Chapter 8. Urban Areas

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Executive Summary

[to be developed]

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8.1.1. Key Issues

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8.1.3. Context – an Urbanizing World

The world's urban centres now house more than 3.5 billion people; over half the world's total population (see Table 8-1). This chapter describes how a large and growing proportion of this urban population is at risk from climate change impacts. United Nations projections suggest that the urban population in what are today low- and middle income nations will grow by 1.3 billion between 2010 and 2030; this represents almost all the growth in the world's population in these two decades since the urban population in high-income nations is projected to increase by less than 100 million and the world's rural population is projected to decrease by 13 million (United Nations 2010). Thus, the challenge facing national and urban governments is not only around building resilience for the current 3.5 billion urban dwellers but also for making provisions to build resilience to climate change impacts for this growth of 1.3 billion urban dwellers.

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

Urban populations are also expanding in almost all low and middle income nations; for some nations and many cities, very rapidly (United Nations 2010). This can increase the number exposed to climate-related risks and particularly sensitive to these risks. The high proportion of the world's urban population live in informal settlements with inadequate or no provision of the services, infrastructure, and institutional frameworks needed for climate change adaptation. The effects of climate change may be disproportionately borne by such dense, high-risk areas (Hardoy and Romero Lankao 2011: 158-9, UN-Habitat 2011). Low-income households may require particular assistance due to their 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 (Satterthwaite *et al*. 2007, Bartlett 2008, Hardoy and Pandiella 2009).

Urban centres also house the enterprises that generate most of the world's GDP (over 90 percent REF NEEDED) and are homes to a high proportion of the world's wealthy population. So in regard to adaptation, they include a high proportion of the world's assets – assets of households, businesses, cultures and public or private institutions. A large proportion of greenhouse gas emissions are generated within their boundaries or, less directly, by the consumption of their residents. Approximately 70% of the world's greenhouse emissions emerge from urban-related demands (Hoornweg et al. 2011). Urbanization can be considered as a continuous process that is always unfinished as cities and smaller urban centres continue to undergo transformations (Solecki and Leichenko 2006).

AR4 emphasized how human settlements have demonstrated a capacity to adapt to environmental conditions and resource availabilities. Every successful city has had to do so. The fact that cities concentrate people, enterprises and motor vehicles and their wastes could imply high levels of environmental health risks. But successful, well-governed cities demonstrate that this concentration can also be associated with good health standards - for instance in regard to low infant, child and maternal mortality rates and high life expectancies. The concentration of people and enterprises in cities not only provides economies of scale or agglomeration for business but also potential economies of scale or agglomeration for most forms of infrastructure and services that reduce environmental health risks (Hardoy et al 2001, Satterthwaite 2011). However, in a high proportion of the world's urban centres, these economies are not acted upon and there are very large deficits or deficiencies in provision for water, sanitation, drainage, health care, emergency services and disaster risk reduction.

The concentration of people (and their demands) and economic activities in urban centres also provides economies of scale and proximity for much of what constitutes adaptive capacity. This includes lower unit costs per person served in most forms of infrastructure and services that are central to adaptive capacity (refs). Many cities have demonstrated a capacity to reduce risks from local environmental hazards including extreme weather events on which climate change adaptation can build (Velasquez 1998, Hardoy et al 2001, Wilbanks, Romero Lankao et al 2007, IFRC 2010, UN Habitat 2011). As UN Habitat 2011 notes, "Perhaps not enough recognition has been given to the enormous progress achieved over the last 100–120 years within successful, well governed cities, in dramatically reducing environmental hazards and their impacts on potentially vulnerable populations. This is also an important part of why life expectancies have increased so much over the last 100-150 years in successful cities, including many in developing countries" (page xx)

Cities can be considered as "hubs of development" that can facilitate effective responses to climate change (Romero Lankao and Dodman 2011: 113) and that often have capacities to mobilize resources for investment in adaptation. But this depends on the effectiveness of city and municipal governments and their capacity to work with a range of government and civil society institutions at local and national level. Thus, urbanization is likely to bring increased risk levels to a range of climate-related hazards for a large and growing proportion of the world's population – while also having the potential to support increased adaptive capacity.

Many scholars have commented on the importance of equity issues in regard to the consequences of climate change and how they are connected to development challenges, particularly in low-income countries (O'Brien and Leichenko, 2000; Mirza, 2003; O'Brien et al, 2004; Tol et al, 2004; Thomas and Twyman, 2005; Paavola and Adger, 2006; Reid and Vogel, 2006). The close association of vulnerability and inequity is highlighted by contributions drawing attention to factors influencing individuals' or groups' capacity to anticipate, cope, resist and recover from the impact of a natural hazard (Bohle et al, 1994; Wisner, 2004). These factors (assets, sources of livelihood, class, race, ethnicity, gender and poverty) are also part of the discussion of social justice presented in approaches seeking higher states of social well-being (development, sustainable development and decentralization). Scholars have also raised awareness about equity issues in adaptation to climate change. Adger et al (2005) call attention to distributional issues of adaptation and to the balance between private and public costs and benefits of adaptation action. Their efforts to identify the criteria for success in adaptation recognize possible externalities at other geographical and temporal scales and the risk that actions effective for the adapting agent may produce negative externalities and spatial spill-overs, potentially increasing impacts upon others or reducing their capacity to adapt. Dow et al (2006) argue that a moral imperative exists for the most vulnerable people in adaptation efforts if social justice is to be achieved; as this chapter emphasizes, a significant proportion of the world's most vulnerable people live and work in urban areas.

Most cities have significant spatial and socioeconomic disparities in regard to vulnerability to environmental hazards (Stephens 1996, Hardoy et al 2001, GRNUHE 2010) and climate change may reinforce inequalities based on income, gender, or other differences (Terry 2009). In all urban centres, there are likely to be differentials within the population in vulnerability to climate change impacts – for instance by income group, age and gender (Bartlett 2008). These differentials are usually in all three of the components of vulnerability – exposure, sensitivity and adaptive capacity. Almost all the likely impacts of climate change may disproportionately affect low-income groups (see for example Revi 2008). Most of those who are killed or injured in most extreme weather events in urban areas and most of those who lose most or all their assets are from low-income groups (UN 2009, IFRC 2010, UN Habitat 2011). For low-income groups, the scale of these differentials are much influenced by the extent to which these groups can find and afford accommodation that is structurally safe and served by infrastructure and services. Also by the extent to which low-income groups are served by measures for disaster prevention and preparedness (and these measures' effectiveness). The likely increase in risks from the expansion of the range of the mosquitoes that cause dengue fever and malaria are likely to impact those who live and work in homes and neighbourhoods where public health measures to eliminate disease vectors are absent or ineffective and where access to appropriate health care services is limited or absent. Higher temperatures and less reliable water supplies will also increase risks from diarrhoeal diseases, especially from flooding.

In regard to who is least able to cope with impacts, the increased health risks noted above become all the more serious if those who get sick or injured by extreme events have to rely on overtaxed and often ineffective health care systems, and lose school and work days to health problems that should have been prevented (United Nations 2009, 2011). Here the speed and effectiveness of post-disaster response has such importance for helping the groups affected to cope with the impacts – for instance in making immediate provision for safe locations for those who have been displaced, in rapid and effective treatment for those who are injured and in supporting those who have been displaced to plan and implement their own individual, household and community recovery (Boonyabancha and Archer 2011, Carcellar et al 2011, IFRC 2010.) Post-disaster responses including the provision for temporary accommodation also need to understand the different needs and priorities by different age groups and the different risks they face; of course, this also applies to women and girls.

Differentials in vulnerability by gender and age issues here?
Residents in more affluent cities may face 'double exposure,' stemming from climate change and globalization that encouraged settlement in 'amenity landscapes' or other areas vulnerable to the effects of climate change (Leichenko, O'Brien, and Solecki 2010: 965).

In relation to the potential vulnerability of urban populations and economies to climate change, two aspects need attention. The first is the extent to which in each urban centre, current provisions for infrastructure and services and for ensuring health and safety standards in all buildings (and the governance base needed to achieve this) provide a basis for building resilience to different climate change impacts. There are very large differences among the world's urban centres in the extent to which there is such a basis. The second is how the current and likely future drivers of urbanization change this – including the extent to which the growth in urban areas and economic activities within existing urban centres or new ones is taking into consideration climate change risks and making provision for adaptation.

Thus, this chapter has to present a summary of what is very diverse. From urban centres with high living standards where environmental health risks including those associated with extreme weather have been greatly reduced - to those with very poor living standards for most of all of the population where there are very large deficits in provision for most or all the infrastructure and services that should reduce environmental health risks. From urban centres with competent governments that have substantial capacities to invest in climate change adaptation to those that have weak and ineffective governments with little or no investment capacity. From urban centres and systems that are very large (including the 21 city agglomerations that had more than 10 million inhabitants by 2010 and so were termed mega-cities) to the tens of thousands of urban centres with under 10,000 inhabitants. From urban centres on sites at very high risk from sea-level rise and/or extreme weather and other very likely climate change impacts to those on sites that are, at least for the likely climate change impacts for the next few decades, facing relatively low risks (and a proportion whose economies will benefit from climate change). From urban centres with successful economies that continue to attract new enterprises to those with weak economic bases, including major cities that are losing population and have lost their previous comparative advantage. From urban economic bases that are comparatively insensitive to climate change to those that are very sensitive – for instance agro-industrial centres reliant on crops whose production faces constraints or tourist centres whose attraction is lessened.

In high-income nations, urban populations expect there to be a web of institutions, infrastructure, services and regulations that protect them from extreme weather/floods. Much of this comes from infrastructure and services that also provides everyday needs including health care services and storm and surface drainage. Early warning for approaching storms are expected, as is a rapid emergency response from the police, armed services, health services and fire services, when needed. Almost all buildings conform to health and safety regulations and are served by piped water, sewers, all-weather roads, electricity and drains 24 hours a day. The costs of such infrastructure and services represent a small proportion of income for most citizens - whether paid direct as service charges or within taxes. While coverage for some services may be sub-standard and some groups ill-served or excluded, a high proportion of the urban population are well served and well protected. In addition, there are functioning systems of city planning and land-use regulation that can adjust to new or heightened risk that climate change will or may bring – and this is likely to be supported by changes in private sector investments (over time shifting from high-risk areas) and changes in insurance premiums and coverage. So most urban centres in high income nations have the capacity to adapt to most of the likely impacts from climate change in the next few decades (although this does not mean they are currently doing so).

The financial and institutional capacity for urban adaptation is weaker in urban centres in low-income and most middle-income nations (Bicknell et al 2009, UN Habitat 2011). For most such urban centres, large sections of their population and workforce are not served by a comparable web of institutions, infrastructure, services and protective regulations. This can be seen in the proportion of their populations living in poor quality and often overcrowded accommodation that lacks provision for (among other things) water piped into homes, provision for sanitation and drainage, health care services , schools and emergency services. It is common for a high proportion of this population to be living in settlements that are illegal – either on land occupied illegally or on land sub-divided illegally. For instance, it is common for 20 to 60 percent of the population of cities to live in such informal or illegal settlements. This means that the homes, neighbourhoods and livelihoods of their population fall outside the regulatory framework (see for instance Awuor, Orindi and Adwerah 2008, Adelekan 2010, Jabeen, Allen and Johnson 2010). For a high proportion of the world's urban centres, the scale of current deficiencies in provision for infrastructure and services makes it difficult to see how they can adapt to climate change. For instance, most urban centres in low-income nations in Africa and Asia have no sewers (including many major cities) and much of the population have no water piped to their home and no official solid waste collection service (Hardoy, Mitlin and Satterthwaite 2001, UN-Habitat 2003a). For cities in these nations that do have sewers, these often serve less than 10 percent of the population.

Add here a paragraph on where risks are highest and note where in the text there is more detail on this. Note the two recent World Bank Reports: Cities and Climate Change: An Urgent Agenda (2010) and Economics of Adaptation to Climate Change (2010) indicate that up to 80 percent of the expected $80 billion to $100 billion per year in climate change adaptation costs are expected to be associated with cities in low- and middle-income nations/

Thus, each urban centre falls within a continuum in regard to at least four key factors in regard to adaptation: the competence, capacity and accountability of its government; the proportion of its 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) live in good quality homes on safe sites and are served by the basic infrastructure and network of services that should serve as the main reducers of risk; and the extent to which their site is at risk from climate change impacts.

HERE OR CONCLUSIONS? In urban areas, the challenges and opportunities for adaptation are often derived from the same features of city life – the concentration of people, buildings and economic activities. Large, dense urban centres serve to concentrate and often exacerbate climate-related risks in regard to health impacts and economic losses (Munich Re 2005, United Nations 2009). The risks from rising temperatures due to climate change may be further elevated by the urban heat island effect (McMichael *et al*. 2008, Kovats and Akhtar 2008, Harlan and Ruddell 2011). Floods and other climate-related extreme events may have more severe impacts as a result of how urban development alters hydrological patterns and where inadequate provision is made for drainage

(Douglas et al 2008, Nicholls 2004, others). Many of the world's largest cities are on the coast and with substantial proportions of their urbanized areas in low elevation coastal zones and so at risk from sea-level rise and storm surges (McGranahan, Balk, and Anderson 2007: 19). Many large cities are dependent on freshwater resources that are likely to become more constrained – and this is particularly serious for cities where demands (and water needs) are already facing serious constraints (REFS). The inhabitants and enterprises concentrated in cities depend on reliable supply chains for food and many other essential goods and so are vulnerable to any climate-related change that disrupts or diminishes supplies.

There is a growing literature discussing how successful adaptation requires recognising the interrelations and interdependence between sectors (Roberts 2010, Gasper, Blohm, and Ruth 2011, Sánchez-Rodriguez 2009). Adaptation is "deeply and complexly linked with other economic and social goals", so that climate policies in cities may need to be embedded in responses to multiple threats and stresses (Wilbanks and Kates 2010: 720). Some assessments have examined the effects of climate change in multiple sectors, helping to inform integrated adaptation measures (Kirshen, Ruth, and Anderson 2008). Other plans have identified sectoral strategies to overcome deficits in housing, water, or other infrastructures critical in adapting to climate change (see section 3.3).

(This is a summary section pointing the reader to where more detailed discussions of these issues are)
Many of the responsibilities for reducing environmental health risks and preparedness for disasters in urban areas fall to local governments. But it is now widely recognized that adapting urban centres to climate change requires support for urban governments from higher levels of government and support from residents, community-based and other civil society organizations and enterprises – hence the increased focus in the literature on adaptation on 'governance, ' on its multi-level aspects and on the roles and responsibilities of local stakeholders. Issues of governance and the role of non-state stakeholders increase in importance where local governments lack the capacity or commitment to meet their responsibilities for risk reduction.

Note here mentioning what section 4 covers on this issue

Role of local government. Examples of local government acting on adaptation. Local governments have shaped a range of adaptation plans and strategies (Hunt and Watkiss 2011, Zimmerman and Faris 2011). Local adaptation plans may be stand-alone, as in London or Copenhagen, and further integration into urban planning frameworks may be needed (Carter 2011). Transnational urban networks have encouraged action by urban governments on climate change, though usually with a focus upon mitigation (Toly 2008, Bulkeley 2010). (THIS MAY HAVE DETAIL BETTER PLACED ELSEWHERE)

8.1.4. Conclusions from Fourth Assessment Report and What this Chapter does beyond that Assessment

In AR4, urban areas were covered in chapter 7 that dealt with industries, settlements and human society. This chapter noted that all three are accustomed to variability in environmental conditions; in many ways they become more resilient to it when this is part of their normal experience. But they are more at risk if change is more extreme, persistent or rapid, especially if not foreseen or capacities for adaptation limited.

One of the most valuable contributions of AR4's Chapter 7 was to describe how climate change impacts and most key vulnerabilities are rooted in local contexts in terms of geographic location, sectoral focus, local government capacity, 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); adaptation in urban areas depends on competence and capacity of local governments. Thus, climate change impacts are likely to require responses that go beyond normal adaptations to varying conditions.

AR4 noted that except for abrupt extreme events, climate change impacts are not the dominant issues in urban centres – but their importance is in their interactions with other stresses such as rapid population growth, political and social instability, poverty and inequality, weak or ineffective local governments (and jurisdictional fragmentation) and aging or inadequate infrastructure. Climate change can ease or aggravate such stresses.

AR4 described key vulnerabilities of urban centres, urban populations and urban enterprises to:

1) **Interactions between climate change and global urbanization,** especially in urban areas in low- and middle-income nations which are housing most of the increase in the world's population and where adaptation capacity is usually weakest.
2) **Interactions between climate change and the globalized economy –** for instance in how climate change impacts resource supplies and prices (water, fuels). The global economy depends on long supply chains and multiple complex linkages between urban centres. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages. Many impacts are unanticipated and total impacts are poorly estimated by considering only direct impacts. Vulnerabilities include interregional trade patterns and migration patterns.
3) **The availability of infrastructure and services important for human needs and for adaptation**. These are susceptible to damage from extreme weather, sea level rise and other climate change impacts. Where infrastructure and services are inadequate, an additional source of stress could push system over threshold of failure

Key points from AR4 of relevance to urban areas:

Climate change impacts and most key vulnerabilities are rooted in local contexts in terms of geographic location (for instance sites at high risk from extreme weather), sectoral focus (for instance much tourism and agro-industry), development pathways and segments of the population (particular groups being more at risk to climate change impacts by age, gender and income-level or living in particularly dangerous areas).

The importance of developing a better local knowledge on risks and vulnerabilities. But it is difficult to project the magnitudes of changes in particular places and sectors (and thresholds) with precision, whether by downscaling global climate models or extrapolating from past experience with climate variation. Historic experience of limited value when potentially impacted systems are changing. Limits on predictability will delay adaptation. So too will the weak knowledge base on the costs of adaptation. There are also all the uncertainties about socio-economic and technological and institutional change within each location, nationally and globally.

Vulnerabilities tend to be localized. The vulnerabilities of industry, infrastructure, settlements and society greater in certain high risk locations, particularly coastal and riverine locations Rapid urbanization in most low and middle income nations are often in relatively high risk areas, increasing the proportion of their economies and populations at risk.

Vulnerable sectors: There are large differentials in how sensitive urban economies are to climate change impacts – for instance where urban economies are closely linked with climate sensitive resources such as agro processing, water resources and tourism). Industry is considered less sensitive to climatic variability and with high capacity to adapt, except where it is in high risk areas, or dependent on climate-sensitive inputs (food processing). However, where extreme weather events threaten infra, bridges, pipelines and transmission networks, industry can experience large losses or have the supply of key inputs disrupted. Perishable commodities among the most climate sensitive retail markets; climate change may alter sourcing and processing of agricultural produce. For many businesses including informal industries, adaptation will require a greater awareness of threats and alternatives that go beyond historic experience and current access to finance. Many adaptations are incremental adjustments to current business activities. Planning guidance and risk management by insurers will have role for structural adaptations such as choice of location for industry.

Much tourism **is** sensitive to climate change – and increases in temperature, more rain and other aspects of climate change can make popular tourist centres less attractive. Climate change may damage some key tourist assets eg coral reefs and beaches. Energy price changes will affect travel and costs of comfort.

Technological innovation for climate change 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.

Vulnerable infrastructures and services. Infrastructure plans and investments generally include some scope for coping with climate variability but in many locations, these will need to increase reserve margins, develop back up capacity and take other adaptation measures. Certain types of infrastructure are more at risk – for instance most transport, drainage and electricity transmission systems and many water supply abstraction and treatment works.

Climate change will increase demands on water and energy supplies and often on health care and emergency response systems in many locations.

Vulnerable populations. Among groups of the population particularly at risk are those with limited or inadequate incomes and limited asset bases (which limits their adaptation capacity) and living in substandard accommodation lacking infrastructure and services and in at risk locations (which increases the risks they face). Particular attention needs to be paid not only to those with inadequate incomes and assets but also infants and children, the elderly, the least skilled, the powerless, those who are linguistically isolated and those who face discrimination (including women).

Adapting to climate change involves cascading decisions across a landscape made up of agents from individuals, firms and civil society and public bodies operating at different scales. Individual adaptation may not produce systemic adaptation, adaptation of systems may not benefit all (some increase vulnerabilities of people and places). Adaptation is not a capital stock that can be invested in projects but a process of learning about changing risks and opportunities, making decisions, revising strategies.

Adaptation of infrastructure and building stock often dependent on changes in institutions and governance framework (what is often termed soft infrastructure). But institutions that can address risk and vulnerability also depend on hard infrastructure – for instance for health care and emergency services to function. Climate change becomes one of many changes to be understood and planned by for by local managers and decision makers.

Prospects for adaptation depend on magnitude and rate of climate change; slowing climate change makes adaptation easier

The long time horizon of climate change and impacts makes potential for technological change a critical issue in evaluating adaptation prospects.

Adaptation not necessarily optimal. Plausible actions can create net social and economic losses.

Key uncertainties and research priorities:
- Research on vulnerabilities and adaptation potentials of human systems lagging behind
- Understanding of impacts of climate change at fine grained geographic and sectoral scale; also of second and third order impacts eg from temperature or precipitation change, storm behaviour change, sea level rise,
- Uncertainties about potentials, costs and limits of adaptation
- Uncertainties about trends in societal, economic and technological change with or without climate change.
- Underlying all these research needs are often painfully serious limitations on data on nature-society links and detailed scale contexts. Have to incorporate physical and earth science based data and in situ observation systems with socio-economic data.

What has changed since AR4?

A larger and more diverse literature on current and potential vulnerabilities of different urban centres and different sectors of urban economies to the impacts of climate change on their structure and functioning

A much larger body of evidence on adaptation responses being considered or taken by cities with more discussion of the factors that encourage this

A more detailed and nuanced understanding of the many ways by which poverty exacerbates vulnerability to climate change impacts

More consideration of the role of green infrastructure and eco system services in adaptation strategies

More considerations on the financing, enabling and supporting of adaptation

More case studies of community-based adaptation both in its potential contributions in urban areas and in its limitations

More on learning from innovation in disaster risk reduction

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

8.2.1. Introduction

The objective of this section is to summarize and assess connections between ongoing urbanization and climate change with respect to changing patterns and conditions of climate risk and vulnerability. Focus will be on urbanization and its environmental consequences, impacts and challenges (locally, regionally, and globally) and the processes that lead to risk exposure and constrain people in high-risk livelihoods and residences, and generate vulnerabilities in critical infrastructure. Governance and the institutional environment in the context of shifting urban risk and vulnerability conditions are examined as well. Understanding urbanization is critical for an effective global response to climate change as well-governed cities demonstrate a capacity to adapt and to learn from difficulties and recover from crises (Solnit 2009; Vale and Campanella 2005).

