viable investment option in support of a range of adaptation linked policy goals including food security, urban development, water purification and waste water treatment, regional development and climate change mitigation and adaption. But there are considerable knowledge gaps in determining the limits or thresholds to adaptation of various ecosystems and where and how ecosystem based adaptation is best integrated with other adaptation measures. There is also some indication that the costs of ecosystem based adaptation in urban contexts might be higher than expected, in large part because costs are higher for land acquisition and for land development limitations (Roberts et. al. 2012).

Links between adaptation and mitigation: Initially, mitigation received more attention in urban areas, in part, because of political fear that pursuing adaptation might undermine the importance of mitigation (Satterthwaite 2008, Heleen-Lydeke et al. 2011, Bulkeley et al. 2011, Heinrichs et al. 2011, Moser 2012). The identification of positive synergies may help focus more attention on adaptation as discussed in 8.3 in regard e.g. to green infrastructure. Similarly, increasing the size of urban open space networks and tree planting to decrease the urban heat island effect (adaptation) and reduce energy demand to cool buildings (mitigation) indicates the complementarity between the two agendas. Case studies also suggest that the achievement of "other sustainability benefits associated with the use of green and blue infrastructure (e.g. climate change mitigation, biodiversity conservation) often seems to be a more significant trigger for action than the climate change adaptation agenda itself" (Kazmierczak and Carter 2010 :140). A similar relationship exists between climate change adaptation and the disaster risk reduction agenda as reducing risk can provide a compelling vehicle for adaptation action (see 8.3.2.2)

Institutional changes are needed to support city adaptation strategies (Lowe *et al*. 2009, Roberts 2008, Kazmierczak and Carter 2010). Transformative action necessitates working across city departments and jurisdictions and aligning national and regional governments' legal and regulatory frameworks, policies and inter-governmental resource flows. Many local government decisions are bounded or constrained by higher levels of government – but they could also be enabled by these. The use of sectoral champions to carry the adaptation message forward (e.g. Durban) and the need for dedicated staff to build institutional memory and prevent the message being lost or diluted (e.g. Chicago, Toronto) are also important considerations. Continuity is particularly important given the circuitous and iterative nature of adaptation and the need to deal with institutional limitations, lack of resources, limited buy-in and competing powerbases which hinder progress (Roberts 2010).

Engaging Stakeholders and awareness raising: There is a need for dialogue and opportunities to advance the adaptation agenda through internal and external collaboration. These range from cross-cutting technical advisory groups often with sectoral or task group focal areas (Lowe et al. 2009, Parzen 2009, Boston 2011, City of New York 2011, Heleen-Lydeke et al. 2011) to more broadly representative multi-stakeholder or multi-departmental groups with a core working group (Tyler et al. 2010, Roberts 2010, Brown et al. 2012, Boston 2010, Kazmierczak and Carter 2010, Anguelovski and Carmin 2011). Equally important is building public awareness and support for adaptation as transformation at a "neighborhood by neighborhood" level (Foster et al. 2011, also Kazmierczak and Carter 2010). Stakeholder engagement at the public and community level on needs and priorities is one of the key functions of local government and is especially important where large sections of the population live and work in informal settlements and include a high proportion of those most at risk from climate change. Awareness raising and knowledge sharing has therefore been identified as a critical part of adaptation planning (Kazmierczak and Carter 2010) as also support for community-based adaptation that can work with local government led adaptation initiations.

Focusing local attention on adaptation and risk reduction: This can occur by responding to existing challenges (for instance extreme weather events) and opportunities (for instance disaster risk reduction after a disaster that 'builds back better' (Lyons 2009) in ways that enhance adaptive capacity (Kazmierczak and Carter, 2010). Experience to date on this is mixed and it depends on how successfully disaster risk reduction and adaptation become embedded within local development processes and the extent to which they address the structural causes of vulnerability (Pelling 2011). The experience with disaster risk reduction has much to contribute to adaptation – for instance its far more detailed, locally rooted analyses of risk and vulnerability, its recognition that most disasters are the result of a failure to identify and act and its focus on multi-level government responses that recognize the central role of local government and other local institutions but also the importance of supportive policies, institutions and legislation at higher levels of government (see 8.3.2.2). But disaster risk reduction is informed by analyses of past disasters; climate change adaptation needs to also be informed by new risks and vulnerabilities. Other means of generating local interest are the possible co-benefits such as enhanced competitiveness, improved service delivery, economic resilience (and success), job creation and risk management and these help get the attention of politicians (e.g. Durban, London, New York and Copenhagen) (Foster et al. 2011, Roberts 2010, GLA 2011, City of New York 2011, City of Copenhagen 2011).

Institutional and social learning: Adaptation planning requires that urban areas plan for an uncertain future using scenario-based projections about the future, often with limited or unreliable data about the past. It includes hazard and risk assessment; vulnerability assessment; capacity/institutional assessment and capacity building. Successful adaptation requires a learning organization that adapts to changing environmental factors and incorporates new data on a regular and flexible basis – producing an iterative process of learning about changing risks and opportunities and drawing in different stakeholders. This is difficult to achieve in the situation of 'organized' chaos that prevails in many local governments around the world, with weak governmental structures, lack of funding and trained staff, where "decisions are delayed, correspondences lost in bureaucratic black-holes and ascription of responsibility is obfuscated" (Kithiia 2009, also Brown 2011). Social learning is also critical to ensure new ideas are popularized and commonly articulated in society (Pelling 2011), translating stakeholder engagement into adaptation action.