The section is organized into the following sub-sections and topics detailed in Figure 8-1. Section 2.1 introduces the conditions and process of contemporary urbanization, urban livelihoods, and the prospects for future growth. The next section (2.2) assesses the recognized direct impacts of climate change on critical urban systems and functions, focusing more explicitly on changes in exposure. The effect on these direct impacts on the process of ongoing urbanization is detailed in section 2.3. These effects include shifts in the understanding and management of urban functions. Together, the direct climate impacts and shifts in urbanization change the profile of societal risk and vulnerability in urban communities. These conditions are assessed in section 2.4. The final section (2.5) reviews the conditions of governance which are in direct reaction to changes in actual and perceived risk and vulnerability. As such, the focus is on exposure and vulnerability reduction as opposed to adaptation outlined more completed in sections 3 and 4.

[INSERT FIGURE 8-1 HERE
Figure 8-1: The structure of this section.]

8.2.2. Urbanization

Even the high concentration of the world's GDP and assets in urban centers and the growing concentration of people who live and work as described in section 1, it is anticipated that with time more people will be exposed to impacts of climate change due to not only the increase in number of population living in urban areas but also due to an increase in large cities, including mega cities (Sherbinin, *et. al*. 2007; Revi 2007). Sherbinin et al. (2007) point out that the mega cities of Mumbai, Rio de Janeiro and Shanghai will be more vulnerable to climate change impacts especially those related to flooding based on a business as usual scenario.

8.2.2.1. Magnitude and Connections to Climate Change

The conditions of urbanization vary widely throughout the world and as discussed in section 1, the factors that influence these conditions include the competence, capacity and accountability of its government; 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; and the extent to which their site is at risk from climate change impacts. This variation has important consequences both for the process of climate change and how cities might be able to respond to climate change (Seto and Satterthwaite 2010; Güneralp and Seto 2008). This section reviews urbanization across a set of important parameters and qualities – e.g., spatiality, temporal, and sustainability - and within a global-regional context.

Urbanization brings forward a set of environmental challenges and opportunities vis-à-vis climate change (Simon and Leck 2010). Urbanization alters local environments via a series of phenomena (e.g., heat islands, hydrologic) that can be exacerbated with climate change. Extensive research has been done recently which attempts to connect recent climate shifts and weather variable changes (mostly during the 20th century) and rates of urbanization with linkages to on-going and future climate change (Manton 2010). For example, urban heat island intensity has been found to be associated with the intensity of urbanization (Chen et al. 2011; Iqbal et al. 2011; Fujibe XXXX; Rim 2009; Santos et al. 2009; Tayanc et al. 2009; Sajjad et al. 2009; Jung 2008; He et al. 2007; Stone 2007).

8.2.2.2. Spatial

The pattern of urban spatial development is a critical component of understanding the interactions between urbanization and climate risk and vulnerability. While urban form can vary widely in different regional and development settings, urban areas include a range of conditions from concentrated to disperse. Most urban areas include core, suburban, and exurban components. In general, recent patterns of urbanization continue a long term trend of de-centralization and with many large cities developing into extended metropolitan regions which include a diversity of settlement density conditions (Leichenko and Solecki 2005). The expansion of cities both with respect to total population and density has fostered the development of extensive networks of critical infrastructure and market connectivity which are vulnerable to climate change (e.g., Crona et al. 2009).

8.2.2.3. Temporal

The rate of urbanization (which includes the level of population growth, urban spatial expansion, and redevelopment of existing urbanized areas) in any individual city or region is critical to understanding the connection to climate risk and vulnerability. Urbanization is associated with changing dimensions of migration and materials flows both into and out of cities and within them. The level of increase and some case 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, urban water shortages in many developing country cities are already a chronic condition, and typically worsen as the population continues to grow. Overlaying climate change, related water supply deficiencies over this existing instability creates the conditions for greater management and governance crises.

8.2.2.4. Sustainability and Ecological Habitat

Contemporary urbanization is directly connected to the question of sustainability, and to the ecological underpinning of urban life. As cities grow and change, the demand for resources expands and transforms increasing the cities' ecological footprint and long distance resource linkages (e.g., teleconnections). In many cases, city-resource supply connections have become more distant and fragile (e.g., Darrel and Larsen 2006). Cities can have specific environmental and ecological thresholds in their development trajectories. Cities, particularly those within developing country contexts, have local ecological carrying capacities. Climate change impacts can accelerate the approach to the carrying capacity. For example, climate change will reduce or make available local water supplies more at risk to shortage because of shifts in precipitation and/or evaporation at the same time of increased water demands.

8.2.2.5. Regional Patterns

The impact of climate change will be experienced by the wide diversity of cities throughout the various regions of the globe. The level of climate change impact and associated risk and vulnerability is in part associated with the extent and character of urbanization in each of these regional settings. This is the result of similar urban development patterns within each region. Region-specific case studies have been conducted recently which reveal trends and conditions within each. Some common threads to the conditions of urbanization and types of impacts that are highlighted in the recent literature across the different regions are noted below.

[INSERT TABLE 8-2 HERE
Table 8-2: Title? To be completed….]

Risk distribution in urban areas at the global level will be determined by economic status of the country, percentage of the national populations living in urban areas, the size city, and urban governance. Economic status of the country may partly contribute to the distribution of the risks among the global cities as it is expected that urban areas in developed countries compared to urban areas in less developed countries have more resources for climate change mitigation and adaptation. Hence less risk for climate change impacts. Global regions like Latin America, which has a high urban population in urban areas compared to Africa are likely to have higher numbers of its population being exposed to the impacts of climate change, although the improvements in this region in urban governance and capacity may also mean greater adaptive capacity for many urban centres. Due to the inherent characteristics of the urban centers in low and middle income countries, the exposure to climatic extreme events will be higher in countries that have mega cities like China and India compared to countries that have small cities.

Revi (2007); Sharma and Tomar (2010)**;** Adelekan, (2010); Sherbinin et. al., (2007); and Hardoy and Pandiella (2009) all point out that a large percentage of the population in African, Asian and Latin American urban areas are poor and live in informal settlements, many located in unsafe areas. UN Habitat estimates that around 900 million urban dwellers live in informal settlements or other settlements classified as 'slums' (UN 2003, others). Many urban centres in India have 25 to 50 percent of the population live in "slums" while in Latin American cities about 50 percent of the urban dwellers are classified as poor and in Rio de Janeiro alone about 1.1 million people live in *favelas*. In Africa using the 2006 UN-HABITAT data, it is estimated, that about 72 percent of African urban dwellers live in unplanned settlements (Wisner and Pelling 2008). Service provision in terms of water supply, waste water disposal, and solid waste management is inadequate in most urban areas of low and middle income countries (Kovats and Akhtar 2008; Sharma and Tomar 2010; Lwasa 2010). The situation in terms of service provision is much worse in the unplanned settlements and a large proportion of urban communities in low and middle income economies work in the informal sector.

Based on the studies from African, Asian and Latin American cities, though the distribution of risks due to climate change impacts is likely to vary in an urban settlement and among the national and global urban areas, the most at risk in all cases are vulnerable communities. However, it should be pointed out that the most vulnerable in the poor communities are the women, children, health compromised, and the old people due to the fact that either they have less mobile (e.g., women with child care responsibilities), less resources or are physically weak. One key primary factor contributing to vulnerability is lack of capital assets available to prepare for and cope with disasters (Moser and Satterthwaite 2008). Other key factors which result from this deficiency or occur simultaneously is lack of infrastructure and services. The vulnerable communities in urban areas are likely to be living and working in unplanned settlements, or in settlements located in hazardous areas, including steep slopes and low lands adjacent to unprotected river banks or ocean shorelines, or areas that have poor public services such as drainage, sanitary, solid waste and transportation systems or in areas where structures are built on unconsolidated soil materials, or areas where building codes are not enforced.

8.2.3. Direct Climate Impacts

8.2.3.1. Introduction

The objective of this section is to assess the observed and forecasted direct impacts that climate change will have on city residents, infrastructure, and systems. Particular focus will be on climate risk-related impacts that might place increased stress, burden or instability on the operation of critical resource supply activities and the presence of resource constraints in cities. Two critical aspects of the urban sector discussed in this context include the types of hazards they are vulnerable to and the associated costs. The section examines both the temporal and spatial scale of the shifts in climate risk across cities and urbanizing sites in the next several decades and beyond. The focus is on how the scale and character of risks may change and grow in cities with respect to shifts in climate extremes, means and long-term trends (e.g., sea-level rise).

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. Costs impacting the health, livelihoods and wellbeing (most importantly psychological wellbeing) will be assessed as well where appropriate.

Climate impacts will have profound impacts on a broad spectrum of city functions, infrastructure, and services (Rosenzweig et al. 2011; UN Habitat 2011). Climate change will connect with ongoing underlying stresses in cities (e.g., poverty, rapid population growth) (Mehrotra et al. 2011). Interaction between ongoing environmental stresses in urbanizing areas and climate change impacts lead to a wide range of synergies, acceleration of crises, challenges and opportunities for adaptation. These connections are complex and present a set of uncertainties with respect to individual and multi-hazards. The origin of these hazards can occur both *in situ* and as well as through long-distance connections between cities and other, often rural locations, such as sites of resource production and extraction.

Similarly, it is understand that urban infrastructure also will be impacted by systematic or cascading risks (e.g. Hunt and Watkiss 2011). Climate stresses and particularly extreme events will have effects across interconnected urban systems – both within specific sectors and across multiple sectors. This condition can be especially prevalent in water and sanitation, energy, and transportation sectors. This process results from the often tightly coupled character of urban infrastructure systems (see Rosenzweig and Solecki 2010 for a discussion of New York infrastructure). These cascades of impact can have both direct economic as well as indirect economic impacts (e.g. Hallegatte et al. 2011; Ranger et al. 2011). The impacts also can extend from built environment sectors to other types of impacts particularly on urban public health.

A critical element of climate impacts is that they will affect many infrastructure investments that have long operational lives - in some cases up to 100 years or more. It is important to recognize that there are regional (e.g., Africa, North America, Europe) and income level distinctions (e.g., least developed, low, lower-middle, upper-middle and high income nations) with respect to how urban systems will be impacted by climate change.

8.2.3.2. Water and Sanitation

Climate change will have dramatic impacts on local and regional water supply and sanitation systems for cities (e.g., Capetown – Ziervogel et al. 2010). The impacts will be significant with respect the availability and quality of the resource. 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., Andean cities and Mexico City).

Climate will exacerbate existing and expected increases in urban water resource tensions and conflicts that are present in the varying water sectors: residential, commercial, industrial, agricultural, and infrastructural. Water and climate change will impact residential water demand and supply and its management. Large-scale critical infrastructure also will be impacted. For example, warming has forced the closure of nuclear power stations in the UK as river water was too warm to provide adequate water (REF).

Wastewater and sanitation systems during extreme precipitation events can be overburdened due to the limited capacity of drainage systems in old cities and in unplanned settlements or where drains are not maintained (Howard et al. 2010; Wong and Brown 2009). Solutions include waste collection businesses, cleaning of drains, and construction of the bigger systems. In New York City, city maintenance crews as part of improved storm water management clean drains when intense precipitation is predicted.

8.2.3.3. Energy

Climate change will alter the patterns of energy consumption in cities, particularly with respect to electricity demand and/or energy needed for cooling or heating. In settings with extensive air conditioning use, climate change will bring increases in air conditioning demand and in turn heightened electricity demand. Warmer temperatures and more and more intense heat waves also makes likely the rapid increase in the use of air conditioning in cities where extensive air conditioning use is not now 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. In most cases within individual cities, potential increases in summertime energy demand from climate change will exceed reductions in winter energy demand reductions.

Another globally widespread energy-related impact and vulnerability from climate change is the disruption of energy systems during peak demands which exceed capacity or extreme weather events. Electricity energy demand will spike during summer time heat waves in areas with extensive use of air conditioning resulting in brownouts or blackouts. Furthermore, the projected increased projected frequency of snow storms 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 powerlines and other infrastructure. The role of distributed urban energy production as it related to adaptation and mitigation also need to will be assessed.

8.2.3.4. Transportation and Telecommunications

Transportation (impacts on capital stock - extreme events, wear and tear, bridges, specialist equipment, roads, railways; evacuation). Assessing the disruption of transport networks inside and outside the city is critical. Disruptions outside cites can impact the urban economy (e.g., Mombasa urban region and Mozambique floods). Telecommunications (phone networks: crashing post-disaster or working better than land-lines).

8.2.3.5. Built Environment, and Recreation and Heritage Sites

The built environment – buildings and other structures including heritage sites – will be impacted by climate change. Structures include residential, commercial, and industrial sites. Recreational sites such as parks, playground and playground will be affected as well. Climate warming, increased climate variability, 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).

8.2.3.6. 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.

8.2.3.7. Social and Public Services

The effects of climate change also will be evident within a diverse set of climate change impacts on urban social and public services. These include services such as health and social care provision, education, and police and emergency services.

8.2.4. Urbanization Impacts

8.2.4.1. Introduction

The objective of this section is to assess how aspects of climate change risks impact the process of urbanization. Climate change because it represents increased uncertainty of the future, probability of extreme events, and environmental dynamism overall is affecting how cities are managed, developed, and even conceived at a time when many cities continue to face a set of other significant stressors such as rapid population growth, increased pollution, resource demands, and concentrated poverty.

This section assesses several metrics of this shift in the process of urbanization as driven by the qualities of climate impacts, and does not in of itself represent a review of formal integrated climate risk planning and management. But rather, this section attempts to illustrate how climate change knowledge, perception, and understanding increasingly held by city stakeholders and residents affects their decision making frames vis-a-vis conception of their city as an engine for economic growth, as a mechanism for political aspirations, and as a vehicle for meeting livelihoods and basic needs.

8.2.4.2. Uncertainty and Surprise

Climate change creates increased dynamism in environmental conditions in cities. As a result past environmental responses and baselines have become less a valuable predictor of future urban environments. Adaptation planning at urban levels will need to take into account uncertainty about future climates and extremes and consider direct and indirect economic costs, notably the trade-off of inaction and thus locking in to ill-adapted infrastructure versus investment in adaptation when change in climate is less than anticipated (Hallegatte et al. 2007). There are several decision-making settings in cities that are influenced by shifts in the likelihood of extreme weather events and responding to climate-related surprises. Urban decision-making venues which have been most impacted include water resource managers (e.g., Fane and Turner 2010), insurance companies, emergency health responders, disaster preparedness planners, and urban infrastructure engineering offices.

8.2.4.3. Extreme Event Probability

The objective of this section is to assess how shifts in extreme event probability have impacted how cities are understood by stakeholders and decision-makers, and how in turn these understandings are integrated into local decision-making. In many major cities such as London and New York, the prospect of increased climate variability has spurred an integration of climate resiliency efforts into extreme event planning. Actions include increased stormwater management during intense precipitation events to forestall or prevent inland and street-level flooding (Rosenzweig and Solecki 2010).

8.2.4.4. Transitions

Climate change has encouraged stakeholders and decision-makers to revaluate the environment of their cities as dynamic and increasingly variable. This situation also is associated with an understanding of the urban systems and functions that are more and more under stress and potentially being pushed toward a state of transition – i.e., what was done in the past will not work in the future.

Transitions in the context of climate change emerge in two contexts: 1) a systems level perspective where urban systems could reach a tipping point in which a failure or collapse could occur; and 2) a broader scale societal transition to enhanced resilience and adaptive capacity in the face of accelerated climate change (Ernstson et al. 2010; Tompkins et al. 2010; Gusdorf et al. 2008). The first context can occur often without resulting in a broader scale transition; while, a broader scale transition almost invariably must result from a series of smaller and more discrete system failures.

In recent years, several urban environmental transition models (e.g.,McGranahan and Marcotullio 2007) have been introduced to show transitions between environmental degradation and health hazards as cities and neighbourhoods develop. Within these models, key variables have been identified that make cities vulnerable to climate change (e.g., concentrated urban form and extensive infrastructure networks). Several elements of transitions have addressed these concerns within the context of established sustainability approaches (e.g., compact cities, eco-regions, polycentric new-town planning systems, rural development as a strategy for moderating urbanization).

8.2.4.5. Social Dynamics and Economic Tensions

Climate change impacts can exacerbate existing social dynamics and economic tensions in cities – frequently accelerating the pace and condition of societal conflict. Climate change makes the management of social impacts more complex because it enhances income disparities and poverty conditions, and deepens existing social differentials - e.g., impacts on income, assets, health, need to migrate.

Climate change creates implications for equity from different management solutions. For example, the privatization of urban water supply and sanitation systems will advantage specific groups over others. Conversely, community-based solutions that also build social capital can be a component in generating generic urban resilience.

Specific tensions emerging from climate change impacts have been derived from studies connecting climate impacts with the disaster recovery literature (Solecki et al. 2011). These tensions include 1) temporary or permanent poverty; 2) food security; and 3) shifts in the informal economy. Shifts in social dynamics include the possibility and aspiration that reconstruction and recovery can improve people's livelihoods, changing 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.

8.2.4.6. Historical Analogs

The experience of cities in coping with environmental/resource crises in the past can provide a useful analog to understand the impact of climate change and the prospects for meaningful shifts in urbanization (Ranger et al. 2011; Hallegate et al 2007; Gibbons et al. 2006). In the past, many cities 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 casting the environmental quality threats (e.g., sewerage, rubbish) to more remote and distant locations. What is more complex in the case of climate change, the source of the risk and vulnerability is external to individual cities.

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 XXXX), and natural hazards such as earthquakes, hurricanes, as well as the application of new technologies (e.g., automobile, electricity). For these cases, it is evident that well-governed cities demonstrate a capacity to adapt and to learn from difficulties (and crises). 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 – for good and bad.

8.2.5. Changes in Risk and Vulnerability

8.2.5.1. Introduction

This section focuses on how climate change impacts influence the distribution of risk within urban centres and across urban populations globally. It includes changes in those exposed and in turn the relative vulnerability across a set of key urban climate risks. Climate change is likely to lead increased occurrences 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 and Solecki 2011 for recent reviews).

This section's explicit focus is on how the scale and nature of risk and vulnerability from climate change is influenced by both the modulated process of urbanization and by socio-economic context specific conditions including income-levels, asset bases, age, sex and gender. A key component is a discussion of which are the most vulnerable populations and of populations most at risk, and the overall impact of climate change on urban livelihoods, economic opportunity, and public health (e.g., Few and Pham 2010; Palutikof 2010). An assessment of the discrimination in individual-household and community/urban centres ability to adapt (e.g., by ethnic group, migrant status) is included as well. A critical component of the changes in risk and vulnerability are how they are manifest socially (e.g., equity and justice issues), geographically (e.g., high density locations, suburban, exurban locations) and temporally (e.g., short, medium, and long term shifts). The distribution of risk within an urban area will vary due to a number of factors including first, physical features of the different parts of an urban area, especially topography and geological conditions.

8.2.5.2. Inland Flooding

Heavy rainfall and storms surges would impact the 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 Gl'ehouenou-Dossou (2007); Kovats and Akhtar (2008); Sharma and Tomar (2010); Adelekkan (2010); Hardoy and Pandiella (2009); Sherbinin et. al., (2007); Douglas et. al,(2008); Roberts (2008); Nie et al. 2009). Extensive studies have attempted to better model the frequency and condition of extreme precipitation events and associated flooding (e.g., Detlef et al. 2011; Ranger et al. 2011; Onof and Arnbjerg-Nielsen 2009; Nelson et al. 2009; Olsson et al. 2009; Sen 2009).

Lowland areas in Dhaka, Lagos, Mombasa or Mumbai cities are likely to be more prone to flooding than areas of higher elevation in same cities (Adelekan 2010, Awuor et al. 2007, Revi 2005). Dhaka is a particularly important example because in that case most of the hazard is from river flooding where many other example cities include sites that have both a riverine and coastal storm surge component to the flooding. Similarly the steep slopes of many Latin American cities are likely to be more to prone to landslides. Houses and structures built 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.

8.2.5.3. Coastal Flooding, Sea-Level Rise, and Storm Surge

Sea-level rise represent one of the primary if not primary shift in vulnerability that results from climate change given the accelerating urban growth of cities in coastal locations. Coastal sea level rise and associated coastal and riverbank erosion, flooding with storm surge could lead to widespread vulnerability of 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). Urban areas located in coastal areas throughout the world such as Lagos, Cape Town, Miami, Shanghai or Mombasa will in addition to other risks, face risks related to sea-level rise, which will not be the case for urban areas that are located in the hinterland of these countries (See discussion of this for Cotonou in Dossou and Glehouenou-Dossou 2007)

Hanson et al. 2011 estimate the change in exposure of large global port cities to coastal flooding in the 2070s compared to today with plausible scenarios of socio-economic growth, sea level rise, storm surge and subsidence; they find that population could more than triple while asset exposure is expected to increase more than ten-fold in this period with a 0.5 metre rise in sea-level – a change which is driven simultaneously by climate change and socio-economic growth to flood prone coastal areas. The study identifies the "top-20" cities for both population and asset exposure to coastal flooding.

With respect to population, some cities in both current and future 2070s rankings are spread across developed and developing countries, concentrating in Asian deltaic cities, to 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, a different ranking is obtained with greater dominance of the developed countries (e.g. Miami, New York City, Tokyo and New Orleans as well as China (e.g. Guangzhou, Shanghai, Tianjin). This type of analysis underscores the urgent need for urban risk reduction measures.

8.2.5.4. Urban Heat and Cold

Heat waves and warm spells could exacerbate urban heat island effects, including increased air pollution, heat related health problems, increased salinity of shallow aquifers in drylands due increased evapo-transpiration and spread to new areas of some diseases including malaria. Conversely, widespread reduction in cold waves will induce shifts in heating demands. 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 (e.g., Thorsson et. al. 2011).

8.2.5.5. Drought and Water Scarcity

Drought will lead to food insecurity, increase in fuelwood prices, water shortages, increased rural urban migration, electricity power shortages for urban areas that depend mostly on hydropower, increased food prices and an increase in water related diseases (e.g., Farley et al. 2011; Herrfahrdt-Pahle 2010; Vairavamoorthy et al. 2008)

8.2.5.6. Air Pollution and Public Health

Climate change will exacerbate existing air pollution related public health issues in cities via a variety of mechanisms. Most significantly, increased temperatures will raise the potential for secondary air pollutant production (e.g. ozone) which in turn results in more frequent acute and chronic respiratory exposure among urban residents.

8.2.5.7. Geohydrological Hazards

The exposure to climate related hazards will vary due to differences in the geomorphologic characteristics of the city. 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. As an example, urban areas located in lowlands will have a high risk to flooding while urban centers located in hilly areas will be exposed to landslides. The number of people exposed to a hazards or hazards will partly be determined by the size of the city. The number of people will be greater in a megacity compared to a small urban settlement, especially in low and medium income countries.

8.2.6. Urban Governance

8.2.6.1. Introduction

The objective of this section is to assess what roles and responsibilities have fallen to city and municipal governments in regard to changing risks and vulnerability, and how urban governance (government and civil society and their interactions) has responded to climate change. A crucial issue is where and whether there is capacity to address the direct and indirect impacts of climate change. Significant limitations and lack of capacities to address climate change risks are present in much of the world's urban centres – including a proportion within failed or fragile states where there is almost no capacity. In many cases there is the large disjuncture between the magnitude of the problem and the resources available. Several specific factors compromise governance response capacity of cities to climate change. These include human and capital resources, understanding of local environmental change, and limited institutional capacity to develop, initiate and implement public policy.