The importance of mainstreaming climate change adaption requirements into municipal planning systems, building codes and land-use management: This chapter opened with an acknowledgement that local governments must provide the frameworks that ensure that investments and actions by businesses and households contribute to adaptation. An important part of this is providing an appropriate regulatory framework in the management of land use (with new sites available for development and key ecological services protected) and the application of building standards within their jurisdiction. Although mainstreaming climate change adaptation through municipal planning systems such as policies, action plans, subsidies and incentives (Kazmierczak and Carter 2010, Brown 2011, Heleen-Lydeke et al. 2011) is a major avenue for transformation, it is necessary to avoid overloading already complex and inadequate planning systems with new requirements (Kithiia 2010, Roberts 2008). Other challenges include the lack of information, institutional constraints and resource limitations and in many nations a strong rural (rather than urban) adaptation focus (Brown 2011). Where mainstreaming is possible, however, it ensures that limited financial resources are spent "with adaptation needs in mind" (Lowe et al. 2009) and fosters a move to a risk-based design for a range of future projected climate conditions. This can be enhanced further by encouraging each sector to consider its need for and role in adaptation action. A sectoral approach makes the climate message easier for local governments and other stakeholders to understand and the associated responsibilities and actions clearer and simpler to identify and assign (Roberts 2010, UN-Habitat 2011). Most city adaptation strategies include some pilot projects, which are useful in rooting the often vague concept of adaptation in a practical reality (Roberts 2010, Tyler et al. 2010) but often do not provide the evidence required for scaling up.

The importance of champions for adaptation in local government (Lowe et al. 2009, Roberts 2008, Parzen 2009, Shaw and Theobald 2011, Anguelovski and Carmin 2011, Carmin et. al. 2012, Heleen-Lydeke et al. 2011, Martins and Ferreira 2011) . The role of local government champions is often critical in providing initial leadership (e.g. Sydney, Chicago, New York, Durban, London) and promoting and sustaining the adaptation agenda. Such leadership may face a lack of continuity due to changes in positions or people leaving office. It is important therefore to develop a broad base of support for adaptation across many sectors - within and outside government - so that progress is not stalled or undermined by leadership changes. Champions, regardless of their location or affiliation are important stakeholders in sustaining and driving successful adaptation action (Kazmierczak and Carter 2010).

Networking and sharing experiences amongst practitioners: The value of sharing experiences and practices amongst urban practitioners is generally valued as shown by the existence of a number of city focused adaptation networks and of city networks that initially focused on mitigation and that now give more attention to adaptation (see 8.4.2.6). Peer influence and learning, as well as reputational issues are also powerful motivators for local governments beginning to tackle climate adaptation (Carmin et al. 2012, Foster et al. 2011, GLA 2011, Kazmierczak and Carter 2010).

Scientific support and the creation of an evidence base for adaptation action (Lowe et al, 2009, Roberts 2008, Kazmierczak and Carter 2010): There is a need for access to reliable, accurate, useable scientific data. Even where these are available, however, local government staff often cannot utilize them because of the language gap between information producers (scientists) and information users (local decision makers) (Lowe et al. 2009, Opitz-Stapleton 2010). In these circumstances, local level risk assessments of existing hazards, challenges and vulnerabilities that are likely to be exacerbated by climate change could offer a useful alternative starting point and facilitate the creation of an appropriate evidence base (Tyler et al. 2010, Kazmierczak and Carter 2010). Collaboration and partnerships with research institutes and external agents such as consultancies (especially those with local knowledge) (e.g. Durban Chicago, Seattle, Manchester) can also be useful tools for gaining knowledge about climate impacts from a trusted source (Lowe et al. 2009, Kazmierczak and Carter 2010).

Catalytic role of multilateral and bilateral funding: While conventional delivery institutions through multilateral and bilateral channels appear to be playing the biggest role in adaptation financing (Ayers 2008), there is an emerging argument that that finance for resilience and adaptation needs to be demand-driven, rather than having conventional top-down global financing mechanisms determining which local actions are eligible for funding (ICLEI 2011b, Brugmann 2012). This demand-driven model of urban adaptation financing may be a pilot case of demand-driven finance in other areas. Current case studies also suggest that there is substantial spend on adaptation from the local and national level fiscus in many nations (Kazmierczak and Carter 2010).

Phased approaches: A phased approach that prioritizes the most urgent matters (rapid onset disasters) or near term climate impacts, leaving a longer time period to plan for those impacts that may occur in the future and be associated with greater uncertainty (slow onset disasters) is most likely to attract local government attention (Foster et al. 2011, City of Copenhagen 2011, Boston 2011, Wajih et al. 2010). For the slow-onset impacts, strategic forward planning is critical, and existing planning instruments such as land use planning may need to be altered to take changes in climatic stressors into account. Often the initial phases of action are made possible by the existence of previous or current environmental initiatives, or strong environmental traditions at the local level (Kazmierczak and Carter 2010).

8.5.3. *What Hinders Adaptation Progress in Urban Areas?*

Lack of mandate: There is a need to clarify which level (national, provincial and local) sphere of government has a legal mandate to act on climate change through the promulgation and assignment of appropriate constitutional and legal powers. Without these formal mandates, adaptation becomes an optional and discretionary extra, dependent on local level interest and resources and particularly vulnerable to leadership change. Although much of the innovation in urban adaptation has come from particular local governments, for these to become effective at a national scale needs support from higher levels of government. Where mandates exist they have been important in driving local level action (Kazmierczak and Carter 2010) but need co-ordination if they as shared between the different levels and spheres of government (Martins and Ferreira 2011). This has also highlighted the "importance of policy and legislative frameworks at higher levels" which provide the basis for adaptation responses within local authorities or other organisations (Kazmierczak and Carter 2010, also Carter 2011, Brown 2011, Martins and Ferreira 2011). Challenges emerge, however, when the required adaptation action extends outside the boundaries of local government as this requires high levels of co-operative and multi-level governance (Carter 2011) which is often difficult to achieve given problematic governance systems, particularly in the global South.

Political obstacles: In urban areas decisions, including those related to climate change adaptation, are affected by political interests and the competition for support (Heleen-Lydeke et al. 2011). Those who are most at risk from climate change are often those with the least voice and influence in local decisions. Addressing constraints such as information and resources alone will not ensure transformation if there is political resistance, particularly as political leaders control local level resources (Roberts 2008). A further complicating factor is the disjuncture between political and climate time lines (Mes and Driessen, 2011). This sets short-term (often personal advancement) priorities against generational, public good impacts of climate change adaptation making communicating and negotiating climate change related objectives in the political space often very difficult to achieve (UN-Habitat, undated).

The constraints on transformative approaches: Even under existing patterns of climate variability there are many competing priorities, with most local governments already "involved with everything from babies to bitumen" (Measham et al. 2010). There is also a concern that in the current recessionary environment that local authorities will prioritise conventional economic goals and conventional infrastructure and service delivery. So the climate change agenda becomes an additional burden displaced by seemingly more urgent, short-term priorities (Shaw and Theobald 2011) given that financial capacity is already a limiting factor in many urban areas (Martins and Ferreira 2011, Heleen-Lydeke et al. 2011). This is further complicated by "compartmentalization and institutional fragmentation (Heleen-Lydeke et al. 2011) which prevents effective integration within urban governance structures. The current lack of resources and capacity in urban areas, however, also offers an opportunity by encouraging environmental entrepreneurship and innovation in the development of novel adaptation approaches (Anguelovski and Carmin 2011).

The weakness of climate change focal points within local government: These are often housed in or championed by environmental line department which leads to marginalisation (Roberts 2010, Hardoy and Romero Lankao 2011 and limited institutional influence and access to resources given the low priority usually assigned to environmental departments. Climate change adaptation is also so often seen as an environmental problem, not as a problem needing changed approaches in all sectors and departments. This situation is exacerbated by the lack of awareness "of the need for adaptation, within and outside the organisation" resulting in low prioritisation of adaptation on the policy agenda (Kazmierczak and Carter 2010).

Undervaluing community resources and social capital: Although 8.3.2.4 and 5 gave examples of the effectiveness of household and community based adaptation in urban contexts, there is still limited work and limited understanding of the potentials and limitations (Jones et al. 2010). This is a critical gap given that social capital may provide opportunities to achieve the "bouncing forward" required by adaptation, as community collaboration, relationships and trust can provide a platform to generate material interventions directed at reducing vulnerability (Kithiia 2009). The issue of social capacity has been identified as important to urban resilience in a number of urban areas (TARU

2011, Habitat undated d, Roberts 2010) but there is also a need to determine the limits of community based intervention; for example, communities cannot install, maintain and fund infrastructure and services at scale.

Assumption that good development produces adaptation: As 8.1 made clear, adaptation is well served by good infrastructure and services and the institutional capacity to provide, and manage these and expand these when needed. This provides a foundation for building climate change resilience but it needs additional knowledge, capacity and skills beyond this (or the use of existing funding and knowledge in new and creative ways). Some evidence (especially in the urban areas of the global South) suggests that new patterns and forms of urban development and new management skills are required (e.g. restoring deforested areas to sequester carbon, protecting catchments, creating employment, identifying new staple food crops) (Roberts 2010, Roberts et. al. 2012) These generate the need for a new understanding of what might constitute progress, and new ways to set targets and measure this progress (Foster et al. 2011, Shaw and Theobald 2011, Roberts 2010). Thus, there is a need to increase the profile of adaptation over and above the concept of 'good development' (Kazmierczak and Carter 2010).

Prioritising poverty reduction within the climate change responses: There is a dichotomy between the global North and global South in the emphasis placed on poverty and its reduction through adaptation action. While cities like Boston and London consider low-income groups among the vulnerable groups in their planning (Boston 2011, GLA 2011) for most cities in low and middle income nations, poverty reduction needs more attention within any climate agenda because of the strong association between poverty and environmental health risks (Hardoy et al. 2001) and more specifically climate change risks (Hardoy and Romero Lankao 2011). Given the scale of the pressing development needs of these cities (e.g. infrastructure, public health, education, housing and energy) and the rapid urbanization of poverty, climate change adaptation needs are viewed as marginal in comparison. Without combating urban poverty and supporting more robust sources of livelihood, little will be achieved in either mitigation or adaptation in low income countries (Kithiia 2010). There is therefore a need to demonstrate how adaptation can support development that is safe and cost effective (Kazmierczak and Carter 2010) and reduces poverty. As a result, any adaptation strategy must be crafted within the development context of the city or country (Kithiia and Dowling 2010, Roberts 2008) and requires harmonization with priorities such as poverty reduction, food security, provision for safe sufficient water and for effective sanitation and disaster management (UN-Habitat, undated b). However, it should be noted that much of the resilience to climate change in cities in high-income nations relate to the investments made in extending infrastructure and services to their low income populations – and these came out of political changes that allowed more voice and influence to low-income groups (Satterthwaite 2011).