The section draws on specific country or city case studies to make clear the multiple roles of urban governments for which there is no credible substitute. In many cases, urban areas that have sound urban governance have lower risks compared with urban areas that are economically weak and have poor urban governance. In settings where enhanced capacity exists, governance focus is on response strategies and decision-support tools.

Overall, it is clear that literature on multi-level governance shows how adaptive capacity in cities depends on coherent policies, support from higher levels of government, and capacities of city governments to work at neighbourhood levels. Where urban management and governance has proved effective in building resilience – including building this for impacts that are uncertain – and their limits is a critical issue discussed in section 3 below.

8.2.6.2. Institutional Environment

City governments increasingly are seen as active agents in the management of increased climate risk and vulnerability (Howe et al. 2010; Rosenzweig et al. 2010; Wolf et al. 2010). City managers and stakeholders have grouped themselves together in national, regional, and international networks such as C40, Mayor's Summit (Roman 2010). ICLEI Individual cities such as Chicago, Seattle (Kings County), New York, London, and Melbourne (Donald and Seeger 2010) have become widely recognized as global leaders. This activity has significantly enhanced the institutional environment for robust climate change adaptation and mitigation.

Cities also maintain limitations with respect to their ability to limit risk and vulnerability. Studies in African, Asian and Latin American cities have shown that the risks due to climate change impacts are likely to be higher in squatter areas, which have poor public services compared to planned areas with good public services. Spatial distribution of communities within the urban areas is partly based on income levels, which gives rise to poor and rich neighborhoods. The rich neighborhoods are likely to face fewer risks compared to areas where the poor people live. Urban areas that have high population density are likely to have higher risks compared to low population density areas.

8.2.6.3. Governance and Civil Society

In many urban settings, civil society including non-governmental organizations plays a significant role particularly in those areas of informal settlement where no or limited formal infrastructures and services are provided for urban environmental management. The role of civil society particularly as a means for participatory community risk, local expert knowledge, and local capacity building are areas of significant contribution (e.g., Krishnamurthy et al. 2011; Fazey et al. 2010; Shaw et al. 2009; Tompkins et al. 2008; Van Aalst et al. 2008).

8.2.6.4. Science-Policy Linkages

The evolving understanding of climate risks and vulnerability demand a continuous re-assessment of the scientific knowledge of local climate conditions and how this information can be translated into local decision-making. Understanding the structure and dynamic quality of science-policy linkages are critical to the governance and management of climate risk (Rosenzweig and Solecki 2010).

8.2.6.5. Decision-Support Tools

A variety of climate risk and vulnerability decision-support tools have been developed in recent years. These tools are designed around a variety of methods and objectives. A central element of tools that organize and rank information is to identify relative and absolute differences in risk and vulnerability and resilience capacity (e.g., Manuel-Navarrete et al. 2011; Hahna et al. 2009; Posey 2009; Milman and Short 2008). Another theme of decision-support tools is to make the climate scenarios and modelling results more useful for local decision-making (e.g., Hallegatte et al. 2011; Van Vuuren 2007).

8.2.6.6. Development as Risk and Vulnerability Reduction

An emerging central component of urban governance and climate risk and vulnerability management is its direct connection to urban development strategies. Urban development initiatives are seen as a way of simultaneously promoting climate resilience, adaptive capacity, and community empowerment (e.g., Burch 2010; Johnson and Krishnamurthy 2010; Ebert et al. 2009; Gujja et al. 2009; Yu 2009). A significant focus has been on how to make these linkages with respect to urban water supply development projects.

8.2.6.7. Private Sector

The private sector increasingly serves as an important consideration within the governance decision-making process. The insurance industry is particularly important for risk management in flood prone areas (Rosenzweig and Solecki 2010). In other contexts, the private sector can play a relatively prominent role when the local governments and/or civil society component of the governance structure are limited (Eakin et al. 2010; Chu and Schroeder 2010).

8.3. Adapting Urban Areas

8.3.1. Introduction

This section draws from a growing literature that discusses how and what urban centres can and should be do to address climate change adaptation – often based on local risk and vulnerability assessments. But there is less evidence from the literature of government decisions to act and to include climate change adaptation in the plans and investment programmes of city and municipal governments. One of the constraints on this that is often noted is the uncertainty as to what climate change will bring (and when) in each locality. For most urban centres in low- and middle-income nations and many in high-income nations, it is also constrained by city government priorities focusing on economic growth in ways that as yet do not recognize the importance of incorporating adaptation measures (and often also of addressing mitigation). Local decision-makers frequently view climate change as a marginal issue, with adaptation usually ranked even lower than mitigation in urban policy agendas (Bulkeley 2010, Simon 2010).

Perhaps the main exception to this is the documentation on cities where local or regional governments have engaged in disaster risk reduction to extreme weather (United Nations 2009, 2011. IFRC 2010, Hardoy, Pandiella and Velasquez 2011, others). Little of this was done with climate change adaptation in mind but this has often built an information base and a network of institutions and invested in risk reduction measures that contribute to resilience and adaptive capacity to some climate change risks. One limitation is that disaster risk reduction in cities is usually based on precise and detailed analyses of the impact of past extreme weather events (or other catalysts for disasters) and for this to serve climate change adaptation, this has to include a consideration as to how these will or may change in the future.

Although there are examples of city governments giving some consideration to climate change adaptation, these still represent a small proportion of all cities and small urban centres. In addition, there are often institutional constraints to acting on the findings of assessments of climate change related risks and vulnerabilities (Roberts 2010, Hunt & Watkiss 2011, Corfee-Morlot et al 2011)**.**

Limited data to support adaptation. The inadequacies in climate data available at the city scale may constrain city governments and enterprises from taking action. Climate data are limited in many cities, rarely downscaled to urban areas, or often fragmented across local departments (Hardoy and Pandiella 2009). Jakarta's urban planning agencies already have geographic information system (GIS) data, yet they are not connected with other social or economic statistics nor are there sufficient longitudinal climate data (Firman *et al*. 2011: 375-6). Detailed data on urban climate or proactive adaptation strategies or quantitative assessments remain exceptional (Hunt and Watkiss 2011). Many adaptation measures are adopted "only in response to specific local or regional natural disasters, which may or may not be climate-related" (Bulkeley 2010: 245). To be useful to stakeholders and spark local dialogue, climate data needs to be integrated geographically, across time-scales, and consider a range of regional benefits and costs of climate policy (Ruth 2010).

Nevertheless, there is a growing documentation on opportunities to strengthen urban resilience to climate change through including this in household, community and city development plans (section 3.2), sectoral responses (Section 3.3), responsive planning and governance (Section 3.4) and managing cities' physical expansion (Section 3.5). Underscoring the interrelations in urban systems, there is some discussion of synergies that can be created between mitigation and adaptation policies in cities (Section 3.6). Local governments may be able to simultaneously address adaptation and mitigation using the "same policy levers", such as building standards, transportation infrastructure, and other urban planning tools (Hallegate, Henriet and Corfee-Morlot 2011: 72). Finally, limits to adaptation are reviewed (Section 3.7) such as questions of scale, overlapping or conflicting jurisdictions, or inadequate resources. A further challenge is to develop methods to evaluate adaptation measures, though methods have recently been proposed (Hedger *et al*. 2009, Preston, Westaway and Yuen 2011).

This section will also present details of community-based adaptation in urban centres – where it is civil society groups that have taken the initiatives. This includes community-based initiatives that have sought to work with local governments. These also illustrate possibilities to address adaptation-vulnerability and development together.

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 investment and of public investment in infrastructure (Wilbanks, Romero Lankao et al 2007). These also influence the scale and location of climate-related risks to urban enterprises and populations and thus also what is needed for adaptation. Urbanization is largely driven by where private enterprises choose to locate or concentrate. Both national and local governments generally prioritize economic growth over environmental protection. Even where national and regional governments do not use spatial development planning (for instance specifying the locations where new investment is allowed or not allowed), they directly or indirectly influence the location of private investment through many other measures – for instance in which urban centres and regions are best served with infrastructure, in special incentives given to investors in particular regions or settlements and in the powers, responsibilities, financial capacities and revenue-raising powers permitted to local governments. At the regional and national scales,. The responsibility to encourage new investments and migration flows to safe sites and away from sites at high risk from climate/weather - through a combination of disaster risk management and urban planning/zoning – is often be shared between local and national and provincial governments.

Government's social policies and priorities also influence the social and spatial distribution of climate related risk and vulnerability. Sánchez-Rodríguez 2009 notes that "...despite the fact that social change is a central element of development, there is perhaps not enough attention to livelihoods in development studies to connect adaptation, vulnerability, and development mentioned above. This can be particularly relevant to address adaptation in informal settlements and incorporate individual and groups agency in bottom-up adaptation strategies in low-income and medium-income countries. (page 203).

To ADD? - Need to summarize literature on NAPAs and other national level measures as they relate to urban centres and their adaptation. Also on the extent to which these influence the development plans and investment priorities of national and regional governments in ways that support or go against climate change adaptation (Urwin and Jordan 2008; Corfee-Morlot et al. 2011). Examples of conventional, government-led routes with adaptation folded into development and disaster risk reduction; strong examples of where this is happening (good examples from some Latin American nations in this). Good practice for adaptation and development. Costs and benefits of adaptation strategies (impacts if people are moved, additional costs), prioritization strategies, equity issues (Ranger et al. 2011 – for Mumbai on the benefits of adaptation [no info on the costs]). Difficulties in getting detailed local information base to support these.

8.3.2.1. Adaptation and Development Planning

Adaptation for urban areas is becoming an issue of concern for some national and regional governments and city governments where the first steps have come from different actors, institutions and sectors. Some local programmes and national and international initiatives are being designed and implemented at city level (Roberts, 2008, Solecki, 200XX) One of the most interesting aspects of recent contributions of adaptation to climate change in urban areas is the growing attention to middle-income and low-income countries (Sánchez-Rodríguez 2009:202). Several scholars (Blanco, 2007; Carolini, 2007, Martine et al. 2007, Mc Granahan et al. 2007, Satterthwaite et al. 2007, Scherbinin et al. 2007, UN-Habitat, 2007; United Nations Population Fund, 2007, Agrawala and van Aalst, 2008; Ayers, 2008, Bartlett, 2008, Caney, 2008, Douglas et al. 2008, , Kovatrs and Akhtar, 2008, Revi, 2008, Roberts, 2008, Stren, 2008, Tanner et al. 2008, , O'Demsey, 2009, Hardoy and Pandiella, 2009,Wong 2009, Navarrete et al. 2010) have studied different dimensions of climate change adaptation in these low and middle-income countries.

To Sánchez-Rodríguez (2009:202) there are four significant contributions from these publications to urban adaptation: first, they provide attention to urban areas in low and middle-income countries where the large majority of current and future urban inhabitants in the world live; second, they consider poverty and social inequality are multidimensional problems likely to be aggravated by climate change; third, they consider human agency among poor inhabitants an important resource in building local responses to climate change; fourth, they highlight the importance of multilevel governance in adaptation strategies.

Although few of these contributions suggest specific steps for operational strategies for climate change, they stress the important relation between adaptation to climate change and development. In this regard, Manuel-Navarrete et al. (2011) outline a critical approach to adaptation and explores the interplay between visions of development, governance structures, and strategies to cope with hurricanes in the Mexican Caribbean, a region at the 'front line' of both globalization and climatic extreme phenomena. Critical adaptation formulates the experiencing of hazards as essentially political and tied to contingent development paths, which may eventually become hegemonic.

According to Sánchez-Rodríguez (2009:201), during the last few years the debate on adaptation to climate change in urban areas has shown two developments; on the one hand, there are diverse and useful disciplinary contributions and experiences to build adaptation strategies, but few efforts to create multidimensional approaches guiding operational strategies; and on the other, there is growing attention to integrate adaptation as part of a development process addressing structural condition causing social and urban vulnerability. In this regard, the author discusses the relation between adaptation and development in middle-income and low-income countries. Mexico City, Cartagena and San Andrés de Tumaco, Colombia provide interesting early lesson potentially useful to other cities.

[Possible box summarizing experience from these cities]

However, many sources note how the growing concern among city and national governments on climate change often focuses more on mitigation. For instance, a closer look at Mexico City climate change agenda shows that mitigation mainly through the reduction GHG emissions prevails and adaptation is still a vague concept that has not been incorporated into concrete actions and decisions (GDF, 2007; GDF, 2008, GDF, 2011). *El Programa de Acción Climática de la Ciudad de México 2008-2012* includes a brief section on adaptation and policy actions; it identifies the main hazards as the basis for vulnerability analysis, adaptation `mainstreaming` into Mexico City ministries taking into consideration both the civil protection system and the environment. Implementation, on the other hand, is conceived as the needed modifications in water infrastructure, buildings and bio-diversity to cope with the impact associated to climate change. However no clear guidelines or concrete measures are detailed in the document. In the short-run, adaptation is seen as the capacity to withstand weather-related impacts such as floods and forest fire through early warning systems, whereas in the long-run adaptation to climate change relies on micro-basin conservation. It is worth mentioning that, so far, implementation has not been assessed.

As yet, there is little academic and policy literature on climate change adaptation for Brazilian cities (Ojima, 2009; Soares de Moura, 2009). The government of the city of Sao Paulo has expressed its commitment to climate change actions but as in the case of Mexico City, mitigation actions are in forefront of the agenda whereas adaptation measures are broad declarations about the needed actions in different sectors like water and sanitation, green spaces and urban parks, among others (INPE, UNICAMP, USP, 2010) According to Ojima (2009) it has been very difficult to integrate climate change adaptation into urban policies in Brazil due to two reasons: there is no connection between climate and social policies and the few existing initiatives are drawn from the international context. Apparently there is no Brazilian Adaptation Programme (More references and details to come).

In Colombia there are few references concerning global warming and associated phenomena like sea level rise and climate change. In the policy document entitled *Preparándose para el futuro. Amenazas, riesgos, vulnerabilidad y adaptación frente al cambio climático* published by United Nations Office on Drugs and Crime (UNODC, 2008) a brief section is devoted to the impact on settlements by climate change with no indication, specifically, on how this interaction will likely be. The document contains some Colombian experiences on vulnerability assessment: water and mountain ecosystems. With regards to adaptation, in this document the UNDP adaptation policy framework is adopted and described with the intention of designing adaptation indicators for vulnerability assessment.

In Argentina, there are no in-depth analysis on vulnerability and adaptation for urban areas. Even though the federal government is actively participating in UNCCC and other forums, and that within the Ministry of Environment and Sustainable Development there is an office in charge of urban affairs, few concrete actions have been proposed to foster adaptation. The office of urban affairs is too weak to influence other ministries so implementation has not taken place. There has also been little funding available to advance this (Hardoy and Pandiella, 2007). For Uruguay, Nagy et al. (2007) estimate trends and vulnerabilities as a result of sea level rise on the coastal areas of Rio de la Plata. The authors identify some barriers for adaptation within the framework Integrated Management of Coastal Zone, EcoPlata Programme. The aim of the programme is to link knowledge to action in order to promote a cultural change in policy makers and public servants. This study addresses vulnerability and existing and potential impacts in coastal zone of Metropolitan Montevideo and the city of La Plata. Barriers identified are: 1) no public awareness of climate change, integrated coastal management, stakeholders participation and 2) gaps of information regarding monitoring and economic-environment assessments. In turn adaptation measures proposed are: 1) to improve monitoring systems and modelling of the sea level, winds, coastal rivers, flooding prone areas, among others; 2) to develop an early warning system comprising storms and SIG and risk communication to social actors and 3) estimate physical, environmental, economic and human thresholds and conservation of native ecosystems.

Besides, framing adaptation within the context of development and urban planning in middle-income nations implies, among other issues, looking at how knowledge of vulnerability and adaptation is produced within the two different epistemic communities involved: scientists and policy makers. The origin, destination and use of knowledge differ between them, so it is not unusual to find a "gap" between knowledge and practice. When it comes to adaptation policy and planning these differences have to be acknowledged. In this regard, the study of city of Tijuana, Baja Califonia, México (Sanchez-Rodríguez, 2011) illustrates the existence of this "knowledge gap" and the participation of scientists and policy makers in seeking ways to be better prepared for negative consequences of climate variability. In this vein, it is worth asking whether adaptation can be conceived as a rational management practice given its cross-sectoral and cross-institutional nature, involving a broad range of stakeholders and, as discussed above, their particular ways of framing vulnerability and therefore adaptation practices.

Need to balance this good level of detail from Latin America with more material from other regions

8.3.2.2. Mainstreaming Adaptation into Development Planning

There are now some case studies of how climate change adaption requirements are being considered by city government – including whether and how these may be introduced into mainstream municipal planning systems is a major avenue for achieving adaptation. This has importance, particularly in the Global South where it makes little sense to introduce an additional layer of climate change planning to already complex (and often fragmented) planning systems (Kithiia, 2010 pg 3; Roberts, 2008 pg 533). This approach faces significant challenges such as lack of information, institutional constraints and resource limitations (Measham *et al.*, 2010 pg 4) and the fact that in "any given authority the planning agenda is usually already full" (Measham *et al.*, 2010 pg 19). As a result it is often hard to find the requisite institutional space for climate change adaptation. Not to mainstream adaptation plans, however, increases the danger that climate change issues will be seen merely as "add-ons to the overall strategies driven by economic and spatial concerns" (Kithiia and Dowling, 2010 pg 474). Mainstreaming also has the added advantage, that given municipalities' resource limitations the adaptation agenda can be significantly advanced by ensuring that local levels funds are spent "with adaptation needs in mind" (Lowe *et al.,* 2009 pg 6). "For example, integrating climate change in urban development could help planners to rethink the traditional approach of designing infrastructure based on weather patterns and changes in sea level experienced in the past and move towards a new approach of forward looking risk-based design for a range of climate conditions projected in the future" (Kithiia, 2010, pg 3)

Often the most effective way to mainstream adaptation issues within government agencies is not to focus on climate change *per se*, but to talk in terms of improved service delivery, economic development (and protecting economic success) and resilience. Other effective mainstreaming tools include encouraging adaptation action at a sectoral level, rather than adopting a more cross-sectoral approach and initiating pilot projects. A sectoral approach makes the climate message easier to understand and the associated responsibilities and actions clearer and simpler to identify and assign (Roberts, 2010, pg 401; UN-Habitat, 2011 pg 147) while pilot projects root the (often vague) concept of adaptation in reality and allow a practical demonstration of the gains to be achieved (Roberts, 2010 pg 408, Tyler et al, 2010 pg 21). In this vein municipal authorities in India can perceive climate change adaptation as a priority if they see co-benefits between adaptation and measures to address development and environmental health concerns (Sharma, D and Sanjay Tomar, 2010)

8.3.2.3. Risk Reduction, Disaster Prevention, and Adaptation to Climate Change at the Policy Level

From the late 1980s, a new approach to reducing disaster risk in urban areas was developed in some Latin American nations that had three important characteristics: it was based on analyses of detailed local records of disasters that included 'small' disasters that are not recorded in international disaster databases; it recognized that most disasters were caused by local failures to assess and act on risk; and it recognized the importance of local governments and national and local civil defence organizations working with civil society groups including community organizations within the settlements or districts most at risk (United Nations 2009, IFRC 2010). This can be seen in the work of the academics and practitioners that were part of La Red that was founded in 1992 (IFRC 2010). From this and from some experiences in Asian cities with community-driven 'slum' upgrading (see Boonyabancha 2005, 2009) came a recognition of the potential of community-based initiatives in disaster risk reduction, especially where these were supported by local government and by civil defence or emergency response agencies (Archer and Boonyabancha 2011, Pelling 2011b).

This new focus on identifying measures to reduce disaster risk also brought new methods of documenting and mapping informal settlements, including detailed enumerations in informal settlements that are undertaken by their inhabitants, supported by local governments (Patel 2004, Karanja 2010). These provide the data needed to plan for the installation or upgrading of infrastructure including that needed to reduce risks from extreme weather. From this has developed the inclusion in these community-managed data gathering of documenting and mapping risks and vulnerabilities to extreme weather (and other hazards) (Pelling 2011b, Carcellar et al 2011, Livengood 2012). This kind of risk and vulnerability 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).

A few studies have addressed the existing and potential synergies between civil protection, disaster prevention and climate change as a way to foster adaptation within policies and programmes for middle-income nations. In Latin America and particularly in Mexico, Aragón-Durand (2008) analysed civil protection and hydro-meteorological risk reduction strategies within the context of climate change. He argues that in order to link climate change adaptation to such risk reduction measures, two issues need consideration: 1) To recognise that risk perception and natural hazards, risk and vulnerability mean different things to the two policy communities: the disaster management community and the climate change community, 2) To understand that those conceptual differences imply different policy values and therefore different institutional responses. (Add detail here from SREX?) The study identifies existing opportunities and strengths in Mexico's National System of Civil Protection that can allow improvements to the hydrometeorological risk management to then promote climate change adaptation, in particular regarding the Fund for Natural Disasters Prevention and the Fund for Natural Disasters. The study proposes concrete linkages between the Program of Climate Change of Veracruz with the Civil Protection Program of Veracruz; however, a more detailed analysis for the main cities exposed to climate risks is necessary in order to propose concrete adaptation actions for cities. It concludes that there are already institutional and policy values (not clear what is meant by policy values) in Mexico to foster climate change adaptation through hidrometeorological risk reduction. The case of the State of Veracruz can serve as a framework to be applied to other States that already have Civil Protection Programmes and that are currently elaborating their Climate Change Action Plans as proposed by the Federal Programme on Climate Change. No other policy documents like the one referred above for Veracuz were found so far for other Latin America cases.

The innovations in disaster risk reduction within urban centres in Latin America have also led to institutional changes at national or regional level and new legislation or amendments to existing legislation to support disaster risk reduction (Gavidia 2006, other refs). These provide precedents from which to learn how these can support local action. For instance, in Colombia, a national law supports disaster risk reduction and a National System for Prevention and Response to Disasters (Sistema Nacional para la Prevención y Atención de Desastres). This system works on prevention and includes public and private organizations, NGOs and citizen groups at different territorial levels (national, regional and local) – but the main responsibility for action lies with the municipal administrations. A National Calamity Fund (Fondo Nacional de Calamidades) was set up to address the needs generated by disasters and implement preventive actions (Von Hesse, Kamiche and de la Torre 2008). The National System for Disaster Prevention, Mitigation and Response (SINAPRED)[1] developed in Nicaragua share some of the approaches of that in Colombia (IFRC 2010). This 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, Kamiche and de la Torre 2008). Several municipalities are incorporating preventive planning especially in regard to approving building licences and land use changes, and different sectors including health, education, and planning are sharing disaster risk information (IFRC 2010). The system is supported by a National Disaster Fund. There are also international networks that help support innovation and inter-city learning – for instance and Andes network and CEPREDENAC.