The complexities of developing locally relevant adaptation plans: Mitigation-focused interventions provided the early experiential training ground for most local governments engaging with climate change for the first time. These were usually based on step-wise guidebooks or programmes (e.g. ICLEI's Cities for Climate Protection Programme) (Anguelovski and Carmin 2011, Martins and Ferreira 2011). Experience with adaptation programmes show these are less open to a standard set of requirements, given that the actions are often complex, rooted in local particulars, chaotic, cross-sectoral, cross-institutional, operate across a range of scales and timelines, involve more stakeholders and include a high level of uncertainty (Roberts et. al. 2012). More than standardised guidelines, urban adaptation practitioners need clarity, creativity, and courage (ICLEI Oceania 2008).

Dealing with uncertainty: Adaptation costs are immediate, a fact which contrasts with the uncertainty associated with climate change projections and the likely delay in the benefits (OECD 2010). In order to make effective use of available climate information despite "the large uncertainties and unfamiliar or unhelpful data formats" (Tyler et al., 2010) and the "varying degrees of confidence attached to the modeled climate signals" (Hunt and Watkiss 2011: 19) a pragmatic approach is to focus on existing vulnerabilities and to use those to identify 'no-regrets' options with near and long-term co-benefits. The use of scenario planning rather than scaled down projections, the undertaking of further studies to develop better local data, avoiding maladaptation and increasing awareness also contribute to increased adaptive capacity (Tyler et al. 2010, OECD 2010, TARU 2010). Facilitating networking and learning between adaptation practitioners also assists in improving the capacity to deal with uncertainty (Heleen-Lydeke et al. 2011). While understanding the costs of inaction is also important for dealing with institutional hesitancy that can come from confronting uncertainty

The issue of thresholds and conflicting agendas in getting co-benefits: Most local governments acknowledge the value of mitigation and adaptation, but the tendency is for cities to treat adaptation and mitigation separately and to lead with one or the other depending on circumstances, priorities, resources and institutional affiliations (Roberts 2010, Carmin et al. 2012, Hamin 2011, Moser 2012). The result is that little progress has been made in ensuring that adaptation and mitigation policy goals are not in conflict (Hamin and Gurran 2009, Moser 2012).

Section 8.3.3.7 discussed what Hamin and Gurran, 2009 described as the “density conundrum” where the densities that serve mitigation can prevent or limit the possibilities of ecosystem based adaptation and may also exacerbate the urban heat island and limit the possibility of utilizing solar energy. There is therefore an urgent need for research to determine the thresholds for unacceptable biodiversity change in urban areas and to derive from these local specific limits to urban densification.

It has been suggested that the appropriate response to this density conundrum is to provide multi-use greenspace along linear features (transport routes and rivers and floodplains) with larger open areas being limited to the urban periphery (Hamin and Gurran, 2009). This makes little biological sense, especially where urban areas are located in areas of high biodiversity and endemism and where there is a need to conserve sizeable natural areas within the heart of the urban fabric to meet local, national and international conservation targets and the associated ecosystem services they deliver. Both Durban and Cape Town face this dilemma (EThekwini Municipality 2007, Holmes et al. 2008). Given that biodiversity is key to the “continued functioning of complex ecosystem interactions which underpin the habitability of the planet and provide a host of services to humans” (Gill et al. 2009:9) it is critical that there is a more careful integration of the various climate agendas adaptation and mitigation agendas, and that climate actions do not undermine other global environmental change such as biodiversity (Moser 2012).

The issue of thresholds is also relevant beyond biodiversity concerns, for example, determining when and where adaptation is no longer possible in urban areas, due to technical difficulties or cost (or both) resulting in residual damage (UN-Habitat 2011, Parry et al. 2009). This knowledge about limits within existing systems will be vital in developing appropriate transformative planning responses to future climate challenges, especially as there is increasing concern that the current state of global inaction and lack of ambition on mitigation could result in 4 degrees of global warming, with much larger impacts and adaptation challenges than the 2 degree limit (Warren 2011). Adaptation in a 4 degree world will have to be a “more substantial, continuous and transformative process” (Smith et. al. 2011:196) than for a 2 degree world, and will have to contend with the possibility of thresholds, that once crossed, will lead to abrupt, non-linear and unpredictable global environmental change (Rockström et al. 2009). This will stretch the adaptive capacity not only of existing urban systems, but of the whole global system.

Role of international institutions: The adaptation efforts of local governments are mostly a response to internal motivations (e.g. perception of threat, city agendas, leadership, improving city image) (Anguelovski and Carmin, 2011, Carmin et. al. 2012, Kazmierczak and Carter 2010) but in low- and many middle-income nations. The lack of skills and resources in local governments gives international institutions an important role in initiating and shaping the adaptation agenda. These international programmes are often the main form of institutional and financial support to mitigation and adaptation work at local level. The danger of the donor driven model is that the funding agency’s agenda may not coincide with local priorities, resulting in little lasting local ownership once support is withdrawn. The manner in which information is delivered by international agencies during these programmes is also critical in determining the efficacy of the intervention. Local decision-makers access and use scientific and expert information about climate change differently to the research community, relying more on informal sources and formats such as colleagues and the internet (Corfee-Morlot et al. 2011). Failure to note this distinction can result in a significant waste of effort and resources.