[INSERT FOOTNOTE 1 HERE: The Sistema Nacional para la Prevencion, Mitigacion y Atencion de Desastres was initially known by the acronym SNPMAD and later changed to SINAPRED.]

However, there is a worry that local governments can be allocated responsibilities for disaster risk reduction (and other key aspects of adaptation) for which they lack the capacities and resources (Von Hesse, Kamiche and de la Torre 2008). There is also the issue that the duration of policies is often tied to the duration of particular party political groups/administrations and as new administrations come in, programmes are abandoned and staff changed (Mansilla with Brenes and Icaza 2008, Hardoy, Pandiella and Velasquez 2011). No government gets recognition for the disasters its 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. In most cases, disaster risk reduction is still not integrated into development plans and there is reticence to address disaster risk as a cross-cutting issue, drawing in all relevant departments and divisions of local government. There are examples of where this is overcome, as in Manizales where disaster risk reduction is seen as part of local development and where collective interests overcome individual and party political interests (Hardoy, Pandiella and Velasquez 2011).

Other routes to adaptation include autonomous community based adaptation (with all its strengths and limits in urban areas) and community based adaptation in partnership with local governments (where these complement each other). A credible urban future with resilience to climate change for cities in low- and middle-income nations as well as high-income nations. Building on long experience of poor with coping and autonomous adaptation.

8.3.2.4. Household- and Community-Based Adaptation in Urban Areas

Community-based adaptation implies that a group of people (usually residents in a particular settlement) agree to work together to address some perceived vulnerability to climate change (or variability). It implies that community-action is needed (i.e. that government agencies are not going to take this action). The action may take the form of autonomous action (i.e. done without external support) or action to engage with local governments or other groups to get action.

In high-income nations, although discussions within particular cities on adaptation have usually included measures to encourage community participation, 'communities' however defined are not considered as major providers of risk reducing infrastructure and services. In low- and middle-income nations, there has been more discussion of Community Based Adaptation, in part because of the incapacity of governments to provide needed risk-reducing infrastructure and services, in part because of higher risks and vulnerabilities among urban populations, in part in recognition that local populations have knowledge and capacities that could reduce their vulnerabilities (Dodman and Mitlin 2011, Anguelovski and Carmin 2011pg 4). In part, community based adaptation is a response to the lack of action on adaptation by governments and international agencies (Boyd et al 2009, Dodman and Mitlin 2011).

Within urban areas, as describe already, hundreds of millions of people live and work in settlements that are or are considered 'illegal' by local governments and this may inhibit or prevent government provision of risk-reducing infrastructure and public services. It also often means that not only do a high proportion live in settlements lacking infrastructure but they also live on sites at high risk from extreme weather because they would not be permitted to settle on less dangerous, more valuable sites (Hardoy et al 2001).

In these informal settlements, both individual/households actions (for instance building, improving or extending homes) and 'community-based development' (where groups of individuals and households undertake measures together) have long been important for improving conditions and reducing risks from extreme weather. The unwillingness or incapacity of city and municipal governments to provide the infrastructure and services that can reduce vulnerability to climate change implies a need to support individual/household action and community-based action for adaptation. One reason why certain international agencies have supported CBA is because of the incapacity or unwillingness of local governments to act.

For community-based adaptation, this can take the form of autonomous action (as residents within a particular settlement work together to install or repair infrastructure or provide services) or action that seeks to engage local government and where possible work with it. There are many precedents for this from development – including 'slum' or 'squatter' upgrading programmes through which community organizations formed by the residents of these settlements work with government agencies. Many upgrading programmes have reduced many of the risks and vulnerabilities associated with climate change as the quality of housing improved, as provision for piped water, sanitation and drainage was made – and, more generally, as those living in these settlements became incorporated into 'the formal' city (Almansi 2009, Boonyabancha 2005, Fernandes 2007, Ferguson and Navarrete 2003, Imparato and Ruster 2003, Some, Hafidz and Sauter 2009, UN Millennium Project 2005). The issue of land tenure, however, remains difficult to resolve and is likely to impede local level adaptation action, particularly given that the GLTN (2008 pg 13) states that in 2005, an estimated 934 million people lived without secure tenure in informal settlements in the urban areas of developing countries, and predicts that the number will increase to 1.5 billion by 2020 and two billion by 2030.

Household based adaptation in urban areas

Many case studies of risk and vulnerability in informal settlements show the responses of individuals and households, where there is a history of extreme events (for instance floods, heat waves and high winds) (Wamsler 2007, Adelekan 2010, Jabeen, Johnson and Allen 2010, Livengood 2012). These measures include those that reduce the risk to themselves (eg ventilation and roofs or roof covering that reduce maximum temperatures during heat waves, barriers built to prevent floodwater entering homes) or reduce their exposure (moving temporarily to safer locations, sleeping and keeping food stores on top of high furniture).

In some instances, the inhabitants of informal settlements have taken developed a range of measures for risk reduction. For instance, in Dar es Salaam, in settlement x, walls with steps have been constructed around doors.

Measures that limit exposure to the risks are the most common. For instance, one inhabitant of an informal settlement 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 on our very high beds which are reached by climbing ladders. Also children who sleep on the floor are transferred to the high beds"(*Douglas et al 2008). Box 8-1 outlines the various measures taken by household in Korail, one of the largest informal settlements in Dhaka, that includes adjustments to housing and measures to reduce exposure. Interviews with Korail's inhabitants revealed that some moved to safer locations when monsoon rains were expected but most did not as they felt this risked losing assets and disrupting income-sources and livelihoods (Jabeen, Allen and Johnson 2010). They also worried about whether they would be allowed to return to their settlement if they moved. Similar concerns were expressed by the inhabitants of informal settlements in Santa Fe, Argentina; part of their reluctance to move from their homes to escape floods was a worry that their homes would be looted and that they would not be allowed back (Hardoy, Pandiella and Velasquez 2011). Cultural concerns are also a significant factor influencing the adaptive responses of communities (Carter, 2011 pg 196) and these may include beliefs that hinder household or community adaptation (Golder Associates, 2010 pg 24). Other factors affecting the opportunities for community based adaptation included issues of land tenure and cost effectiveness. For example "buying" a plot on a floodplain for a once-off cost of R500, was preferable to renting a room in a safe high lying area for R300 (Golder Associates, pg 24).

_____ START BOX 8-1 HERE _____

Box 8-1. Household Adaptation in Korail

In this informal settlement, most impact-minimizing actions were temporary and part of regular practice – for instance putting temporary barriers across door fronts to limit flood waters entering the home or temporarily increasing furniture height (for instance putting them onto bricks). Other measures included changes to the house structure – for instance, making higher plinths and arranging higher storage facilities (eg shelves higher up walls). To help cope with very high temperatures, creepers were grown in courtyards to cover roofs and other materials are put on roofs to reduce heat gain; most households used some form of false ceiling or canopy made out of cloth (a popular practice in rural areas, adopted in urban houses) For houses near or on the water's edge, structures are on stilts with platforms constructed higher up the stilts. Wooden planks for flooring are preferred as they suffer less from water clogging once floods subside after heavy rainfall. Stilts also mean expansion is possible over the lake adjoining the settlement. During flooding or water clogging, most residents sleep on furniture, use movable cookers for food preparation (that can be used on shelves or on top of furniture); some shared services with unaffected neighbours. Other measures include making outlets to help get the floodwater out of the house

SOURCE: Jabeen, Johnson and Allen 2011

[INSERT FIGURE 8-2 HERE
Figure 8-2: A cross-section of a house in Korail showing measures taken to cope with flooding and high temperatures (Jabeen, Johnson, and Allen 2011).]

_____ END BOX 8-1 HERE _____

In Korail, as in other informal settlements, it was mostly actions by individual and households, not communities. In El Salvador interviews and discussions with the inhabitants of 15 disaster-prone "slum" communities and with local organizations showed the difficulties in getting community action. The inhabitants recognized that flooding and landslides were the most serious risks to their lives and livelihoods – although discussions with them also highlighted other problems such as lack of job opportunities, inadequate water provision and juvenile violence. Many households had invested in risk reduction – for instance more diverse livelihoods, assets that could be sold and remittance from family members working abroad. But a range of issues limited them working together for collective measures – including no representative community organizations through which to design and implement settlement-measures and a lack of support from government agencies. In addition, most of the institutions that could have supported improved housing did not consider risk-reduction (Wamsler 2007).

In a study of the risks faced by the residents of four informal settlements in Lagos to flooding, there were some community initiatives to clear blocked drainage channels but most responses were by individuals or households – for instance, constructing drains, trenches or walls to try to protect their houses. Food and other household items were stored on shelves or cupboards above anticipated flood levels. Those interviewed highlighted how any climate hazard reduces earnings through missed working hours or days (Adelekan 2010)

Community-based adaptation

The willingness of individuals to invest in collective actions for risk reduction in their settlement will be influenced by how secure they feel from eviction and their tenure status (for instance tenants are usually unwilling to invest in improving the housing they live in and less willing to invest in community initiatives). This willingness also depends on how their settlement is viewed by local government and the relationships between local government and community organizations or community leaders. But the contribution of community-level organization and action to disaster risk reduction (and development and climate change adaptation) can also be greatly enhanced where local governments and other key bodies (for instance, for disasters, civil defence organizations) recognize their role or their potential role and support them. It has become common for local governments to work with community-based organizations in upgrading (see for instance Boonyabancha 2005, 2009) and in disaster risk reduction (see Pelling 2011b, United Nations 2009, 2011, IFRC 2010). Community-based adaptation has many precedents in community-based actions to reduce risks and vulnerabilities to floods, storms and heat waves in the past (see for instance Archer and Boonyabancha 2011).

Ayers and Forsyth 2009 suggest that community-based adaptation implies operating at the level of a neighbourhood, settlement or village in communities that are vulnerable to climate change and includes identifying and implementing community-based activities that strengthen their adaptive capacities and address local development concerns that underlie vulnerability.

Interest in community-based adaptation has grown among researchers and international agencies but this has tended to focus more on rural areas and in relation to rural livelihoods (Dodman and Mitlin 2011). In part, this is because much of the exposure to environmental risk among urban populations is because of deficiencies in provision for infrastructure and services to those living in informal settlements. For instance, community organizations may be able to help construct or improve drainage and collect solid waste within their settlement but there are obvious limits in what community-organizations can do; community based organization and action cannot provide the network infrastructure that local infrastructure needs (eg piped water systems or drainage networks) or city-region management – for instance land-use management that avoids settlement on sites at risk, needed revisions in building codes (Satterthwaite, Dodman and Bicknell 2009). Most informal settlements are embedded in a larger built up area and if community action does improve drains and solid waste collection, these need larger systems – for the drains to feed into, for the solid waste collected to be removed. They need road, path and bridge networks beyond their settlements that can withstand extreme weather and which allow them to evacuate if needed. A focus on community-action may mean a lack of attention to the structural inequalities that underlie these deficiencies (Mohan 2002) and a lack of attention to the responsibilities of local governments and international agencies (Dodman and Mitlin 2011). In addition, low-income communities may not see climate change adaptation as a priority, especially if confronted with pressing issues such as daily difficulties in generating sufficient income and a threat of eviction (see Banks et al 2011).

The effectiveness of community-based action is also dependent on how representative and inclusive the community leaders and organizations are. In Durban, a high reliance on government grants for income, general community apathy and high levels of crime act as barriers to community mobilisation (Golder Associates, pg 25). Also significant is the issue of social cohesion and distrust. For example, in Durban, the use of water tanks for rain water harvesting is affected by the fear that neighbours or other groups may contaminate the tanks (ibid).

Examples of community based adaptation
Lessons. Gender.
How representative are community organizations
Does it generate pressure for larger changes.
Does it learn from participatory development. Does it engage with key development agendas that reduce poverty and vulnerability (Sabates-Wheeler et al 2008). Does it underplay local inequalities and adverse power relations at district, city, national and transnational levels (Mohan and Stokke 2000).
What about the difficulties of those who are chronically ill or disabled – including role of HIV

8.3.3. Adapting Key Sectors

This section reviews what is known about adapting the key sectors of urban areas to climate change – sectors whose vulnerability to such change was discussed in section 2.

8.3.3.1. Adapting the Economic Base of Urban Centers

Cities concentrate a high proportion of the world's GNP and its economic assets and a high proportion of all new private sector investment (World Bank 2008, Munich Re 2004, McKinsey 2011). They are often leading nodes of growth and innovation, with clusters of significant industries and services (World Bank 2008. **more cites).** As described in section 2, a large and growing proportion of disasters associated with extreme weather in urban centres show their vulnerability to extreme weather events whose intensity and/or frequency climate change is likely to increase. Adjustments for many manufacturing industries may be especially challenging as a result of the lengthy lead times, slow turnover rates for capital stock, and significant capital requirements (Ruth 2010: 390). Without farsighted adaptation strategies in manufacturing and other sectors, climate change is likely to hamper growth in most urban centres.

As section 8.3.x describes in more detail, the economic underpinning of cities includes the ecosystems and ecosystem services that provide the platform for human well-being and economic development (see e.g. MA, 2005, TEEB, 2010). Adaptation of these natural ecosystems in urban areas is therefore also critical as the ecosystem services contribute to the economic base. For instance, one estimate for Durban suggested that these were worth R3.1 billion (eThekwini Municipality, 2007).

For any urban centre, a failure to adapt to climate change is likely to discourage new investments and over the long term also to some of its 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 (refs) so they can choose to avoid urban centres facing high risks linked both to climate change and a failure to adapt.

Disasters can also have important long-term economic consequences, as illustrated by the economic difficulties that still face the city of New Orleans, after Hurricane Katrina (although even before Katrina, new investments there had been discouraged by previous disasters). These arise from changes in risk perceptions that deter new investments. They also derive from clustered and increasing-return effects that lead businesses to move outside the affected area when many other businesses and services that they use (especially basic services like utilities, schools, and hospitals) are seriously affected (Hallegatte and Dumas 2008). A lack of capacity to reconstruct means increased vulnerability to the next extreme weather event and less new investment (that in turn weakens the economic base) (see Benson and Clay 2004; Hallegatte et al. 2007, Hallegatte, Henriet and Corfee-Morlot 2011):

THIS PARAGRAPH AND SOME OTHER PARTS IN THIS MAY BELONG IN SECTION 2: Many case studies show how extreme weather events can impede economic activities in cities, such as damaging industrial infrastructure, disrupting coastal ports and broader supply chains, or curtailing urban tourism (Gasper, Blohm, and Ruth 2011). This is illustrated by the costs of flooding for the city of Villahermosa in the state of Tabasco, Mexico located in the delta of Grijalva river. This also illustrates both primary and secondary impacts. As a result of the floods in 2007 that covered 65% of Tabasco State, Villahermosa´s economic base got seriously depleted. Regional damages and asset and infrastructure losses amounted for up to US$ 3.1 billion, equivalent to 30% of Tabasco State GDP (CEPAL, 2008). Reconstruction of the city and the region is still underway. Even though the Integrated Hydraulic Integral Programme of Tabasco (PHIT) was designed and still being implemented, not enough information is available on to what extent this has become a successful water management planning process oriented to reduce the urban risk of future flooding events that may be caused by climatic factors. This is in part due to the lack of policy assessment and research and the mismatch between local economy needs and policies aimed at restoring the Tabasco state economy. In this regard, adaptation of key economic city sectors such as peri-urban agriculture, services including water and sanitation and tourism is a must. It is worth noting that Villahermosa neighbouring medium-sized cities such as Cárdenas and Huimanguillo are also vulnerable to regional flooding – and were affected in 2008- so a comprehensive disaster prevention and climate change adaptation plan is required. Tabasco´s main public university, along with other research institutes, are about to release the Climate Change Action Plan for Tabasco[2],CCAP Tabasco (UJAT-INE, 2011) that comprises both mitigation and adaptation measures. However, scientific research and evaluation of current and potential vulnerabilities to climate change in this region are focused on primary sectors and on coastal ecosystems so adaptation measures proposed are centred on the impact of sea-level rise and coastal-line depletion and saline intrusion in aquifers near rural communities – such as Sánchez-Magallanes and Frontera, Tabasco (Vázquez-Botello, 2010). The consideration of urban vulnerability and therefore cities´ adaptation to climate and weather hazards is lacking in the CCAP Tabasco. This is in part due to the professional background and institutional adscription of those who are in charge of drafting the CCAP Tabasco and also to the fact that urban planning has not yet envisioned an adaptation route.
Case study of flooding, the inadequacies of local government responses and the costs to the economy in Santa Fe (Argentina) could be added here (Hardoy, Pandiella and Velasquez 2011).

[INSERT FOOTNOTE 2 HERE: Climate Change Action Plan of Tabasco will be published in 2011.]

Drought will threaten cities like Naivasha, Kenya, that rely upon high-value horticultural exports (Simon 2010: 243). NEED DISCUSSION HERE OF CITIES WHOSE ECONOMIC BASE IS TIED TO PROSPEROUS AGRICULTURE IN AREAS WHERE DROUGHT OR DECREASES IN RAILFALL THREATEN THIS
Some regions and sectors will be particularly affected by climate change – for instance many tourist centres and agricultural production as discussed in later sections. Losses in these can lead to significant indirect economic losses

and unemployment. Past experience of de-industrialization (e.g., in many cities in the U.S. and Europe whose prosperity was based on industry) has shown how difficult it is for a region to shift from one activity to another. When the main activity of a region disappears, inhabitant revenue and local authority revenues (through taxes) decrease, making it more difficult to re-invest in new business and less attractive for alternative businesses to establish in the region. If climate change forces many regions to change their business models, transitions may prove difficult to manage (see Berger 2003), and specific adaptation policy 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 as new areas within or around cities are settled, rather than retrofitting infrastructure and where industries are already in place (McGranahan, Balk, and Anderson 2007: 21).

Within and around urban centres, local governments may need to utilise several strategies including selective relocation, land use planning to reduce exposure and shifting development from floodplains, and revised building regulations to retrofit or flood-proof structures (Hanson *et al*. 2011: 103).
There may be important opportunities for proactive adaptation outside the larger cities where, as noted in section 1 much of the future urban growth is likely to occur (Satterthwaite 2007). But smaller urban centres are often institutionally weaker and lack critical infrastructure. Local authorities can seek to adapt and mitigate climate change as these facilities are established (Hardoy and Romero-Lankao 2011: 159) The local government in Manizales, Colombia, has begun incorporating climate change and environmental management into its local development agenda, including the establishment of city climate monitoring systems (*ibid.,* p. 160). In many low and middle income nations with successful economies, a new generation of cities have emerged that are attracting new investment away from the largest cities – often supported by decentralization, more accountable and competent local governments and better quality national systems of infrastructure for transport and communications (ibid, Satterthwaite et al 2010*,* Dávila 2009).

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 profound in poorer households, which lack assets or insurance that help them cope with shocks (Moser and Satterthwaite 2008). Although many of the urban poor engage in informal livelihood strategies, the effects of extreme weather on the informal economy are rarely measured. For instance, the floods in Santa Fe, Argentina in 2003 caused an estimated US$1bn in losses but these estimates do not include lost workdays and income for informal labourers (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: 21).
The importance of support for a 'green economy' and for its support with green infrastructure to help shift the economic base (and employment) towards lower carbon, more climate resilient urban patterns is recognized but as yet not much developed.

The scale, nature and importance of the 'waste economy' in cities in low- and middle-income nations and its importance for livelihoods for large sections of the low-income population is now well documented (Thieme 2010, Medina 2007, Hasan 2010, others), as are its contribution to waste reduction and greenhouse gas emission reduction (Huq and Ayers 2009). For example, in Brazil's main cities, over 500,000 people are engaged in waste picking and recycling (REFS); an estimated 17,000 people in Lima and 40,000 in Cairo earn their livelihoods from informal recycling (Scheinberg *et al*. 2011: 193).

For some cities, there is some documentation of the kinds of adaptation needed to protect or enhance their economic base. For instance, climate change is likely to have major impacts on Mombasa and its surrounding regional economy. As well as a tourist destination and industrial centre, Mombasa is the second largest city in Kenya, the largest seaport in East Africa and gateway for Kenya's landlocked neighbours (Kithiia and Dowling 2010). The city's annual costs of coastal flooding due to sea level rise may reach $7-58m in 2030 and perhaps $31-313m annually by 2050 (Kithiia 2011: 177 **using 2009 SEI report**). Local authorities may need to redesign and reconstruct the city's ports; cement industries and oil refineries may necessitate major financial and capital investments as well (Awuor, Orindi and Adwera 2009: 84). Relocation of industries further inland may be required in other cases (*ibid.*). Recent plans have sought to restore coastal zones, improve climate data collection, and strengthen disaster management capacities (*ibid*.), but further steps are needed to adapt Mombasa's economy to climate change. (ADD DETAILS OF VULNERABILTY OF INFORMAL ECONOMY FROM MOSER AND STEIN 2011)

Climate change may have similarly negative effects upon Rio de Janeiro's diverse economy (including industry, oil refineries, shipyards and tourism) and adaptive measures may create difficult trade-offs for the city (de Sherbinin, Schiller, and Pulsipher 2007). Many parts of the city are also vulnerable to climate hazards, including erratic precipitation, flooding, and landslides (*ibid*.). It is mostly those living in informal settlements (favelas) on land at risk of landslides that are most impacted (REFS). Defences needed to help safeguard coastal industries and residential areas could threaten the city's beach tourist industry (de Sherbinin et al 2007.). Adapting Rio's economic base will need to resolve such tensions and trade-offs, necessitating dialogue amongst local stakeholders (Ruth 2010). In this regard, a policy document on Rio de Janeiro´s vulnerability and adaptation to climate change is to be released in 2011. To check adaptation measures proposed <Fernando will try to get that information>

Many cities' economies will be impacted if climate change brings water scarcity and variability that interrupt hydropower supplies. Climate change may interrupt Brazil's hydroelectric supplies, with negative knock-on effects upon the economies of many urban centres – for instance Rio's industries (de Sherbinin, Schiller, and Pulsipher 2007). Cities in sub-Saharan African often rely on hydropower for their electricity, and failures in hydropower supplies "can lead to more general 'urban failure' " (Muller 2007). 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).

As yet, there is little evidence that the location of private sector investments is influenced by climate-change related risks or by cities adaptive capacities, although of course it is influenced by the availability of infrastructure and services that are an essential part of adaptive capacity. Many of the cities in Asia with successful economies are located on low-lying coastal areas, which are undergoing rapid urbanisation and economic transformation (McGranahan, Balk, and Anderson 2007).[3] 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 will likely be a non-linear increase in coastal vulnerability over the next 2 decades (Revi 2009: 322). The same is true for China (McGranahan et al 2007). 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). Additionally, frameworks have sought to capture the direct and indirect economic impacts of climate change in urban areas (Hallegatte, Henriet and Corfee-Morlot 2011)

[INSERT FOOTNOTE 3 HERE: 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 have been completed in West African coastal cities, which are threatened by climate change as well as facing ecological degradation and urban management challenges. But national and city governments will face difficulties protecting many cities or parts of cities, including industries, infrastructure and tourism (see Doussou and Gléhouenou-Doussou 2009: 116 **no source).** 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: 244). Compounding the climate change-induced flooding risks are the cities' rapid coastal construction, destruction of mangrove swamps, and inadequate refuse collection (*ibid*.). Artisanal fishing communities, tourism, and other industries may require adaptive strategies to manage these complex risks to local economic development. This is also happening in the Caribbean coast of Mexico where tourism and cities such as Cancun and Tulum have grown close to areas exposed to hurricanes (Pelling 2011) and also in the coast of the city of Campeche, in Mexico, Gulf of Mexico (Palacio, A et al 2005)

8.3.3.2. Adapting Food and Biomass for Urban Populations

For the world's growing urban population, climate change adaptation in regard to food and biomass fuels will require measures to ensure sufficient food and fuel supplies within each nation (and region within these) and to ensure that urban and rural dwellers have the means to access sufficient food and fuel. A very large (rural and urban) population currently suffer hunger and a larger population experiences food insecurity irrespective of the challenges from climate change (FAO 2010). Of course, climate-change related constraints on agricultural production and the food supply chain can impact urban areas through reduced supplies or higher prices. But there is also the disruption to agricultural production that can come from reductions in urban demand for agricultural products or reductions in remittance flows from urban to rural areas or disruptions to the urban based enterprises that provide farmers and rural dwellers with goods and services and some rural dwellers with employment (Satterthwaite, McGranahan and Tacoli 2010: 2817)

The impacts of climate change on agriculture will vary between regions and over time, but the overall effects will likely be negative (IPCC 4AR). Population growth, increased affluence, and competing pressures for water or bio-fuels may further erode food security (Godfray *et al*. 2010). However, 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 shifts in diets that are far more meat and carbon intensive and often land intensive (Satterthwaite, McGranahan and Tacoli 2010). There are many examples of cities expanding onto valuable agricultural land, although the global and regional scale of this may be exaggerated. One recent study suggests that the urban built up area represents only 0.5 percent of global land area and it is only in Europe that it exceeds 1 percent (Schneider, Friedl and Potere 2009). In addition, the loss of agricultural land to urban development may in part be compensated by the development of urban agriculture and shifts in agriculture to higher value agricultural products, in part stimulated by rising demand from urban populations. Although adjustments in farming practices are essential, adapting urban food systems represents a major challenge as well and will necessitate radical changes in food production, storage, processing, distribution, and access (*Godfray et al.*).

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). The fact that large sections of the urban population in low- and middle-income countries suffer hunger while a larger number face food insecurity is due more to their low incomes and limited capacities to access food than to overall food shortages (Cohen and Garrett 2010).

In low-income urban households in low and middle income nations, food expenditures generally represent more than half of total expenditures (and often more than this) (Cohen and Garrett 2011: 469). This makes low income urban populations particularly at risk from food price rises. While discussions of hunger and food insecurity usually focus on rural areas, there is a growing literature showing the scale and nature of under nutrition and food insecurity in urban areas (Montgomery et al 2004, Ahmed et al 2007, Cohen and Garrett 2010).
In general, urban dwellers have far fewer possibilities of producing food than rural dwellers (although urban agriculture may be important) so rising prices may increase under nutrition and prevent the urban poor from purchasing a healthy diet (Godfray *et al*. 2010: 814 ***or other cite***). PERHAPS A BOX HERE SUMMARIZING RECENT EVIDENCE ON THE SCALE AND IMPORTANCE OF URBAN AGRI AND THE SIGNIFICANCE FOR CLIMATE CHANGE ADPATATION? a study utilising nationally-representative household survey data in 15 low- and middle-income countries found that the shares of urban households earning income from agriculture "varied from 11% in Indonesia to almost 70% in Vietnam and Nicaragua. In 11 of the 15 countries...the share of households participating is over 30%" (Zezza and Tasciotti 2010: 267). Prolonged drought in Australia, for instance, may decrease the availability of fresh produce and costs could be prohibitive for poorer urban households (Bambrick *et al*. 2011: 70).

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). After the 2004 floods in Bangladesh, Dhaka's rice prices increased by 30 percent and vegetable prices more than doubled (Douglas 2009: 131 **no source).** 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 adopt a range of coping strategies such as reduced consumption, purchasing less nutritious foods, or increasing labour particularly by women and children (Cohen and Garrett 2011: 473-5). But households may thereby erode vital assets and fail to achieve resilience, particularly in the context of more frequent disasters due to climate change.

Other adaptive responses have included support for urban agriculture, local markets, or 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: 478-9). Food security may also be enhanced by government support for urban agriculture and street food vendors (*ibid.,* also Lee-Smith 2011**).** Food security for urban dwellers with low incomes is also obviously increased if these groups' purchasing power increases or they have access to cheaper food or to social incomes – for instance conditional credit or cash transfers (for instance in Brazil the bolsa familia) or, for older groups pensions (Soares, Ribas and Guerreiro Osório 2010).

Additionally, various studies have shown how improving food security in the context of climate change needs to consider the multiple connections between rural and urban areas. In India, for example, the urban metabolism is still heavily shaped by flows of traditional bio-fuels and unprocessed food (Revi 2009: 331). Rather than focusing only on cities, "regional climate change risk adaptation strategies and action plans are needed" (*ibid*.). Complex rural-urban linkages may be decisive in shaping food policies that can address climate change.. Thus, a portfolio of responses that can bridge rural and urban boundaries, as well as action at the household, local, national, and international levels, will be needed to strengthen food security.

8.3.3.3. Adapting Housing and Settlement

Housing is a key social determinant of health so it "clearly plays a role in the susceptibility of the target group to climatic conditions and in planned adaptive strategies by government, the community, and families..." (Maller and Strengers 2011: 4). Housing is "often the major part of the infrastructure affected [by disasters]..." (Jacobs and Williams 2011: 176) although good quality housing is also among the factors that limit the impact of extreme weather. Adapting housing can also help to minimise losses, ill-health, mental distress, or displacement following extreme weather. Housing that is well adapted to climate change also has particular importance for safeguarding potentially vulnerable groups including children (Bartlett 2008), older residents or those with pre-existing chronic health conditions. These can be especially vulnerable to extreme heat (Hajat, O'Connor, and Kosatsky 2010). However, passive cooling or other design measures can reduce the health impacts of heat waves and help maintain comfortable temperatures (Roberts 2008a, Hacker and Holmes 2007).

As the vulnerability of housing to climate change is shaped by multiple factors, resilience may be enhanced via a range of structural and non-structural interventions. Wealthier households in Latin American cities often live in risky sites near rivers, coasts, or on slopes; but they frequently have insurance and the assets "to reinforce their house structures, get protective infrastructure, and lobby for policies and actions that protect their homes and neighbourhoods" (Hardoy and Pandiella 2009: 215). By contrast, low-income households who live in areas at risk usually live in poor quality housing lacking infrastructure and insurance (Moser and Satterthwaite 2008). Adaptation interventions in low-income and most middle-income nations will need to address the high risks facing those living in informal settlements – and so adaptation interventions encompass those that improve the quality and safety of existing and new buildings as well as access to insurance, services, or infrastructure. Strategies will be needed both to retrofit the existing stock and to guide new-build construction, both of which are needed to ensure resilience in the housing sector. The relative contribution of these varies. For instance, the UK's housing stock is replaced at just 1% annually (Roberts 2008a) whereas for many rapidly growing cities, the new housing stock is growing much more rapidly and measures to ensure the resilience of new housing to climate change have great importance for the city's adaptation.

In the absence of appropriate adaptation, housing damages may increase with possible knock-on effects on residents' health, the economy, or resettlement patterns. Chittagong's landslides in June 2007 were prompted by heavy rain and illegal "hill-cutting," resulting in the deaths of 126 people who were mainly slum-dwellers in steep hillside areas (Rahman, Haughton, and Jonas 2010: 561). Climate change may amplify the risks by promoting more frequent or intense storms (posing particular challenges in marginal or hazardous sites where low-income residents frequently reside, as in Chittagong). Although climate-related effects on migration cannot be reliably predicted (Tacoli 2009), adapting housing can help to minimise the displacement and disruption that climate change may otherwise bring.

This section discusses shelter design strategies and planned interventions by local governments, while later sections consider complementary interventions in health, public services, infrastructure, energy, or other sectors. Passive cooling designs (section a) and measures to ensure resilience to floods or other storms (section b) have gained attention in the literature. Few urban policy-makers have implemented such measures, although some cities' plans have begun to identify strategies to adapt the housing sector (section c). Community-based adaptation (considered in section 8.2.3.4) provides another route to improve housing, and households' private adaptation measures will likely be significant in many cities (Fankhauser 2010: 28). The range of actors in the housing sector, its myriad connections to other sectors, and its potential to promote mitigation, adaptation, and development goals all suggest the need for better-coordinated strategies that can support resilience (see also Maller and Strengers 2011 for a research agenda on housing, health and climate change).

Housing and extreme heat: cooling strategies

Measures to cope with extreme heat will be increasingly important in many cities, given the interactions between climate change, housing, and higher temperatures due to the already-existing urban heat island (**cites on UHI).** A review of the health effects of hot weather identified contextual risk factors in residential settings, including "living in homes with high thermal mass and little ventilation," occupying the upper stories of high-rise buildings, or "no access to an air-conditioned environment" (Hajat, O'Connor, and Kosatsky 2010: 858). Mechanical cooling can provide relief from high temperatures, but these devices are potentially mal-adaptive as they contribute to greenhouse gas emissions[4] and may exacerbate residents' vulnerabilities "if blackouts occur on the hottest days when peak demand is at its worst" (Maller and Strengers 2011: 3). As discussed below, extreme heat may instead be reduced using passive cooling measures and adapting green infrastructure (section 8.3.3.7) could readily complement the residential interventions discussed below. Cities will also need heat-wave plans to ensure adequate water provision, back-up electricity supplies, emergency healthcare, and other public services particularly for vulnerable residents such as the elderly.[5]

[INSERT FOOTNOTE 4 HERE: For instance, Australia's cooling and heating appliances accounted for 19% of residential greenhouse gas emissions in 2008 (cited in Maller and Strengers 2011: 3).]

[INSERT FOOTNOTE 5 HERE: These sectoral strategies are discussed in 3.3.XX-XXX, while local government plans to adapt the housing sector are considered below.]

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 2008a and 2008b). Although developments such as BedZED in suburban London[6] (Chance 2009) or Germany's PassiveHaus standard (Rees 2009) have set precedents for mitigating household emissions, these passive designs can simultaneously contribute to adaptation. For instance, loft and wall insulation or double-glazed windows can keep structures cooler in the summer and reduce winter heating demand (Roberts 2008a and 2008b). Other passive measures may include external awnings, or light-coloured paint to increase reflectivity of external walls (*ibid.*). Thermal mass is another key dimension to promote 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[7] (*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.,* p. 111).

[INSERT FOOTNOTE 6 HERE: The designers of Beddington Zero Energy Development (BedZED) sought to reduce energy demand for heating, cooling and ventilation “by 90 per cent compared to the average UK home,” while also utilising super-insulation, ventilation, and other measures to ensure energy is not required for most of the year (Chance 2009: 532).]

[INSERT FOOTNOTE 7 HERE: Info on indigenous architecture +cooling elsewhere?]

Nevertheless, several obstacles may complicate the incorporation of passive designs. Interventions with residents may be needed to ensure proper utilisation of passive cooling features, as BedZED households’ modification (closing windows for privacy, e.g.) increased energy consumption (Chance 2009: 540). Opening windows may also be hampered by cities’ security concerns or noise pollution, and architectural intentions may conflict with the need for high thermal mass or external shading (Hacker and Holmes 2007: 111). 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).

Special attention may also be needed to support adaptation among the elderly in nursing homes, although there is limited research to date on this vulnerable population. A review notes that elderly people in hospitals or residential facilities are at higher risk of heat-related ill-health (Hajat, O’Connor, and Kosatsky 2010: 858). Detailed discussions remain rare and in an observation-based pilot study from a nursing home in northwest England, researchers suggested that pre-existing safety measures and residents’ dependence on nursing staff may actually increase their vulnerability during hot weather (Brown and Walker 2008: 368). For instance, safety-related limiters on windows may obstruct ventilation and wedges to prop doors were banned “because they pose a trip hazard, again making ventilation potentially difficult” (*ibid.,* p. 370). Nursing staff may need additional training in coping with heat and forging appropriate adaptations, such as changing clothes, adjusting food and drink intake, or promoting ventilation and cooling (*ibid.*).

Housing and disaster-preparedness measures

Housing-related adaptations to withstand extreme weather may include revising building codes, providing emergency shelter, and proactive interventions to enhance buildings’ resistance and resilience to flooding. Extreme events such as cyclones and floods may inflict a heavy toll on housing, particularly those structures built with flimsier materials. For instance, floods in Dhaka in 1998 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). Measures to prevent entry points (or ‘resistance’ to flooding) may include blocking doors, covering gaps in external walls around pipes, or preventing water entering through walls (Roberts 2008: 4484). Further steps can be taken that cumulatively reduce the time and cost of recovering from floods (‘resilience’), such as raising electrical points and appliances above water level, or utilising rising hinges to enable door removal (*ibid.*). Many low-income communities have already developed a range of effective responses to flooding (as discussed further in section 8.2.3.4 and 8.4.3 on community-based adaptation). Poorer households in Georgetown, Guyana, utilise stilts or raise their floors with concrete or mud, and findings suggested they were better able to protect their homes from inundation than households in wealthier areas (Linnekamp, Koedam, and Baud 2011: 454).

But other proactive interventions in the housing sector may be needed to ensure residents can cope with more frequent or severe storms. Rotterdam has prioritised adaptive building to provide “permanent protection against flooding” as well as a sustainable, attractive living environment (Rotterdam 2010: 15). The city is developing plans to build floating urban districts by 2040, including 13,000 climate-resilient homes with 1,200 located on water (*ibid.,* see also section 8.3.3.4 on adaptation in the water sector).

Local housing authorities may also need to facilitate emergency shelter and support vulnerable residents or migrants,[8] as occurred after Australia's recent extreme events (Jacobs and Williams 2011). For instance, housing agencies established shelters and recovery centres after Cyclone Larry in Queensland (in 2006) and New South Wales' coastal flooding (in 2007). However, interviewed officials recalled the strains facing 24-hour providers in the shelters and coordination difficulties with emergency health workers, police, insurance, and other agencies (*ibid*.). A Queensland official also noted it was "necessary [that] we conveyed our empathy, especially as many tenants were elderly and vulnerable" (quoted in *ibid.,* p. 188). While not addressing climate change explicitly, the study helps illuminate the range of social support, structural strategies, and interagency efforts that housing authorities may need to develop in order to adapt to climate change. Section c) below considers cities' proposed strategies that may better cope with disasters and promote long-term resilience in the housing sector.

[INSERT FOOTNOTE 8 HERE: See Tacoli 2009 and Adamo 2010 for further discussion of migration and climate change in urban areas.]

Urban adaptation plans in the housing sector

Bangkok Metropolitan Administration (BMA) recently completed a climate change assessment, and interrelated adaptation measures in the residential sector were identified (BMA and UNEP 2009). For instance, it may be necessary to flood-proof homes, build elevated basements, and relocate power-supply boxes upstairs; households will be encouraged to maintain sufficient food, water, fuel, and other supplies to ensure 72 hours of self-sufficiency (*ibid.,* p. 71). The plan also identified regulatory changes that may be needed to bolster resilience. Land use restrictions may be implemented in floodplains, areas prone to land-slides, or other at-risk sites (*ibid.,* p. 72), although the BMA may sponsor flood insurance for areas outside of floodplains. Safety and fire codes may be re-formulated for buildings and other structures; revised floodplain mapping and return frequencies may be reconsidered; and emergency management was identified as a "high priority" (together suggesting the interconnections between housing, public services, and infrastructure in adapting to climate change).

Cape Town's climate change framework (2006) proposed housing interventions, which are seen to support adaptation in the health sector and emergency response services. Thus, health adaptations included improving construction and regulations for building informal housing so as to "minimise health impacts of poor living conditions" (p. 48). Disaster response strategies also "need to be broadened to include adaptation strategies", in order to "reduce the need for emergency response and anticipate projected climatic change" (*ibid.,* p. 44). Recent disaster responses already highlighted the linkages between housing, emergency services, and lasting reconstruction in informal settlements. After fires left 12,000 low-income residents homeless in January 2005, Cape Town's Mayor issued a statement with plans outlining emergency shelter provision, pre-fabricated fire-resistant structures, and a move towards more formal housing (*ibid*.). To reinforce the linkages between housing, health, emergency services, and reconstruction, Cape Town's adaptation framework will need to be fully implemented...**more info**

Regulations in New York and Boston are being updated to address climate-related risks to the built environment. In 2010, the Boston Redevelopment Authority (BRA) inserted an adaptation requirement into the permit for the city's Seaport Square project: developers must "comply with applicable State and City strategies for addressing sea-level rise and climate change" (quoted in Boston 2011: 11). This applies to all the residential, commercial, cultural, and educational components of the 6.3-million ft^2 project; BRA is also modifying its Development Review Guidelines to explicitly identify where climate change and adaptation should be incorporated into new projects (*ibid*.). PlaNYC recently identified the need to adjust New York City's regulations to increase the resilience of buildings to climate change (PlaNYC 2011: 156). The city already significantly reduced the flood insurance rates for buildings using 'freeboard' (raising the occupied space by 1 to 2 feet above the Federal Emergency Management Administration's 1-in-100-year flood zone). Future studies will explore the implications of amending New York City's Building Code to require freeboard for a wider range of buildings beyond hospitals, schools, utilities, etc. (*ibid*.). As the plan notes, more extensive use of freeboard "can help property-owners manage risk, but may also change the character of buildings and the streetscape" (*ibid*.). With carefully-formulated regulations, policymakers can more effectively balance urban design considerations with the need to adapt to climate change.

Other cities have made slower progress in adjusting their building regulations and housing strategies to reflect climate change. Portland committed to participating in Oregon's state-wide efforts "to ensure that building codes support buildings that can adapt to higher temperatures, stronger storms, and other physical impacts of climate change" (Portland 2009: 35). But a subsequent report noted that Oregon's changes to the building code do not address adaptation, so that Portland will instead address building adaptation in its own forthcoming Climate Action Plan (Portland 2010: 25). The report identifies challenges to Portland's building and energy climate strategy, such as the "continued slump in new construction" that has delayed development of "any new policy or program efforts about high-performance new construction" (*ibid.,* p. 7). Chicago's 2008 Climate Action Plan included the adaptation strategy of "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" (CCAP 2008: 52). By 2009, 120 green alleys were completed and 13,000 homes retrofitted; another 4 million square feet of green roofs have been "planned or completed since 2008" (CCAP 2010: 2 and 10). But Chicago does not yet seem to have regulations to manage climate-related impacts in the housing sector, and researchers noted that the Chicago Housing Authority had not identified any infrastructure or operating costs that would be altered by climate change (Hayhoe *et al*. 2010: 99). [**check if other sources on this]**

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. For instance, building management strategies can reduce heat island by incorporating green roofs and walls; planting trees to promote summer shade; and avoiding high-glare facades and finishing (London 2010: 80). Approved in 2009, Melbourne's plan similarly combines housing, water, and green infrastructure strategies to promote cooling and long-term adaptation.

[INSERT TABLE 8-3 HERE
Table 8-3: Adaptation measures – long-term (Melbourne).]

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

By affecting the operations of water, sanitation, and drainage systems, climate change is likely to have far-reaching knock-on impacts on a range of urban systems thereby affecting issues such as urban health and development outcomes. 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, **more cites**). Local government departments responsible for water supply and management must confront new climatic patterns, major uncertainties, and a rapidly evolving knowledge base which have rendered stationarity obsolete as a management principle (Milly *et al*. 2008). It has been suggested that water management is at the "centre of adaptation to climate change," but few cities have made concerted efforts to identify what adaptations are needed and adapt key systems (Muller 2007: **more cites**).

Among the projected impacts of climate change are altered precipitation and runoff patterns in cities; changes in sea level and water availability and quality; and rising uncertainty in the assumptions that underpinned planning and investment in water systems.

Historical records that have formed the basis of water plans may no longer be appropriate but there may be no downscaled or reliable climate projections to inform adaptation (Ziervogel *et al*. 2010). Cities may be increasingly at risk of water stress, water-borne illnesses, and more intense or frequent flooding although the impacts (particularly with respect to precipitation levels) are difficult to predict accurately (Ludwig and Moench 2009). Extreme events whose frequency and/or intensity climate change is likely to be increasing can damage or destroy critical water, sanitation, and storm-water infrastructure. Rising temperatures and/or decreased precipitation levels can have "a double impact" in cities: greater evapo-transpiration and lowered recharge rates may together decrease total water availability and increase the total end-user demand, so that "supply declines while demand increases" (Matthias *et al*. 2007: 1032). Climate change can also affect water treatment by increasing turbidity, algal growth and by reducing the efficacy of water treatment processes such as chlorination (Loftus, 2011). Urban water agencies face the two-pronged challenge of managing these impacts and with the uncertainty regarding water availability (Milly *et al*. 2008, O'Hara and Georgakakos 2008, Fane and Turner 2010).. Another important consideration is the ecological impacts of reduced water availability which would make meeting minimum ecological flow requirements more challenging, and could have implications for water licence renewals (Zwolsman et al., 2009) and the provision of ecosystem services, which in turn would affect opportunities for ecosystem based adaptation.

Provision for water, sanitation and drainage are obviously central to city's economies and the welfare of their population – and in many cities in low and middle income nations, existing systems are very vulnerable to extreme weather-related events. As detailed above, in October-November 2007, the city of Villahermosa, Tabasco, suffered the impact of floods caused by cold front N° 4 and the associated heavy rainfalls. Damages and losses in the water and sanitation system amounted to US$ 50 million. Direct damages in Villahermosa were US$ 26.5 million, which represented 65% of the whole state of Tabasco. Both water supplies for human consumption and sewage system were affected; water pumps, pipes, treatment plants were damaged. Besides, the flowing of wastes obstructed stormwater drains (CEPAL, 2008) Currently the Hydraulic Integral Programme of Tabasco (PHIT) constitutes the main institutional federal programme to manage and control in-city flooding through reinforcing river and open-air sanitation canal walls and constructing and operating dams to divert river flows.