Poorly developed Monitoring, Reporting and Feedback systems: Monitoring, reporting and verifying the development and implementation of adaptation plans is still evolving and not well developed or widely implemented in urban areas (Kazmierczak and Carter 2010). Work is required in this regard, but it is likely to be challenging given the localized nature of adaptation and hence the difficulty of standardizing performance requirements and measurements (Anguelovski and Carmin 2011). The challenge of distinguishing adaptation from development (and one must question if that is even desirable) and the limited quantification and monetization of climate change impacts and adaptation responses in urban areas (Hunt and Watkiss 2011) add further layers of complexity. This is one of the most significant challenges facing the global implementation of tools such as the Durban Adaptation Charter.

Frequently Asked Questions

FAQ 8.1: How does disaster risk reduction relate to climate change adaptation?

There is a 30 year experience with disaster risk reduction that has developed methodologies for locally-driven identification of key hazards, risks and vulnerabilities to disasters and that identifies what should be done to reduce disaster risk. Its importance is that it encourages local governments to act before a disaster – for instance for risks from flooding, to reduce exposure and risk as well as being prepared for emergency responses prior to the flood (eg temporary evacuation from places at risk of flooding) and rapid response and building back afterwards. In some nations, national governments have set up legislative frameworks to strengthen and support local government capacities for this. This is a valuable foundation for assessing and acting on climate-change related hazards, risks and vulnerabilities, especially those linked to extreme weather, and an effective network of disaster risk reduction institutions provides an important component of adaptive capacity. But climate change adaptation needs to take account of how hazards, risks and vulnerabilities will or might change over time. Disaster risk reduction also covers disasters caused by earthquakes, volcanos and other hazards that are not linked to climate change.

FAQ 8.2: Doesn't good development produce urban adaptation?

Adaptation is well served by good infrastructure and services and the institutional capacity to provide, and manage these and expand these when needed. This provides a foundation for building climate change resilience but it needs additional knowledge, capacity and skills beyond this, especially to build resilience to changes beyond the ranges of what have been experienced in the past.

FAQ 8.3: Wouldn't urban problems be lessened by rural development?

The movement of rural dwellers to live and work in urban areas is mostly in response to the concentration of new investments and employment opportunities in urban areas. All high-income nations are predominantly urban and increasing urbanization levels are strongly associated with economic growth. Economic success brings an increasing proportion of GDP and of the workforce in industry and services, most of which are in urban areas. While rapid population growth in any urban centre provides major challenges for its local government, the need here is to develop the capacity of local governments to manage this with climate change adaptation in mind. Rural development and adaptation that protects rural dwellers and their livelihoods and resources has high importance as stressed in other chapters – but this will not necessarily slow migration flows to urban areas, although it will help limit rural disasters and those who move to urban areas in response to these.

FAQ 8.4: Shouldn't urban adaptation plans wait until there is more certainty about local climate change impacts?

More reliable, locally specific and downscaled projections of climate change impacts and tools for risk screening and management are needed. But local risk and vulnerability assessments that include attention to those risks that climate change will or may increase provide a basis for incorporating adaptation into development now. Much infrastructure has a life of many decades so infrastructure investments made now need to consider what changes in risks are likely during its lifetime. In addition, the incorporation of climate change adaptation into each urban centre's development planning and investments is well served by an iterative process within each locality of learning about changing risks and opportunities to inform an assessment of policy options and decisions.

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Table 8-1: The distribution of the world's urban population by region, 1950–2010 with projections to 2030 and 2050.

Urban population (millions of inhabitants)						
Major area, region, country or area	**1950**	**1970**	**1990**	**2010**	**Projected for 2030**	**Projected for 2050**
World	745	1,352	2,281	3,559	4,984	6,252
More developed regions	442	671	827	957	1,064	1,127
Less developed regions	304	682	1,454	2,601	3,920	5,125
Least developed countries	15	41	107	234	477	860
Sub-Saharan Africa	20	56	139	298	596	1,069
Northern Africa	13	31	64	102	149	196
Asia	245	506	1,032	1,848	2,703	3,310
China	65	142	303	660	958	1,002
India	63	109	223	379	606	875
Europe	281	412	503	537	573	591
Latin America and the Caribbean	69	163	312	465	585	650
Northern America	110	171	212	282	344	396
Oceania	8	14	19	26	34	40
Percent of the population in urban areas						
World	29.4	36.6	43.0	51.6	59.9	67.2
More developed regions	54.5	66.6	72.3	77.5	82.1	85.9
Less developed regions	17.6	25.3	34.9	46.0	55.8	64.1
Least developed countries	7.4	13.0	21.0	28.1	38.0	49.8
Sub-Saharan Africa	11.2	19.5	28.2	36.3	45.7	56.5
Northern Africa	25.8	37.2	45.6	51.2	57.5	65.3
Asia	17.5	23.7	32.3	44.4	55.5	64.4
China	11.8	17.4	26.4	49.2	68.7	77.3
India	17.0	19.8	25.5	30.9	39.8	51.7
Europe	51.3	62.8	69.8	72.7	77.4	82.2
Latin America and the Caribbean	41.4	57.1	70.3	78.8	83.4	86.6
Northern America	63.9	73.8	75.4	82.0	85.8	88.6
Oceania	62.4	71.2	70.7	70.7	71.4	73.0
Percent of the world's urban population						
World	100.0	100.0	100.0	100.0	100.0	100.0
More developed regions	59.3	49.6	36.3	26.9	21.4	18.0
Less developed regions	40.7	50.4	63.7	73.1	78.6	82.0
Least developed countries	2.0	3.0	4.7	6.6	9.6	13.8
Sub-Saharan Africa	2.7	4.1	6.1	8.4	11.9	17.1
Northern Africa	1.7	2.3	2.8	2.9	3.0	3.1
Asia	32.9	37.4	45.2	51.9	54.2	52.9
China	8.7	10.5	13.3	18.6	19.2	16.0
India	8.5	8.1	9.8	10.6	12.2	14.0
Europe	37.6	30.5	22.0	15.1	11.5	9.5
Latin America and the Caribbean	9.3	12.1	13.7	13.1	11.7	10.4
Northern America	14.7	12.6	9.3	7.9	6.9	6.3
Oceania	1.1	1.0	0.8	0.7	0.7	0.6

Source: Derived from statistics in United Nations 2012.

Table 8-2: The large spectrum in the capacity of urban centres to adapt to climate change. [Note: One of the challenges for this chapter is to convey the very large differences in adaptive capacity between urban centres. There are tens of thousands of urban centres worldwide with very large and measureable differences between them in population, area, economic output, human development, ecological footprint and greenhouse gas emissions. The differences in adaptive capacity are far less easy to quantify. This Table seeks to illustrate differences in adaptive capacity and factors that influence it.]

Indicator Clusters	**Very little recovery/ 'bounce-back' adaptive capacity**	**Some recovery/ 'bounce-back' adaptive capacity**	**Adequate recovery/ 'bounce-back' adaptive capacity, if acted on**	**Climate Resilience**	**Transformation**
Population served with risk-reducing infrastructure (paved roads, storm and surface drainage, piped water ….) and services relevant to resilience (including health care, emergency services, policing/rule of law) and the institutions needed for such provision	0-30% of the urban centre's population served; most of those unserved or inadequately served living in informal settlements	30-80% of the urban centre's population served; most of those unserved or inadequately served living in informal settlements	80-100% of the urban centre's population served; most of those unserved or inadequately served living in informal settlements	Most/all of the urban centre's population with these and with an active adaptation policy identifying current and likely future risks and with an institutional structure to encourage and support action by all sectors and agencies. In many cities, also address and upgrade ageing infrastructure	Urban centres that have integrated their development and adaptation policies and investments within an understanding of the need for mitigation and limited ecological footprints
The proportion of the population living in legal housing built with permanent materials (meeting health and safety regulations)				Active programme to improve conditions, infrastructure and services to informal settlements; identify and act on areas with higher/increasing risks. Revise building standards.	Land use planning and management successfully providing safe land for housing, avoiding areas at risk and taking account of mitigation
Proportion of urban centres covered	Most urban centres in low-income and many in middle-income nations	Many urban centres in many low-income nations; most urban centres in most middle income nations	Virtually all urban centres in high-income nations, many in middle-income nations	A small proportion of cities in high-income and upper-middle income nations	A few innovative city governments thinking of this and taking some initial steps
Estimated inhabitants of such urban centres	One billion	1.5 billion	1 billion	Very small	
Infrastructure deficit	Much of the built up area lacking infrastructure		Most or all the built up area with infrastructure (paved roads, covered drains, piped water…..)		
Local government investment capacity	Very little or no local investment capacity		Very substantial local investment capacity		
Occurrence of disasters from extreme weather[1]	Very common		Uncommon (mostly due to risk-reducing infrastructure, services and good quality buildings available to almost all the population		

Examples	Dar es Salaam; Dhaka	Nairobi, Mumbai	Cities in high-income nations	New York?; London? Manizales?	
Implications for climate change adaptation	Very limited capacity to adapt. Very large deficits in infrastructure and in institutional capacity. Very large numbers exposed to risk if these are also in locations with high levels of risk from climate change	Some capacity to adapt, especially if this can be combined with development but difficult to get city governments to act. Particular problems for those urban centres in locations with high levels of risk from climate change	Strong basis for adaptation but needs to be acted on and to influence city government	City government that is managing land-use changes as well as having adaptation integrated into all sectors	City government with capacity to influence and work with neighbouring local government units. Also with land-use changes managed to protect eco-system services and mitigation
NB: For cities that are made up of different local government areas, it would be possible to apply the above at an intra-city or intra-metropolitan scale. For instance, for many large Latin American, Asian and African cities, there are local government areas that would fit in each of the first three categories					

[1] See text in regard to disasters and extensive risk (United Nations, 2011).

Table 8-3: Main financial instruments to green urban development and infrastructure investment.