In this section, as in almost all the sections in this chapter, there are the difficulties in summarizing the key adaptation issues for urban centres globally, when there are such large differences between (and often within) urban centres in the quality and extent of provision for urban dwellers' water needs and for sanitation and drainage. In high-income nations and in some middle-income nations, virtually all the urban population is served by water piped to the home of drinking quality 24 hours a day, by sewers or other systems of sanitation that minimize risks of faecal contamination and by storm and surface drainage. As examples given below show, there are many urban centres in such nations that face serious challenges for water from climate change. But their plans do not have to address large deficits in provision for water, sanitation and drainage. They also have in place billing systems that generate a substantial proportion of the funds needed for water provision and management and management systems. At the other extreme there 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, 2006). In many urban centres, there are also the large proportion of the population living in informal settlements and the authorities or companies responsible for water and sanitation provision may not be allowed to work in such informal settlements. 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.

(**Draw from** WHO and UNICEF (2010) *Progress on Sanitation and Drinking-water: 2010 Update,* 60 pages on the scale of the deficit in provision for water and sanitation?)

Impacts, vulnerabilities, and adaptation costs in urban water systems

For most urban centres in Africa, a high proportion in Asia and many in Latin America and the Caribbean, any impacts on from climate change on rainfall and water supplies come to systems with very inadequate provisions for water, sanitation and drainage (Hardoy et al 2001, UN Habitat 2003, other cites). United Nations estimates for 2000 suggest that for sub-Saharan Africa, 35-50% of the urban population lacks adequate provision for water. Most large cities have more than half their population lacking piped connections to their house (some have less than 10%) and the proportion unserved is generally higher in smaller urban centres. Urban poor groups unserved by piped water to their home or yard also generally face higher prices for water (from kiosks, vendors or tankers) that also makes them more vulnerable to water price increases (REFS). 50-60% of the urban population lacks adequate provision for sanitation. Apart from South Africa, most urban centres in sub-Saharan Africa have no sewers – and for those that do, the sewers only reach a small proportion of the population (eg Dar es Salaam the largest and most successful city in Tanzania, with less than 10% of the population connected to sewers; for Nouakchott, 5%, for Bujumbura and Conakry 7%) (REFS). Many cities in this region are growing rapidly but with water resources already poorly-managed, with perhaps half the urban population lacking adequate water and sanitation provision (Hardoy et al 2001, UN Habitat 2003, Satterthwaite *et al*. 2007: 25, **more cites).**

For Asia, estimates for 2000 suggested 35-50 percent of the urban population lacking adequate provision for water and 45-60 % lacking adequate provision for sanitation (UN Habitat 2003)

For Latin America and the Caribbean, the deficits are lower, in part because many cities have extended provision and increased the proportion of their population adequately served – but 20 percent or more of their urban population may still lack adequate provision for water and 20-30 percent lack adequate provision for sanitation (UN Habitat 2003).

These deficits in provision are likely to have grown considerably since 2000. For most urban centres in Africa, adaptation will require 'leapfrogging' over current approaches and meeting their future water needs "in a manner that leaves them more resilient to the potential impacts of climate change" (Muller 2007, page). This is also the case for a high proportion in Asia and many in Latin America and the Caribbean.

In many rapidly-developing cities, climate change's impacts on water supplies will likely interact with growing population, growing demand and economic pressures to heighten water stress and increased negative impacts on the natural resource base, which exacerbate the negative 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, stormwater, and solid wastes (Cashman, Nurse and Charlery 2010). Aggravating such water stresses, climate change could significantly reduce rainfall levels especially during the Caribbean's crucial rainy season (*ibid.,* p. 57).

Water demand may be strongly influenced by factors other than climate change, and studies have found that certain 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: 103). MWRD is thus projected to save money until 2100, but as precipitation is likely to increase afterwards so too will the costs of water management. In another inland city of Hamilton, New Zealand, population pressure was found to be a more significant driver of water demand than climate change (Ruth *et al*. 2007). But under high population scenarios, a small increase in temperature or decrease in rainfall would likely create water shortfalls by 2030 (*ibid.,* p. 1043). These cities' water systems may not experience severe impacts as a result of climate change in the short term, yet results may vary with longer time horizons, faster population or economic growth, higher emissions scenarios, or other factors.

Climate change in arid or semi-arid regions may significantly constrain urban water supplies, especially over longer time horizons. Cities in arid regions frequently "are on the cusp of severe water shortages", although future problems may be hidden by current unsustainable practices such as depriving in-stream flows, high-energy solutions like desalination plants, or excessive groundwater extraction (Gober 2010: 148). Palestinians in the West Bank rely mainly upon 2 overexploited groundwater aquifers, and rising sea levels will further reduce freshwater supplies by promoting saltwater intrusion in the aquifers (Hassan *et al*. 2010). In the short term, the West Bank's rising population is more likely to stress water supplies than climate change. But the combination of population growth and climate change "is likely to create a serious water crisis in the region" (*ibid.,* p. 145). OTHER CITIES THAT RELY ON OVER-EXPLOITING GROUNDWATER RESOURCES. LIMA AND LOSS OF GLACIER-MELT?
In many cities, climate change is likely to contribute both to increased risks of flooding and water stress, necessitating adaptation plans to cope with a range of management challenges. Water availability in Mombasa is just 45% of the amount required, leading residents to drill boreholes that may promote salt-water intrusion into aquifers, while sea-level rise may exacerbate the risks of salinization, flooding, and erosion (Kithiia and Dowling 2010: 271). Mombasa also has many deficiencies in provision for water to homes and businesses (REFS) and still lacks a water planning framework which could help to address its complex bundle of stresses (Kithiia and Dowling 2010). In Shanghai, climate change is likely to promote flooding, salinization, coastal subsidence, and decreased water availability. The city's population of 17 million is projected to continue expanding, often within areas that are "likely increasingly flood-prone" (de Sherbinin, Schiller, and Pulsipher 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*.).

A few studies have sought to estimate the costs of adapting urban water and sanitation systems. In sub-Saharan African cities, perhaps US$2bn-$5bn may be required annually 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 2009 **more info?**). Findings suggest that the cost of adapting water supplies in San Diego may again be high, even under a short-term time horizon of 2030 (O'Hara and Georgakakos 2008). San Diego currently utilises 9 reservoirs to meet 10-20% of its water demand, importing the residual demand, and by 2030 the estimated adaptation costs of expanding reservoir capacities reached hundreds of millions of dollars (*ibid*.).

Stormwater, drainage, and sewerage impacts

Climate change is likely to exacerbate the challenge of providing adequate drainage and sewerage in underserved areas in many urban centres, while making such infrastructure ever more critical. Drainage systems in many urban centres in low- and middle-income nations already struggle to cope with climate variability: Dhaka's drainage congestion, waterlogging, and poor management contributed to large flood damages in 1998 and 2004 (Alam and Rabbani 2007). The storm-water drainage and sewage systems in Dar es Salaam and Mombasa were built in 1950, but are now extremely congested and inadequate (Kithiia 2011: 177). In many cities in India, drainage, flood protection, and storm-surge systems also date from the pre-colonial or colonial era, leaving many of them "dysfunctional or irrelevant" today (Revi 2009: 330). In turn, cyclones and storm surges can have a "devastating impact" upon India's mega-cities like Mumbai, million-cities including Surat and Bharuch, or cause major bottlenecks in ports such as Kandla (*ibid.,* p. 320). Cost-benefit analyses will need to consider whether to repair and strengthen, relocate, or adopt other responses, so that these systems can withstand more intense or frequent storms due to climate change (*ibid*.)

Mexico City is currently implementing a set of engineering works in the drainage system to prepare the city to cope with floods mainly during rainy season. Along with this project, there is an emergency assistance group called *Unidad Tormenta* Storm Unit enabled to provide prompt assistance when floods occur. These measures are part of the adaptation agenda of Mexico City. <No papers or policy document have been found so far. Fernando will get more info on this>

Caribbean cities are often subject to flash flooding, largely as a result of poor drainage and stormwater management, and climate change may exacerbate the vulnerabilities of these low-lying and precarious areas (Vojinovic and Van Teeffelen 2007). Urban areas usually have inadequate, short drainage channels; additionally, steep hillsides denuded of vegetation frequently experience erosion and landslides after "almost any rainfall at all" (*ibid.,* p. 213). Climate change will likely increase the frequency and intensity of rainfall events in the Caribbean, where a combination of structural and non-structural interventions may be needed to adapt (*ibid*.). To improve water management in St. Maarten, Netherlands Antilles, the government recently initiated a stormwater modelling study and is developing a flood warning system (*ibid.,* p. 225). 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 improvements like improving the channel network and draining of areas with a high groundwater table (*ibid.,* p. 229).

Comparable problems have been observed in many cities of middle-income nations such as Mexico City and it can be argued that heavy rainfalls associated to climate change will likely worsen the situation (Romero-Lankao, 2010). For example, the southeast peri-urban interface of Mexico City became a chronic flood prone zone. Aragón-Durand (2007) analysed flooding in the context of illegal urbanization in the south-eastern peri-urban interface of Mexico City and found that flooding was the result of a complex interaction between urbanisation in an ex-lacustrine area, permanent ecological deterioration and ground subsidence, poor sanitation –including the malfunctioning of the main sewage canal- La Compañía Canal- and inadequate policy responses. Far from solving the flooding problem, short-term policy responses have created increasingly unsafe conditions for current vulnerable residents. So far no adequate solution has been designed considering the whole socio-ecological context and technical-engineering measures still dominate sanitation policy such as the piping of La Compañía Canal (Aragón-Durand, 2007) Some studies have pointed to the need for adaptation measures for stormwater and drainage systems in the United States and United Kingdom. An analysis of 3 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). Adapting drainage infrastructure may help to cope with a changing rainfall regime, since it is likely to diverge from current design standards, but findings were still tentative and require further modelling (*ibid*.).Climate change was identified as one of the key drivers affecting Britain's future sewer systems, according to workshops with experts and a literature review (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*., p. 82). Possible responses included optimising existing infrastructure performance, utilising emerging technologies, and developing new institutional, planning, or legislative arrangements (*ibid*.).

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 (in Rosenzweig, Solecki, Hammer and Mehrotra 2011). But there is no evidence that developing such measures is commonplace.

Supply-side approaches to water shortages such as increasing reservoirs are frequently advocated, and Rotterdam has developed strategies that simultaneously seek to enhance reservoirs, adapt to climate change, and promote urban renewal (van der Brugge and de Graaf 2010). Online databases and other tools have also sought to inform adaptation strategies amongst water planners in Cape Town (Ziervogel *et al*. 2010) and in the UK (Wilby and Vaughan 2011). Demand-side approaches have been adopted in Seattle (Vano *et al*. 2010), though more water-stressed cities like Phoenix have yet to embrace such stringent controls (Bolin *et al*. 2010).

In Mexico City, the government of the Federal District has launched two programmes: the Local Strategy of Climate Action of Mexico City and the Programme of Climate Action of Mexico City (2008-2012). Some of the actions suggested to address climate change in the water sector have been proposed many times since the 1950s, without success, including decreases in water use and the restoration and management of both urban and rural micro-basins. Other actions proposed to enhanced adaptation include monitoring of disasters, an early warning systems and provision of disaster relief (Romero-Lankao, 2010) Since the strategy and programme mentioned above privilege mitigation over adaptation, adaptation measures for the water sector have been conceived as too general and lack of institutional commitment.

In cities where a proportion of the population currently lack adequate provision for water and sanitation, adaptation will need to be integrated into plans to address these inadequacies and to incorporate into water plans the needs of those ill-served or un-served.

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-resources and retains skilled staff (Roberts 2010). The water sector has also shown an interest in developing its municipal adaptation programme (ibid).

An analysis of 21 draft Water Resources Management Plans (WRMPs) in the UK found that agencies usually favoured supply-side measures to adapt to climate change (Charlton and Arnell 2011). Reservoirs were frequently cited as key adaptations: for instance, Bristol Water noted that a new reservoir was the most sustainable means of addressing supply-demand mismatches due to climate change (*ibid*., p. 246). Other proposed adaptations included enhancing the inter-connections of water supply and inter-company transfers. The authors suggest that additional demand-side interventions may be needed to cope with reductions in water availability, though some northern UK regions may not face significant climate-related impacts (*ibid*., p. 247). 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 already utilised demand-side strategies to curtail water consumption, and findings suggest that these measures will promote future resilience (Vano *et al*. 2010). The city currently serves over 1.3m people and has utilised aggressive conservation measures, system savings, and price increases for water supply and wastewater treatment linked to consumption levels (*ibid.,* p. 265). Total water use has declined from 7.5 m^3/s (171 mgd) in 1989 and is projected to remain under 6.6 m^3/s (150 mgd) through 2050 (*ibid*.). 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 Seattle's successful reductions in demand (*ibid.,* p. 283).

Cape Town has also utilised water restrictions and tariffs, although it faces profound challenges in ensuring future supplies (Mukheibir and Ziervogel 2009). According to the Department of Water Affairs and Forestry, Cape Town will be the first major South African urban area where demand for water exceeds the potential yield (*ibid.,* p. 278). 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*.). Recent experiences with climate variability have led to some improvements in water management. 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.,* pp. 1271-2). Looking at the 2011 State of Cities report (by South African Cities Network) it indicates: "In Cape Town, the number of households in informal dwellings increased by almost 100 000. This was the steepest growth rate in the country, reflecting strong urbanisation." Pg 50 "Despite the number of informal settlements, few households in the cities have only rudimentary sanitation. In 2009 the proportion of households in the Gauteng metros and eThekwini with basic sanitation was only 1% compared to 6% in Cape Town and Nelson Mandela Bay, and 3% in the secondary cities" pg 53 "Just over one in ten metro households have no access to piped water (off or on-site) compared to nearly one in five in the secondary cities. eThekwini is somewhere in between, perhaps because it includes a sizeable rural catchment." Pg 55.

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 900,000 m^3 in 2050 (*ibid.,* p. 388). New designs and water planning frameworks were developed to realise these goals. As a contribution to the 2005 International Architecture Biennale (with the theme of 'The Flood'), engineers from the Public Works Department collaborated with designers from the Urban Design and Planning Department to create *Rotterdam Water City 2035*. The proposal responded to a possible 6m sea-level rise by mixing economic activities with water-based adaptive designs, including 'water retention squares' and green roofs; floating houses; and networks of channels (*ibid.,* p. 389). Water retention can create a more attractive city centre, supporting urban renewal as well as resilience to climate change. These provide an example of how municipalities can creatively redesign urban environments while developing concrete water plans to meet the challenge of adaptation.

Rainwater harvesting can enhance water supplies, particularly in low-income areas, but scaling-up may be a challenge. In Sydney, rainwater harvesting has "barely begun" although new houses are required under a 2004 law to save 40% of reticulated water for use in gardens and toilets (Warner 2009: 235). Subsidies are being granted to install household roof tanks, with over 36,000 rebates issued to date, and there is scope for expanding the programme (*ibid.,* p. 239). 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, Nurse, and Charlery 2010: 60). Extending the existing communal collection and distribution systems would require community financing or governmental interventions, as well as overcoming such resistance (*ibid*.).

Information-sharing has supported urban water adaptation in the UK and South Africa, but steps may be needed to ensure data are relevant to local stakeholders (Ziervogel *et al*. 2010). In Cape Town, researchers conducted workshops on adaptation with local water managers and produced an online toolkit 'Climate for Water' (www.c4w.org.za). The toolkit linked to a range of forecasts and sought to train stakeholders about climate change, but the authors note that "it was not adopted as a regular source of information and so had limited success" (Ziervogel *et al*. 2010). More effective communication may require improving water managers' education and awareness of climate change, while research funders and forecast producers "need to be aware of the changing and developing needs of users" (*ibid.,* p. 552). Online tools have been developed for British water managers, including the Water Research Foundation's online Climate Change Clearinghouse[9] (Wilby and Vaughan 2011). Additionally, the Department for Communities and Local Government (DCLG) and the Department of Environment, Food and Rural Affairs (Defra) published tables of prescriptive allowances for engineering design, such as "add a 20% sensitivity allowance to daily rainfall, peak river flow volumes and urban drainage volumes to account for climate change by 2050" (quoted in *ibid.,* p. 274). General guidance on adaptation has also been disseminated through online checklists or toolkits.[10]

[INSERT FOOTNOTE 9 HERE: http://www.theclimatechangeclearinghouse.org/Intro/default.aspx.]

[INSERT FOOTNOTE 10 HERE: See, for instance, the Greater London Authority's Adapting to Climate Change: A Checklist for Development (2005) and the Nottingham Declaration Action Pack 2009 (cited in Wilby and Vaughan 2011: 275).]

Research in Phoenix, Arizona, has sought to improve water forecasting data and inform adaptation interventions (Gober *et al*. 2010). Simulations explored how water usage may be reduced to achieve safe yield while accommodating future growth; decision-makers may also require methods to assess the risk and uncertainty associated with climate change (*ibid*.). The rapidly-expanding desert city is projected to reach 11 million people by 2050, with most growth in peripheral areas that depend entirely on groundwater (Bolin *et al*. 2010: 261). Phoenix instituted groundwater restrictions under the 1980 Groundwater Management Act, while also drawing upon the Sale/Verde and Colorado Rivers (*ibid*.). But usage remains high (per capita consumption has stagnated at 220 gallons per day), and water pressures may be exacerbated by reduced precipitation, rising power and water demands due to warmer temperatures, and reduced river runoff levels as a result of climate change (*ibid.,* p. 270). Reducing per capita water use may be achieved through urban densification, increased water prices (which remained less than half the 2007 unit cost of water in Seattle), and water conservation measures (*ibid.,* p. 277). Another study 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" (Gober *et al*. 2010: 370).

New technologies and transfer projects could help to address North China's water shortages, while improved flood and disaster preparedness may be needed in southern and eastern cities (Liu and Deng 2011). Over 400 of China's 669 cities experienced water shortages in 2006, according to the Ministry of Water Resources (cited in *ibid.,* p. 189). Climate change may exacerbate Beijing's water shortages, for example, but the South-to-North Water Transfer Project will add 1×10^9 m^3 fresh water supplies to Beijing when completed (*ibid*.). Adapting China's southern coastal cities may require typhoon and flood warning systems, improved pollution controls, rainwater harvesting, and curtailing groundwater exploitation to prevent saltwater intrusion (Shen 2010: 1068).

The local government of Quito 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).

While only a small-scale process in 2003, Hermosillo's experience suggests that cities can utilise proactive, participatory strategies to enhance resilience in the water sector.

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. Water and energy sectors are frequently linked and problems may ensue if they are considered separately, such as utilising water from distant, low-quality sources that require high levels of energy for conveyance or treatment (Gober 2010: 145). Adaptation in the water sector will requiring identifying such trade-offs, as well as working with multi-partner networks, adopting low-regret anticipatory solutions, and forging multi-partner networks (Wilby and Vaughan 2011). Long-term adaptation strategies still need to meet local developmental needs, improve water management, and address the impacts of climate change (Mukheibir 2008: 1274). In addition, water adaptation planning will need to be developed in concert with green infrastructure strategies (discussed in 3.3.7 below). Integrated strategies can minimise possible conflicts between water-intensive parks or gardens, support local industries, and ensure equitable access to water in cities confronting climatic change.

8.3.3.5. Electricity and Other Energy Sources

Urban economic activities and infrastructure and most urban households rely heavily on power supplies so any disruption or unreliability in provision due to climate change may have far-reaching consequences upon other sectors. Power supplies are also important in for many other urban activities including households' income generation possibilities, education, health, leisure (Halsnaes and Garg 2011: 999-1000).

The IPCC fourth assessment recognized that the energy sector is "particularly sensitive to climate change" (IPCC 4AR, quoted in Mideksa and Kallbekken 2010). Zimmerman and Faris 2010 describe how in New York, electricity provision poses a number of challenges to adaptation. There are around 24 power plants of various size operating within the city and over a dozen more proposed (as of 2005). Transmission lines that service the city are relatively concentrated and provide little flexibility should one of these lines be compromised. Most infrastructure in the city relies on the city's power grid for energy, thus if it fails the other infrastructures that are dependent on it fail. The facilities that produce and distribute energy have traditionally been located in low-lying areas and are difficult and expensive to relocate. In addition, many power plants need to be located near the water to accommodate fuel deliveries, the use of water for cooling and steam generation, and water discharges, making relocation to areas not susceptible to flooding virtually impossible. These facilities are also concentrated in a relatively few locations within the city increasing the impacts of a climate hazard occurring at one location. The electric power industry is subject to a variety of regulations which presents a challenge to incorporating any new demands, such as climate change information, into its portfolio. Limited resources and multiple demands on those resources present another challenge to meeting energy needs. This situation is not only specific to New York City but is also common to the energy sector in general, occurring in many other urban areas as well.

The 2005 hurricanes alone cost the US energy industry about $15 billion (cited in Mideksa and Kallbekken 2010: 3580). Further studies are needed of the costs of adapting power infrastructures to withstand the more extreme weather due to climate change (Mideksa and Kallbekken 2010). Adaptation may also be necessary to cope with more intense peak demand for electricity during heat waves.

In turn, cities are vulnerable to any damage or disruption to the larger systems on which they depend such as "water supply and treatment, transport and electricity (and thus everything that depends on electricity, including lighting, pumping and communications)" (Huq, Kovats, Reid, and Satterthwaite 2007: 3). Past experiences with power outages may 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 signalling outages, "and water supply for a much longer period" (Rosenzweig and Solecki 2010: 20). Research on climate change impacts in Hamilton, New Zealand, suggests that disrupted electricity supplies may also disrupt water supplies and treatment; interrupt traffic signals (during extreme events); and affect public health provision (Jollands *et al*. 2007: 472). The interrelations between energy and other sectors suggests the need for an integrated approach in understanding vulnerability and shaping appropriate responses (Gasper, Blohm and Ruth 2011 **more cites)**

With the literature on energy and climate change focusing on 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 costs of adapting the energy sector may be substantial but there are few estimates of costs. The UNFCCC did not estimate the costs of adapting the energy sector (Fankhauser 2009: 26).
One important component of adaptation will be "private autonomous measures" that "will dominate the adaptation response as people adjust their buildings, [or] change space-cooling and -heating preferences..." (*ibid.,* p. 27).

In the State of Veracruz, Gulf of Mexico, there are cities such as Coatzacoalcos and Minatitlan 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 on the potential impact 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 provisions few climate change adaptation studies have been undertaken. Huang (2008) explores the differential impact climate change will have on the various oil activities: exploration, production processing, transportation and storage and states that adaptation measures must be sensitive to the oil cycle. More research on this regard for Mexico is needed in order to inform oil companies (PEMEX, Mexico Oil Company) on how to adapt its facilities and activities to climate hazards. <To developed in more detail if it´s necessary>

8.3.3.6. Adapting Transport and Telecommunications

Cities depend on road and often rail, air, waterway and subway transport systems for their daily functioning – moving people and goods in and around the city and its surrounds and to and from other locations. Many cities depend on (often large) commuter fields and the transport systems that support these and allowed these to develop. The increased dependence of prosperous cities on regional, national and international supply chains (80 percent of the food consumed in London is imported (GLA) that in turn rely on reliable transport systems so a consideration of transport for urban centres needs to consider their transport links to locations outside their boundaries as well as within them.