<table>
<tr><td></td><td>Developed Country Cities</td><td colspan="3">Developing Country Cities</td></tr>
<tr><td></td><td></td><td>High Income</td><td>Medium Income</td><td>Low Income</td></tr>
<tr><td>Taxes</td><td colspan="3" rowspan="2">♦ Property taxes
♦ Land value capture taxes
♦ Congestion charges
♦ Parking fees
♦ Tariffs and fees (e.g. water)</td><td></td></tr>
<tr><td>Fees and charges</td><td></td></tr>
<tr><td>Public-Private-Partnerships (PPP) contracts and concessions</td><td colspan="3">♦ Concessions and private finance initiatives (PFIs) to build, operate and/or maintain key infrastructure
♦ Energy performance contracting</td><td></td></tr>
<tr><td>Market-based financing</td><td colspan="2">♦ Commercial loans,
♦ Municipal and private bonds</td><td></td><td></td></tr>
<tr><td rowspan="2">Grants, Concessional financing, Revenue transfers</td><td colspan="4">♦ Revenue transfers from central or regional government</td></tr>
<tr><td></td><td colspan="3">♦ Grants, concessional loans and loan guarantees through bilateral and multilateral development assistance
♦ Philanthropic grants</td></tr>
</table>

Source: adapted from OECD 2012 and World Bank forthcoming.

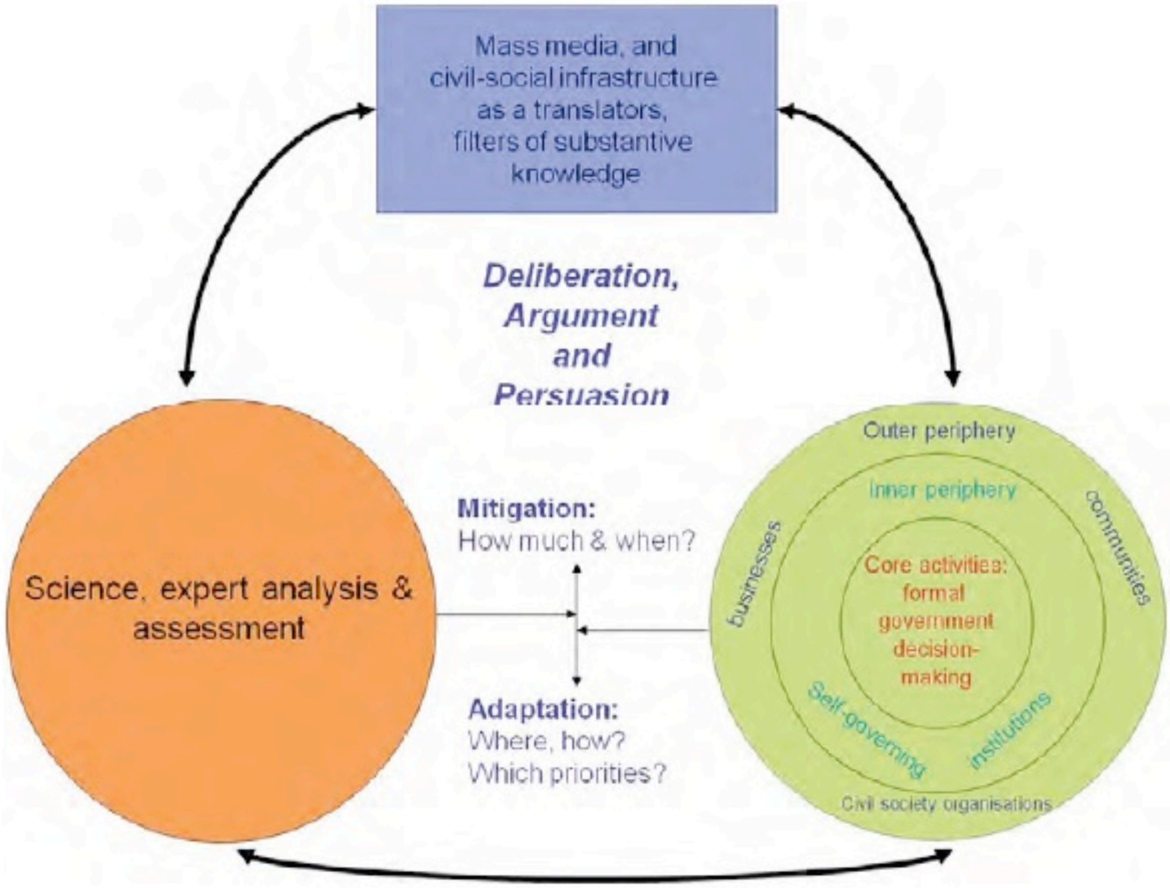

Figure 8-1: Circulation of power for public decision-making on climate change. Source: adapted from Corfee-Morlot, Cochran, Teasdale, and Hallegatte (2011).