A paper that highlights the cost of inaction on climate change noted that "about 60, 000 jobs and US$ 3 billion annually depend directly on the movement of goods in the Great Lakes–St. Lawrence route in the United States. Drought could lower water levels, requiring additional dredging at an annual cost of US$ 85 to US$ 142 million, simply to maintain shipping lanes. Climate-induced changes in water levels and the associated overall decreases in the connectivity of the shipping network will cost the manufacturing sector upward of US$ 850 million per year. The impacts will be higher prices, reduced income and job losses. Estimates for Michigan and Illinois suggest that for every 10 jobs lost as a direct result of these impacts, another 5–7 are lost elsewhere in these states' economies. And because this is one of the manufacturing centres of the United States, the ripple impacts will be felt in the rest of the nation" (Ruth 2010: 390).

Most large and successful cities have also spread spatially with the expansion of transport systems supporting a decentralization of the workforce and businesses, many of which depend on a well-functioning transport system. Daily deliveries are crucial to support a range of economic activities: "manufacturing and service sectors depend heavily on highly reliable delivery of goods and services", while markets "readily penalize cost increases and delays in delivery" (Ruth 2010: 390). 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 (Hunt and Watkiss 2011: 14).

The daily functioning of most transport systems is sensitive to weather extremes, such as extreme precipitation, temperature, winds, visibility, and, for coastal cities, sea level (HIGH TIDES?) (Love, Soares, and Püempel 2010). Such climate-related sensitivities in transport may produce severe delays and affect the provision of emergency services or evacuation procedures. 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). The extent of the impact will depend largely "on the timing, duration, and extent of the disruption" and 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.*).

The direct impacts on transport systems of extreme weather are often more easily assessed than the indirect impacts. 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, most city services were shut down for 5 days without contact via rail, road or air and over 1000 people died (Revi 2009: 320)

The literature on transport and climate change focuses more on mitigation[11] than on adaptation and as yet, transport gets relatively little 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). 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 lifespan (Jaroszweski, Chapman, and Petts 2010: 332).

[INSERT FOOTNOTE 11 HERE: See Section 3.6 on the co-benefits that may be created by combining mitigation and adaptation in the transport sector.]

Most cities in low- and middle-income nations are still developing their transport systems, especially in the larger, more successful and more rapidly growing cities. Few studies have examined transport adaptation for these cities. For instance most cities in Asia are still developing their transport networks and these are often at risk from extreme weather events (Regmi and Hanaoka 2011: 23). 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). In low-income and many middle-income nations, there are major deficits in transport and other infrastructure and resilience to climate change usually depends on addressing these deficiencies (Dodman and Satterthwaite 2009). In addition, in reviewing available literature on the vulnerability of urban transport systems to climate change, there is a far more extensive and detailed literature on this topic in high-income nations, even as these have less than a quarter of the world's urban population.

Incorporating adaptation measures during the planning phase may be easier than after construction is completed. EVIDENCE FOR THIS?

Transport and other urban infrastructure networks are often interdependent and located in close physical proximity to one another (Kirshen, Ruth and Anderson 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).

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, Soares, and Püempel 2010: 144). An interdisciplinary approach can incorporate not only changing meteorological hazards, but also consider the social and political values and governance that can shape more resilient transportation systems (Jaroszweski, Chapman, and Petts 2010).

Adapting roads. Climate change may increase the costs of maintaining and repairing road transport networks. For instance, a study in Chicago indicated….. (Hayhoe *et al*. 2010). To adapt road networks, transport planners are beginning to reassess maintenance costs and traditional materials. Choice of materials will need to reflect local climatic conditions: stiffer bituminous binding materials can 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 the use of adaptive materials. For instance, the Chicago Department of Transportation (CDOT) considered whether to use more permeable, adaptive road materials instead of asphalt and concrete (Hayhoe *et al*. 2010: 104). CDOT rejected the adaptive materials because of higher cost, although it recognised costs may fall with greater economies of scale as worldwide demand rises for such materials (*ibid*.). Meanwhile, Chicago's road maintenance costs are expected to rise by the end of the century, due to rising average temperature and more severe rainfall in winter and spring[12] (*ibid.,* p. 102).

[INSERT FOOTNOTE 12 HERE: Road maintenance costs may 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: 466).]

Colder regions may enjoy increased opportunities for developing road networks or ports due to loss of sea ice, but it may also be a costly challenge to adapt these regions' transport networks. Estimates for Alaska, while not broken down by rural-urban areas, found that projected climate change impacts could add 10-20% to infrastructure costs by 2030 and 10-12% by 2080 (Larsen *et al*. 2008: 453).[13] The additional costs are relatively higher in the short run, because agencies have not had as much time to adapt infrastructure to changing conditions. But strategic design adaptations had strong potential to reduce extra costs by 2080, when adaptation could save between 10-45% of the costs due to climate change (*ibid*.). For industries and communities in Northern Canada, reduced freshwater-ice levels may create economic benefits such as longer shipping seasons (Prowse *et al*. 2009: 279). Lost sea ice could also promote new seaports in marine environments, but inland towns may 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*.). Techniques to reduce ground disturbance, databases of at-risk infrastructure and buildings, and ongoing monitoring are amongst the key adaptation measures in cold regions (*ibid*. **MORE CITES)**

[INSERT FOOTNOTE 13 HERE: According to the sectoral breakdown of additional climate-related costs by 2030, about 25% were for roads, 24% for airports, and 8% for harbours (*ibid*.).]

Adapting surface and underground railways: Few studies have examined the effects of climate change on railways, but weather-related rail failures may be caused by high temperatures, icing, and storms (Koetse and Rietveld 2009: 212). 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 are gradually warming due to engine heat, braking systems, and increased passenger loads (Love, Soares, and Püempel 2010: 137). According to the Greater London Authority, the Underground can already reach temperatures 11°C in excess of ambient temperature above ground (cited in *ibid*.). To cope with increasing frequency of hot days due to climate change, "substantial investment" in ventilation or cooling may be necessary (*ibid*.). New York City's subways may also be vulnerable to climate change, as some 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). New York already has installed pumps throughout the subway system, which helped to cope with severe floods in August 2007 during the morning commute (*ibid.,* p. 70).

Additionally, above-ground railways can be disrupted by rising temperatures and other impacts of climate change. Extreme weather has already disrupted some railways: in winter 2006, high water levels in the Gothenburg area submerged railroad tracks and landslides damaged embankments (Lindgren, Jonsson and Carlsson-Kanyama 2009). Floods in Mumbai. During the 2003 heatwave in the UK, buckled rails and large delays ensued with an economic cost of at least £750,000 in the 4 railway sectors around London (Love, Soares, and Püempel 2010: 137). Rail systems that have struggled to cope with existing climate variability may need considerable investment to be able to withstand changes in extreme events and higher temperatures due to climate change.

Railway systems may 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, Jonsson and Carlsson-Kanyama 2009: 175). The costs of delays and lost trips due to extreme weather events were analysed in Boston (Kirshen, Ruth and Anderson 2008) and in Portland (Chang *et al*. 2010). In both cities, the studies found the costs would be small relative to the damages upon infrastructure and other property, as these mature urban areas have a large number of transport networks and trips (*ibid*.).[14] Portland's nuisance flooding is still likely to increase, and the authors suggest that floodplain restoration, use of porous pavements, or detention ponds may all help adapt to climate change (Chang *et al*. 2010: 947).

[INSERT FOOTNOTE 14 HERE: In Hamilton, New Zealand, future road repair costs and vehicle trips were found to be driven more by population growth than the impacts of climate change (Jollands et al. 2007); however, this study only examined the impacts of gradual climate change, not extreme events.]

But research in some flood-prone cities suggests that more stringent construction standards, design parameters, or even 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 2008: 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: 28). In a study in Portland, 4 out of 5 surveyed bridges and roadways were lower than the current 100-year flood water surface elevation and nuisance flooding was increasingly likely (Chang *et al*. 2010). Possible adaptation strategies in Portland may include restoration of floodplains, utilising porous pavements, or detention pools (*ibid*.). Before implementing a Bangladeshi transport project, a study found it was economically viable to raise the road embankment height from 0.5 to 1m to protect from flooding (cited in *ibid,* p. 29). ***check if urban*** 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, Schiller, and Pulsipher 2007). Rising sea levels may cause shifts at the sub-surface level of landfill areas and structural instabilities (*ibid.,* pp. 49-50).

Hundreds of millions of urban dwellers live in informal settlements that have inadequate or no provision for all-weather roads and paths and supporting infrastructure (for instance storm and surface drainage) and public transport services. A high proportion of these settlements are also in locations that are at risk from extreme weather – for instance floodplains or steep slopes. So poor transport and infrastructure, hazardous locations, and lack of preparedness often combine to heighten these settlements’ vulnerabilities to disaster. By damaging infrastructure and contributing to more intense or frequent extreme events, climate change may only exacerbate these risks in low-income settlements (IPCC 2007).

Dense informal settlements frequently lack the 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 “the ambulance and fire services cannot enter most of these neighbourhoods, thus exacerbating the existing health and fire risks at household level” (Rahman, Haughton, and Jonas 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: 441). 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: 210.). Details of Katrina/other evacuation problems in higher-income cities? **Evidence of community-based responses that have facilitated evacuation? Details from Surat study?**

Low-income residents can also be profoundly affected by transport disruptions 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, Koedam, and Baud 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 2010: 17), so that the gendered impacts of transport disruptions may merit greater consideration.

Telecommunications: In Alaska, telecommunications towers are already settling due to warming permafrost, and United Utilities has sought funds for its cost overruns in the Yukon- Kuskokwim Delta (Larsen *et al*. 2008: 444). New York City’s communication equipment is vulnerable to climate impacts: cell towers may be in danger of toppling due to strong winds, or electrical support facilities may be flooded (Zimmerman and Faris 2010: 74). The authors suggest that adaptation may require moving sensitive electrical equipment to avoid floods, or strengthening cell tower construction (*ibid*.).

8.3.3.7. Green Infrastructure and Ecosystem Services within Urban Adaptation

In recent years, discussions on green infrastructure and its application in and around cities has begun to consider its role in climate change adaptation. 'Green infrastructure' denotes urban ecological features, ranging from wetlands to forests, that provide critical services such as purifying water, cleansing air, and moderating climate (Newman 2010). The Millennium Ecosystem Assessment (REF) noted the contribution of ecosystem services to provisioning (eg food including game and seafood, wild crops and water, energy – hydropower and biomass, pharmaceuticals), regulating (control of climate and disease, waste composition), supporting (nutrient cycles, seed dispersal and crop pollination) and cultural (spiritual and recreational benefits).

Ecosystem based adaptation (EBA) is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem-based adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies." (AHTEG 2009 pg 41).[15]

[INSERT FOOTNOTE 15 HERE: A group established by the Secretariat's office on the Convention on Biological Diversity (CBD) to provide biodiversity-related information to the United Nations Framework Convention on Climate Change (UNFCCC).]

In particular, urban green spaces can facilitate cooler microclimates and reduce surface water runoff, with important potential to adapt to climate change (Gill *et al*. 2007). (Cross reference to cites on urban health island)**.** Other key ecosystem services in cities may include nutrient retention, habitat for diverse biota, and "a sense of place" (Grimm *et al*. 2008: 759). In urban areas lacking the resources for expensive 'grey infrastructure' solutions, adapting green infrastructure may represent a 'no-regret', more cost-effective intervention (Kithiia and Lyth 2011). But green infrastructure is not so much a replacement for conventional infrastructure as a key part of infrastructure design and management that enhances urban resilience. It may also create opportunities for income-generation, as demonstrated by Durban's community 'treepreneurs' rehabilitating degraded forest ecosystems (Roberts 2010: 410-1).[16]

[INSERT FOOTNOTE 16 HERE: See below for additional discussion of the Greening Durban 2010 programme.]

Although green infrastructure can enhance urban resilience, many ecosystem services are themselves vulnerable to climate change. Mombasa will likely experience more variable rainfall as a result of climate change, so that initiating and expanding green infrastructure may become more difficult (Kithiia and Lyth 2011). Street trees in British cities may 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). Dense coastal cities have transformed pre-existing flows of water, energy, and materials—leading to degraded ecosystems, greater exposure to extreme weather events, and in turn heightened vulnerabilities to climate change (McGranahan, Balk, and Anderson 2007). Section (a) briefly reviews the climate-related vulnerabilities of green infrastructure, but most studies are in cities in high-income nations that may have greater adaptive capacity and less severe ecosystem pressures than those facing cities in low and middle-income nations

Few adaptation plans have prioritised green infrastructure, and water-stressed cities may face tensions in seeking to reduce water use while also promoting resilient ecosystems. (Mention here cities in arid/low rainfall regions where much water demand is for gardens, parks and golf clubs with species that are not indigenous). Some cities have taken steps to enhance green infrastructure (section b), though often without an explicit consideration of climate change. Green roofs have recently spread in many cities (section c). But many policy-makers have yet to connect green infrastructure with climate change adaptation, favouring 'hard engineering' solutions instead (Kithiia and Lyth 2011, **more cites)**. Additionally, water-constrained cities may face "critical tradeoffs regarding whether to conserve scarce water resources used for irrigated landscaping at the expense of higher night-time temperatures due to urban heat island effects" (Gober 2010: 146, also Gill *et al*. 2007: 128).

Creative strategies may help safeguard urban ecosystem services, while collaboration between diverse stakeholders can reconcile tensions and promote resilience. Some authors suggest that successful adaptation may require “flexibility in land use and landscape planning,” as well as “stronger engagement with communities, business, and government” (Seabrook, Mcalpine, and Bowen 2011: 409). Other researchers advocate a range of innovative approaches: adapting Manchester’s green infrastructure may require greenspaces to be “added creatively by making the most of all opportunities”, such as introducing green roofs, building facades, planting street trees, and converting selected streets into greenways (Gill *et al*. 2007: 127). As the multiple benefits of green infrastructure are recognised, a range of stakeholders could help to adapt these services in new, more appropriate ways. Cities are “hot spots for solutions as well as problems”, and focusing on urban ecology can suggest new breakthroughs to cope with a changing climate (Grimm *et al*. 2008: 759).

Impacts and models of climate change upon green infrastructure

This section briefly considers the research on climate-related vulnerabilities of green infrastructure, which may already be under stress from extreme weather events, urban development, and rising population. Nearly 5000 trees in Karachi were cut back from 2001-4 and another 1000 removed from 2005-6, as they were said to hamper infrastructure development (Qureshi, Kazmi, and Breust 2010: 188-9). Additional trees were lost in the aftermath of severe cyclones in Karachi (*ibid*.). The study did not consider climate change, but by increasing the frequency or severity of storms as well as altering temperatures and precipitation patterns, climate change may only heighten the strains on local ecosystems. In Indian cities, urban wetlands, riverine, estuarine, and coastal ecosystems are amongst the areas most vulnerable to climate change (Revi 2009: 324).

The impacts of climate change on urban ecosystems may also vary depending upon emission scenarios, local management decisions, land use strategies, and “by the interactions of these factors with climate change” (Hellmann *et al*. 2010: 75). This case study examined Chicago’s climate-related vulnerabilities in terrestrial ecosystems, such as increasing plant pests and diseases, decreases in some plant species, and rising abundances of heat- and drought-tolerant species (*ibid*.). The authors suggest that adaptation strategies should prioritise maintaining and restoring native ecosystems, particularly wetlands, in order to buffer increased storms and support cooling to cope with climate change (*ibid.,* p. 83). Planners may also create migration corridors for plant and animal species, which may need to shift northward in response to warming temperatures; if ecosystem preservation or restoration is not possible, “residential green space can be used to augment natural preserves (*ibid.,* p. 84). Ongoing monitoring (particularly of invasive pests) will be important, and the study advocates “managing the entire mosaic, including the ‘matrix’ of built-up lands” (*ibid*.).

Kyoto has long prioritised landscape measures and its economy depends upon ecosystem services, yet the need for adapting green infrastructure has not gained widespread currency (Morimoto 2011). Although Kyoto has been a “frontrunner in terms of landscape governance”, the surrounding pine and oak ecosystems are experiencing mass dieback; moss withering has intensified due to the urban heat island (*ibid,* p. 12). These threats can impinge upon Kyoto’s key cultural events, such as the Daimonji Bonfire and Gion festival, and the author suggests Kyoto’s recent changes in biodiversity and ecosystem services “should be reconsidered from the viewpoint of smart adaptation to climate change” (*ibid.,* p. 14).

Studies have also examined the climate-related vulnerabilities of UK urban street trees (Tubby and Webber 2010) and the potential of green infrastructure to adapt to climate change (Gill *et al*. 2007). The latter study used an energy exchange model in Manchester and found green infrastructure offered “significant potential in moderating the increase in summer temperatures expected with climate change” (*ibid.,* p. 127). Adding green roofs to all buildings could reduce runoff and exert a “dramatic effect” on maximum surface temperatures, with particular cooling impacts in areas with a high proportion of buildings and low evaporating fraction (*ibid.,* p. 122-3). Additionally, the model “highlights the dangers of removing green [infrastructure]” from the city (*ibid*.). If green cover in Manchester’s high-density residential areas and town centres falls by 10%, surface temperatures are predicted to increase as much as 7°C-8.2°C by the 2080s under a high-emissions scenario (compared to the 1961–1990 baseline case). The study also considers different adaptation functions that green infrastructure may provide, such as flood storage, infiltration capacity, evaporative cooling, and shading (*ibid*.). Section (c) returns to green roofs, which have proved popular, while section (b) discusses other interventions adopted to date.

Adapting green spaces, urban wildscapes, and terrestrial and marine ecosystems

Durban has developed proactive interventions to adapt its green infrastructure, beginning with studies to attempt to understand the impacts of climate change on local biodiversity (Roberts 2008, Roberts 2010). These were undertaken to determine if it were possible to 'climate-proof' the extensive biodiversity resources protected by the Durban Metropolitan Open Space System(covering some 75 000ha), (Roberts 2008: 533). Strategies that are used to achieve biodiversity goals also have adaptation co-benefits include 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 (*ibid*.). The cost benefit of such interventions is highlighted by the fact that in Durban in 2002 the replacement value of the ecosystem services supplied by the city's open space system was R3.1 billion per annum, approximately half the value of the city's operating budget at the time (EThekwini Municipality, 2007 pg 15). Furthermore, a community reforestation project resulted in planting 82,000 trees in a regional landfill site to offset Durban's World Cup carbon footprint (Roberts 2010: 410).
(ABOVE PARA TO BE UPDATED BY DEBRA)

Singapore has also used several anticipatory plans and projects to enhance green infrastructure. The city actively manages its growth boundary and is already "one of the best landscaped cities in tropical Asia," but has recently sought to improve ecosystem services (Newman 2010: 166). The Streetscape Greenery Master Plan created roads "with complete canopy cover and heritage tree programs," while the Park Connector Network "drives green connections across the city along with tree top walks" (*ibid*.). Guidelines have been developed for water-sensitive urban design and constructed wetlands or drains, which are green instead of concrete (*ibid*.). Fruit trees have been planted and 300 community gardens established by 2005, but an urban agriculture strategy could help encourage greater productivity in lawn areas (*ibid*.). **[climate change tie-in or adaptation plans in Singapore? not clear from Newman]**

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). One proactive response was the 2006 Masterplan for Queensborough and Rushenden (a regeneration area on the Thames estuary). This plan took account of biodiversity under a changing climate: a network of permeable habitat spaces was planned for, while green and blue infrastructures were integrated into the site (*ibid*.). Although the Netherlands has a long record of planning for biodiversity and supporting water ecosystems, a stakeholder workshop in the Hague "considered that the link between climate change and biodiversity is not fully apparent" (*ibid.,* p. 142). The authors concluded it was "rare" for French, Dutch, and English authorities to safeguard new sites explicitly for climate change adaptation, and identified several policy barriers to implementing adaptive responses (*ibid*.). 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 (*ibid.,* p. 145).

In many urban centres in coastal areas, adaptation is needed to withstand the impacts of climate change and strengthen urban livelihoods dependent on ecosystem services. Rio de Janeiro's Guanabara Bay has lost the majority of its coastal mangroves, while its coastal marshes have largely been filled in (de Sherbinin, Schiller, and Pulsipher 2007: 56). The few remaining wetlands have limited capacity to act as buffers during storm surges, which are increasingly likely as a result of climate change. Furthermore, warmer water temperatures may create algae blooms "especially if no effort is made to treat discharges into the bay" (*ibid*.). Mumbai's combination of fragile wetlands, inadequate waste treatment and sanitation, and rising prevalence of extreme weather could similarly create a 'stress bundle' that leaves the city highly vulnerable to climate change (*ibid.,* p. 50).

West African coastal cities are already experiencing ecosystem degradation and reduced fish stocks, which may be exacerbated by climate change. Lagos' natural vegetation cover declined from 30.1% in 1986 to 19.4% between 1986 and 2002; wetlands and naturally occurring water bodies have also been sharply reduced by rapid urbanisation and land cover changes (Adelekan 2010: 439). In turn, the expanding coastal settlements are increasingly vulnerable to sea-level rise, storms, and other impacts of climate change (*ibid.*). Coastal fishing is limited in Lagos, but fisheries in nearby Cotonou support 15,000 fishers, wholesalers, and associated labourers (Dossou and Gléhouenou-Dossou 2009: 113). A sea-level rise of 50cm would drastically reduce Cotonou's plant formations, particularly mangroves, and disrupt species such as crabs and turtles (*ibid.,* p. 120). The authors suggest that fish farming may restore fauna, ameliorate overfishing, and bolster livelihoods in the face of climate change (*ibid.,* p. 124).[17]

[INSERT FOOTNOTE 17 HERE: Additional adaptations to sea-level rise and erosion in Cotonou may include technical measures, such as groynes or barriers, and relocating infrastructure (Dossou and Gléhouenou-Dossou 2009: 122-4) as discussed in Section XX on the urban economic base.]

Climate change may exacerbate pressures on Cape Town's marine and terrestrial ecosystems, requiring a range of adaptation strategies. Harvesting of marine resources and *fynbos* products together generate 10% of the region's Gross Geographic Product (Crane and Swilling 2008: 275). But unsustainable exploitation, invasive species, and poor management have led to declining soil productivity and nearly 1,400 plant species currently endangered or near-extinction (*ibid.*). Rising temperatures and decreased precipitation due to climate change may substantially increase the risk of wildfire and promote further losses in biodiversity, increased alien plant invasions, and degraded soils (Mukheibir and Ziervogel 2009: 283). However, fire risks may be reduced by removing plantations, controlling alien species, and creating fire breaks between vegetation and residential areas (*ibid.,* p. 284). Increased capacity for fire-fighting and rapid response measures may also be required (*ibid.*). Interventions to enhance marine biodiversity may include controlling erosion and wetlands, neighbourhood-based sewage treatment linked to greening, and rebuilding fish stocks through quota allocations to benefit fishing communities (Crane and Swilling 2008: 283-4).