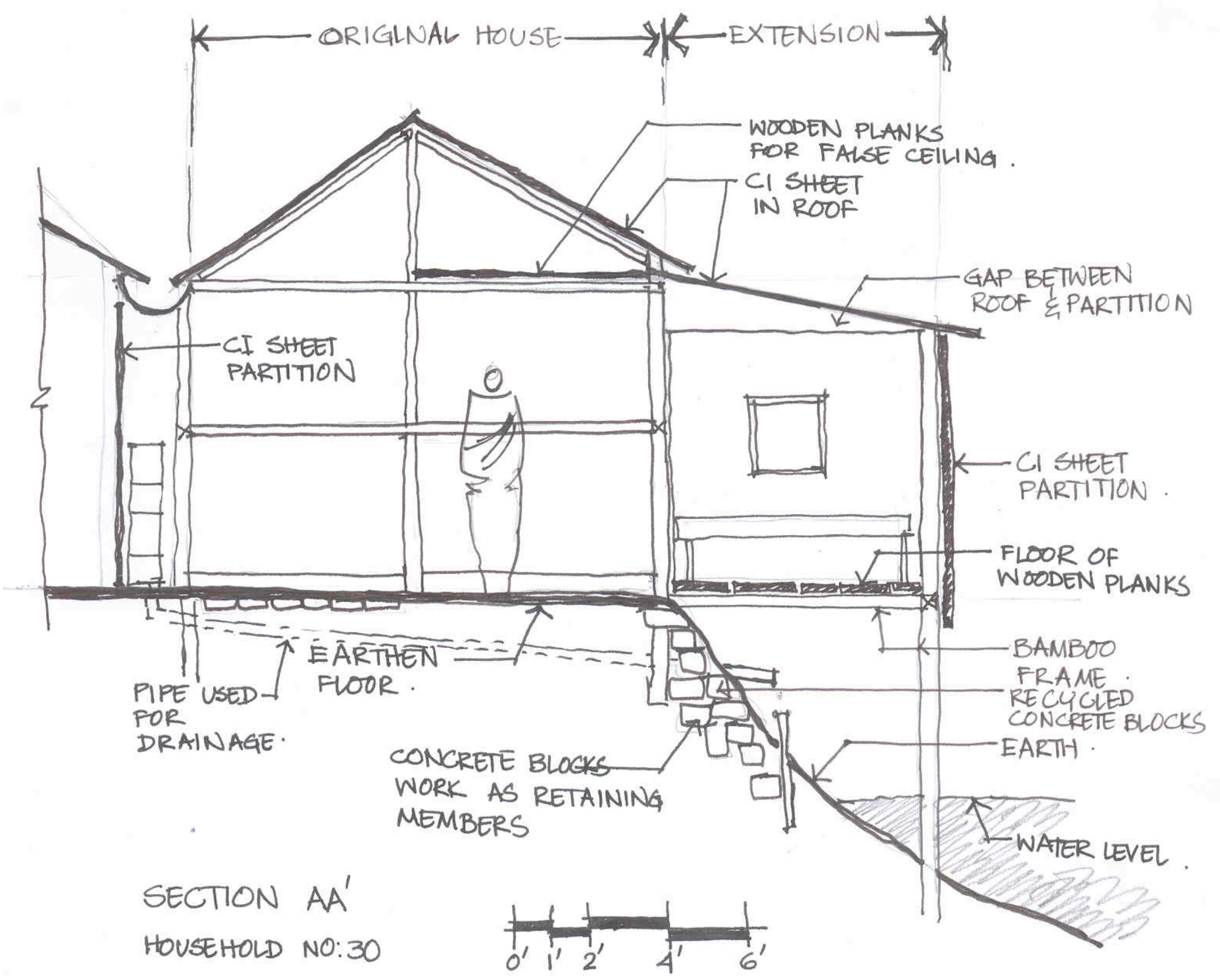

Figure 8-2: Household adaptation - a cross section of a shelter in an informal settlement in Dhaka (Korail) showing measures to cope with flooding and high temperatures. Source: Jabeen et al (2010).

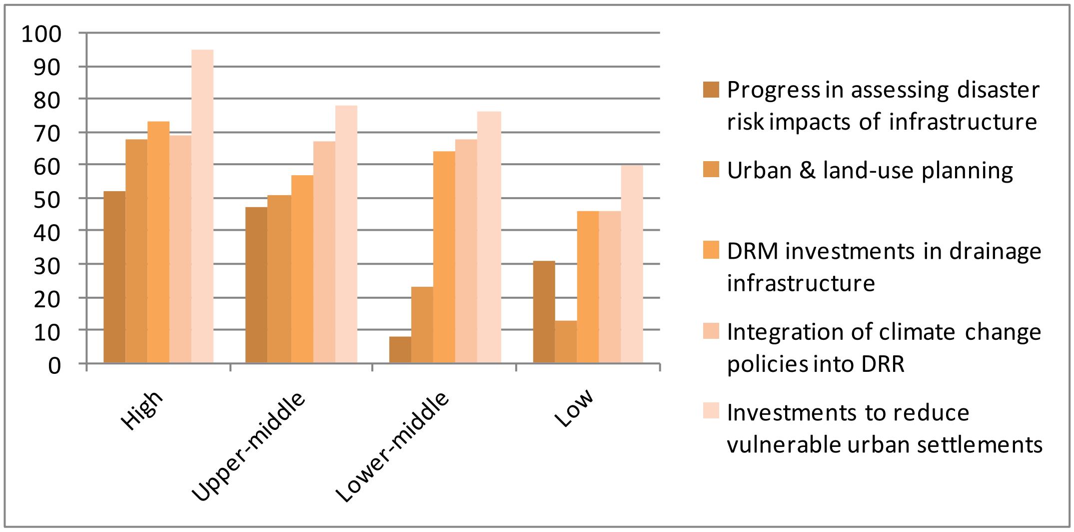

Figure 8-3: Progress reported by 82 governments in addressing some key aspects of disaster risk reduction by countries' per capita income. Source: United Nations (2011).

Figure 8-4: The basic challenge of effective climate change communication to change behavior and norms. Source: Moser and Luers (2008).