Evidence suggests that bottom-up strategies or partnerships can help to restore green infrastructure. In Mombasa, the Bamburi Cement Company has rehabilitated 220 hectares of quarry land now known as Haller Park (Kithiia and Lyth 2011: 258). The restoration began in 1972 and 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.,* p. 260). To involve further businesses or civil-society actors, Mombasa's municipal authority could adopt bye-laws to regulate or encourage green landscaping; offer incentives for residents or local groups; or facilitate other collaborations between diverse stakeholders (*ibid.,* pp. 262-3). Cape Town has already 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.*).

Some cities have made large 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 through a programme of projects that are designed 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. More than £20 million-worth of projects have already been delivered. The Mayor has published Supplementary Planning Guidance100 to enable the implementation of the Green Grid through borough and subregional planning. The same principles will apply to the London wide Green Grid." (GLA, 2010 pg 96).

Worth considering a box on the approach taken by New York to protect and enhance its water supply through its watershed protection programme but making clear what aspects of this are related to climate change adaptation. "To protect our customers and maintain our unfiltered water supply, we must continue to protect water quality. That is why we are implementing a $462 million Watershed Protection Program that targets the greatest potential threats and enlists the help of the surrounding towns, businesses, and organizations. The Watershed Protection Program is a unique strategy that combines protection, land acquisition, and environmentally- sustainable economic development to maintain the high quality of our water supply. We will replace failing septic systems, preserve wetlands, and upgrade wastewater treatment facilities in towns near our reservoirs. We will work with private land owners to improve land management practices. By working with surrounding communities, we will continue to implement sustainable practices that bring economic development to the region and clean water to New York City. We will continue to acquire watershed lands from willing sellers when possible. City ownership of land ensures that crucial natural areas remain undeveloped, while eliminating the threat from more damaging uses. New York City protects more than 115,000 acres of watershed land through land ownership or conservation easement—including more than 78,000 acres acquired since 2002. To maintain this successful program and meet the requirements of our current FAD, we will contact the owners of at least 50,000 acres of land every year. To achieve our land acquisition goals, we secured re-authorization of our Land Acquisition Program from the New York State Department of Environmental Conservation (State DEC) in 2010. We will continue to strike a careful balance between protecting drinking water quality and facilitating sustainable local economic development. The success of this program is possible thanks to strong partnerships with local stakeholders and communities throughout the watershed. Through our work with the Catskill Watershed Corporation, 203 watershed businesses have received $48 million in loans over the last 12 years to support tourism, hospitality, manufacturing, and other industries. We worked with local communities to rehabilitate more than 3,500 septic systems. We will continue to rehabilitate an estimated 300 residential septic systems per year and install new wastewater treatment systems in a number of communities. We will also continue our partnership with the Watershed Agricultural Council to promote sustainable farming techniques that limit the amount of fertilizer and other waste products that run into our reservoirs. The Watershed Protection Program is costly, but 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." (City of New York, pg 81).

Green roofs and cooling impacts of green infrastructure

Green roofs have been introduced in a range of cities, with the potential to create synergies between mitigation and adaptation.[18] 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). 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: 417). Under its Skyrise Greenery project, Singapore has provided subsidies and handbooks for rooftop and wall greening initiatives (Newman 2010: 166-7).

[INSERT FOOTNOTE 18 HERE: See also section XX below on mitigation-adaptation synergies.]

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.,* p. 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.*). **further research needed; add review of other citations on green roofs (below)**

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, several policies were found to increase local temperatures according to the indicators of evapotranspiration and land surface emissivity (*ibid.,* p. 106). Green areas and water surfaces had cooling effects, as expected, and "increasing sealed surfaces leads to increasing temperatures" (*ibid.,* p. 109). The study also identified unintended conflicts between planning strategies, and the authors suggest the method may help set priorities "especially with respect to climate change and increasing temperatures" (*ibid.*).

Need to consider relevance of green walls, green alleys, urban forestry etc

Comment from Debra: Not sure where we deal with the threshold/mitigation/adaptation conflict issue – in many ways it impacts on green infrastructure arguments the most. It is generally accepted that mitigating climate change will require a denser urban form in order to maximize economies of scale, reduce the need for transport and to reduce building energy use. Adaptation alternatively speaks to an urban form that favours green infrastructure such as the provision of open space for stormwater management, species migration, and urban cooling (Hamin and Garrun, 2009 pg 242). This raises the question of thresholds i.e. when will densities be so high that they create negative feedbacks such as the inability to maintain ecologically viable and biodiverse systems, or positive feedbacks such as the exacerbation of 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. Hamin and Garrun (2009 pg 242) refer to this as the "density conundrum".

The dangers to biodiversity particularly are highlighted by Hamin and Garrun's (2009 pg 242) assertion that an appropriate response to the density conundrum would be to provide multi-use greenspace within settlements along linear features (such as transportation routes and rivers and floodplains) while larger open areas are limited to the urban periphery. While this may make sense from a climate perspective – it makes little biological sense, especially in situations where urban areas are located in areas of high biodiversity and endemism. Under these conditions it is often necessary to protect and 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. Such is the case in South African cities such as Durban and Cape Town, both of which are both located within global biodiversity hotspots (EThekwini Municipality, 2007 pg 4; Holmes et al., 2008 pg 4).

8.3.3.8. Adapting Public Services

[The problem with this section is how little discussion there is in the academic literature on this topic – and how most of the existing literature is for cities in high-income nations. We need to draw more on city risk and vulnerability assessments that have been produced and published by city governments even though these are 'grey' literature]

As more cities develop risk and vulnerability assessments for climate change, so attention is beginning to be given to the operations of public services in cities. This is both in regard to the impacts that these services might face from (say) extreme weather and in regard to what these public services can contribute as part of climate change adaptation (or disaster risk reduction). This has been supported by city governments taking measures for disaster risk reduction, as this usually helps reduce risks and vulnerabilities to extreme weather and builds resilience to many likely impacts of climate change – even if the disaster risk reduction methodologies need adjustment to address climate change (ISDR 2009, 2011).

Obviously, health care and emergency services (including those that respond to fires and acute illness and injury) along with agencies with responsibilities for disaster response have particular importance in responding to extreme weather and themselves having the needed resilience to extreme weather. There is also the recognition that public service agencies within urban governments have particular importance in disaster risk reduction – i.e. in identifying the most serious risks and vulnerabilities based on analyses of the impacts of past events and acting on these both to reduce or remove the risks and take damage limitation measures just before an extreme-event (for instance evacuating people temporarily from locations or settlements at particular risk). Table 8-4 highlights the range of local government responsibilities for infrastructure, buildings and services that have importance for risk reduction, damage limitation and immediate and longer term rebuilding.

[INSERT TABLE 8-4 HERE
Table 8-4: The role of city/municipal governments in preventing disasters from extreme weather, limiting their impact and post-disaster responses (Satterthwaite, Dodman, and Bicknell, 2009.]

The interrelated impacts of climate change in urban areas may strain municipalities' limited resources, "all while making the delivery of services more difficult" (Gasper, Blohm, and Ruth 2011: 155). 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 may provide a foundation for adapting to climate change, such as heat warning systems or disease surveillance (Bedsworth 2009, McMichael *et al*. 2008). However, more frequent or severe extreme weather events could heighten the demands on emergency medical services. Multisystem failures (such as power outages during heat-waves) could compound the pressures on emergency responders (Hess *et al*. 2009: 787). Adapting health services may require multi-dimensional strategies and action across local, regional, and national scales (Frumkin *et al*. 2008: 440). As the system failures during Hurricane Katrina revealed, responding to extreme events may require "effective, coordinated approaches for delivering clinical services" (*ibid*.).

The quality, timeliness, and integration of urban public services may help to moderate the impacts of climate variability and change. Even in cities with low-quality housing and deficient infrastructure, the presence of effective early-warning systems, measures taken just before the extreme event, and post-disaster responses can greatly reduce the impacts on populations (IFRC 2010, Dodman and Satterthwaite 2009). Comprehensive urban disaster management may help to minimise economic damages, reduce mental and physical trauma, and enhance resilience to climate change (**ISDR 2009; other cites**). Schooling is often interrupted by disasters, so that maintaining educational and informal enrichment activities may help to adapt to climate change and promote children's future development (Bartlett 2008).

The discussion begins with health and emergency services, followed by a consideration of education and fire-fighting, police, and other public services. Extreme weather events "rarely cause large loss of life or serious injury" in high-income nations with early warning systems, adequate healthcare and emergency services, as well as police, fire services, and other systems to provide rapid response (Moser and Satterthwaite 2008: 14). Integrated, well-functioning public services are uncommon in urban centres in low and most middle income nations and the evidence below suggests that services in high-income areas may need major adaptation.

Adapting health services and emergency care

There is a growing literature on the role of health care services and systems in climate change adaptation in urban areas. Yet few health service officials have identified climate change as a focus area or sought to adapt urban health services. Studies in the U.S. have examined health adaptation strategies, perceptions of climate change, and barriers to adaptation.[19] Amongst 133 randomly-selected local health department directors surveyed in 2007, only 19% said climate change was among their top 10 current priorities; 83% felt their health department lacked expertise to create an effective adaptation plan (Maibach *et al*. 2008). Research in California found higher levels of concern regarding climate change, but these health officials similarly reported limited adaptive capacity (Bedsworth 2009). In a 2007 survey of 34 local health officers, respondents felt climate change posed a large risk to public health but nearly two-thirds said they lacked the information and resources to address such risks (*ibid.,* p. 621). More positively, cities had relevant programmes such as San Diego's heat emergency plan (including a reverse 911 system to all vulnerable groups regarding heat risks and how to minimise them), which could be built upon to respond to climate change (*ibid.,* pp. 618-9).

[INSERT FOOTNOTE 19 HERE: See also Carthey et al. 2009 for limited knowledge and barriers to adaptation amongst health facilities managers in New South Wales, Australia. More info + more cites]

Many urban centres in low- and middle-income nations are facing or likely to face more serious health impacts while also having major deficiencies in health care and emergency services. "More assessments of the impacts of climate change on health at the city level are needed in order to inform decision making" (Kovats and Akhtar 2008: 172). Durban's Municipal Climate Protection Plan already identified the potential health impacts of climate change, and a range of future measures were proposed including an early warning system, public education to enhance community response, and further research on health and climate (Roberts 2008). The development of more detailed, and sectorally focused Municipal Adaptation Plans, however, highlighted that the most urgent requirement in the health sector was the need to strengthen the primary health care services, and to increase their ability to respond to emergencies with fewer referrals to overburdened hospitals (Constable and Cartwright, 2009) The Indonesian Ministry of Health has instructed provincial governments to prepare for dengue outbreaks before the rainy season (Wirawan 2010: 29) and sub-district primary health centres (PHCs) can help to collect and integrate health surveillance data particularly in low-lying settlements vulnerable to climate change (*ibid*.).

Adapting to extreme weather will require enhanced emergency response as well as long-term measures to protect vulnerable communities, as suggested by research in Cavite City, Philippines (Sales, Jr. 2009). With a population of 100,000 bordering the Manila Bay, Cavite City is a largely coastal settlement at high risk of sea-level rise and increased flooding due to climate change (as well as suffering from overfishing, ecosystem degradation, erosion, and other non-climate concerns). The local government has launched strategies to minimise risks and enhance emergency services in low-lying areas, including information campaigns and public advisories; resettling vulnerable coastal families; and constructing breakwaters, seawalls, etc. (*ibid*., p. 399). But a vulnerability assessment with residents suggested that additional evacuation and health centres were needed, as well as further logistical support (such as ambulances and emergency kits).

Enhanced emergency medical services may help cope with extreme events (Hess *et al*. 2009), while health officials can also improve surveillance, forecast the health risks and benefits of adaptation strategies, and support public education campaigns (McMichael *et al*. 2008). Responding to the heightened risk of infectious disease may require health-workers to enhance vector control (e.g. screening windows), improve peri-domestic sanitation to prevent dengue, or bolster food hygiene measures to prevent salmonella poisoning that may increase with rising temperatures (Blashki *et al*. 2011: 137S). Local-level partnerships may be necessary, since action at the local and regional levels are the sites of "identifying health threats and vulnerable populations, designing and implementing adaptive measures, and responding to emergencies" (Frumkin *et al*. 2008: 440). These local health adaptation activities "are also enhanced by a supportive policy environment at the national and international levels" (Keim 2008: 515).

Health infrastructure will also require attention. The Boston Redevelopment Authority for example "has begun asking developers of projects that may be subject to more frequent coastal flooding due to sea-level rise to analyze the effects of climate change. In 2009, as a result of such an analysis, Partners HealthCare raised the base elevation of the proposed Spaulding Rehabilitation Hospital by two feet at its new location in the Charlestown Navy Yard (now under construction). (City Of Boston, 2011 pg 11)

The costs of integrated health adaptation may be considerable, according to some estimates. The U.S. federal funding directly addressing the health risks of climate change was $3m per annum in 2009, but as much as $200m annually may be needed for a comprehensive surveillance and monitoring system, regional centres and programs, and modelling software that can capture the health risks of climate change (Ebi *et al*. 2009). Limited funds for public health are a significant barrier to adaptation in developing regions, but investment alone "is not sufficient to improve health" (Kovats 2009: 52). Other constraints to adapting health services include poor urban governance, low adaptive capacity, and high levels of inequality (*ibid*.). (the literature cited here seems to treat health as "hospitals and medication". Is there a literature on a more preventative and holistic level in terms encouraging local level food gardens (people who eat better stand less chance of getting ill) etc. For instance, Toronto's identification of initiatives that help build a healthy and sustainable food system including making food an essential element of the green economy and linking city and countryside. http://www.toronto.ca/civic-engagement/council-briefing/pdf/1-3-41.pdf in New York, "approximately 80% of the city's community gardens grow food. Most food-producing gardens are located in neighborhoods with limited open space and inadequate access to fresh produce and other healthy foods". Establishment of farmers markets at community garden sites. support for gardens in schools (City of New York, 2011 pg 37). (See also Chehimi et al 2011)

Adapting schools

In urban centres impacted by extreme weather events, schools and disadvantaged students may be negatively affected. These events can damage or close schools or disrupt classes as schools are needed for emergency shelters

(Bartlett 2008: 35). All of the primary schools, high schools, and colleges in east Dhaka were closed during the 1998 floods; the Water and Sewerage Authority reported that in the September 2004 floods, 250 schools were again affected by waterlogging (Alam and Rabbani 2007: 87 and 91). In areas where school drop-out is common, "children are much less likely to continue with school after an interruption" and low-income or female students may be disproportionately affected (Bartlett 2008: 35)

Short-term adaptation measures may include risk assessments of school locations, strengthening disaster preparedness capacities and educational infrastructure, and responding to seasonality changes by adjusting exam schedules (Bangay and Blum 2010: 361). A recent assessment in Chicago explored climate-related vulnerabilities to the school system, which was predicted to save in energy heating costs as winter temperatures rise (Hayhoe *et al.* 2010). But like other municipal buildings, the School Board may experience increased costs for maintenance, repairs, or rising cooling demands due to changes in mean and extreme temperatures (*ibid.,* p.102). **Other assessments needed particularly in low-income cities...**

Adaptations in the education sector may help students and teachers to cope with extreme events, as well as to shape innovative responses to climate-related and other emerging concerns. After a disaster, re-establishing schools can serve to introduce one aspect of 'normal' life to children and their families (Bartlett 2009). The long-term task in adapting educational systems is to "develop education systems that equip learners with the requisite skills, knowledge, and attributes to deal with future challenges" (Bangay and Blum 2010: 361). More cites here on **environmental education/CC awareness?**

Adapting public transport

[to be developed]

Emergency response and disaster risk reduction –
including roles of civil protection, fire and police services, and army

Without adequate adaptation and coordination, climate change may strain the operations of key disaster response providers. The interrelated impacts of climate change in urban areas may strain municipalities' limited resources, "all while making the delivery of services more difficult" (Gasper, Blohm, and Ruth 2011: 155). The disaster risk reduction network in many cities may already be complex, with a range of actors "extending from applied emergency and risk management to development regulation and planning" (Pelling 2011: 80). Research after Australia's recent bushfires and flooding suggested the need for a coordinated response between police, emergency providers, and housing authorities (Jacobs and Williams 2011). The interviewed housing officials were sometimes unsure of each agency's precise remit, and to improve coordination the authors recommended preparing templates or toolkits and establishing "a strong chain of command and clear communication" (*ibid.,* p. 190).

For cities without a robust emergency response network, adapting to climate change may require significant improvements in staffing, resources, and preparedness plans (including particular attention to providing emergency services in informal settlements lacking adequate roads or infrastructure, as discussed in section 3.3.6). In Durban, a significant challenge is the fact that disaster management services are (as a result of past operational exigencies) more reactive than proactive (Roberts, 2010 pg 402) thereby limiting their ability to respond strategically to the growing range of climate change impacts. This highlights the importance of addressing institutional operations as well as the more technical aspects of risk management (Roberts, 2010 pg 402).

Risk of fires is likely to increase in and around many urban centres because of increased prevalence of drought and rising temperatures (**cite).** Studies have suggested that "serious fire disasters are commonplace in many informal settlements," although the events may go unrecorded due to a lack of emergency fire services or the inaccessibility of such settlements (ISDR 2010: 44). Cape Town's fire incidents are most common during hot, dry, and windy summers; informal settlements are highly at risk due to overcrowded, dense, and flammable housing structures; the use of candles or kerosene; and the lack of piped water supplies (*ibid.*). The public health impacts of wildfire may include burn injuries, exacerbated asthma or chronic obstructive pulmonary disease (COPD), and population displacement necessitating humanitarian relief measures (Keim 2008: 512). Anticipatory measures may include a fire hazard evaluation, developing emergency plans, and public education outreach and exercises (*ibid*.). In the absence of such adaptation measures, climate change may only exacerbate the risks of fire in both low- and high-income cities.

Improved fire-fighting responses have been identified as a priority adaptation measure in several cities and at-risk regions. Amongst 34 local health officials in California, 62% reported that wildfire was a 'very serious' health risk associated with climate change (Bedsworth 2009: 620). A climate change assessment in Chicago outlined possible impacts on the Fire Department, such as increased firehouse maintenance and greater volume of fire responses and safety checks (Hayhoe *et al*. 2010). Researchers in Australia noted the need to enhance responses to bushfires in the context of climate change, advocating greater coordination between the health sector and broader community "to develop regional bushfire health response plans and to support community care options and social networks that have a protective effect" on vulnerable populations (Blashki *et al*. 2011: 137S).

To cope with increasingly frequent extreme heat events, Chicago's police department may experience higher costs and challenging trade-offs (Hayhoe *et al*. 2010). This climate change assessment predicted increased overtime costs for Chicago's police and more frequent safety checks. Extreme heat-events may require several responses by police, such as coping with increased crime levels or evacuating residents experiencing electrical black-outs (*ibid.,* p. 102). Moreover, police charged with evacuation assistance "could draw away from the ability to deal with concurrent crime and disorder" (*ibid.,* p. 100). Managing such trade-offs, as well as coordinating with other emergency responders, may be important in adapting to climate change.

In Boston, there are plans by Boston City Government to acquire portable emergency generators adaptation that can be used to power air-conditioning equipment at cooling centers in the event of power outages (The City of Boston, 2011)..

For the civil protection services, It is likely that urban disasters will increase in number and magnitude as a result of climate change and variability, civil protection services will need to adapt to an increasing demand from local, state and federal governments in order to assist affected residents. Since civil protection department (*defesa civil* in Brazil) provides in many countries (to check concrete examples>, along with the Army and Red Cross, prompt assistance during and after the impact of a disaster, it is important to assess to what extent civil protection protects affected people by doing mainly humanitarian work. <No papers, documents have been found so far concerning this issue. Fernando will keep an eye on this>

Army. Similar discussion applies to the Army. In many Latin American countries, the Army constitutes the forefront when a disaster strikes. <To check if there is literature in the context of increasing floods, droughts, etc

8.3.4. Urban Planning, Management, and Governance

What studies have discussed the means used to get local government to recognize that there is a problem they have to address and understanding how climate change adaptation can and should be folded into larger processes. Getting adaptation strategies into the core of local government investment and management with buy-in from key sectors and directorates (draw on Roberts 2010). The experiences with integrating development, disaster risk reduction and climate change adaptation

Tools and methods for risk and vulnerability assessments and how these feed into adaptation plans and strategies and then into key city plans and investment frameworks. Mapping and enumerating risk and vulnerability (reference text in section 4 on this)

Studies showing how building codes, planning regulations and land-use management are being changed in relation to disaster risk reduction (United Nations 2011)– and for climate change

Key obstacles to action at the metropolitan level are the lack of actionable climate information and the vertical and horizontal fragmentation of jurisdictions – for instance, in Argentina, between the city of Buenos Aires and the 26 separate municipalities that are within the province of Buenos Aires and between the different ministries and departments within the national government that are involved in flood management and disaster management (Natenzon and Viand 2008, Mehrotra et al 2011 in Rosenzweig, Solecki, Hammer and Mehrotra 2011, Hallegatte et al. 2011 – Copenhagen study)

8.3.5. Landscape and Regional Connections

Managing urban areas' physical growth and development. Land use planning and management (remembering point about how much low-cost risk reduction often needs areas protected from being built over). Protecting and utilizing productive and protective ecological services. Green infrastructure - How to protect and maintain existing ecosystem services in cities, and how to restore and enhance ecosystem services – promoting 'good transitions' (Does the section on Green Infrastructure in 3.3 belong here?)

Are sprawling cities more vulnerable to climate change than compact cities? Stone, Hess and Frumkin (2010) found that extreme health events (weather events?) in US large cities between 1956 and 2005 in the most sprawling metropolitan region was more than double the rate of increase observed in the most compact metropolitan regions. They propose that the design and management of land use in metropolitan regions may offer an important tool for adapting to the heath-related health effects associated with ongoing climate change.

8.3.6. Building Resilience in Urban Areas within a Commitment to Mitigation

Reviewing what has been discussed above in regard to where and when there are opportunities for mitigation/avoidance of greenhouse gas emission. Co-benefits discussions. Impacts of climate change policy. (Review Wilbanks, Sathaye 2007; Hunt, Watkiss 2011)

8.3.7. The Limits to Adaptation and How these Change over Time

and with this change so influenced by the extent (or not) of effective emissions reduction agreements for wealthy nations and emissions-moderation by others

8.4. Enabling and Supporting Urban Adaptation and Adaptive Capacity

8.4.1. Enabling Frameworks

8.4.1.1. Introduction

Enabling conditions and frameworks to support urban adaptation are grounded in local-national institutional structures, local competences and interests. The context for adaptation decisions will inevitably vary from country to country and location to location. Some of the preconditions for sound adaptation decisions can nevertheless be generalised across locations and relate to principles of good practice in public decision-making as well as to science-policy deliberative practice and risk governance (Adger et al. 2009; NRC 2007, 2008, 2009; Renn 2008; Moser 2009).

In many urban settings, civil society including non-governmental and community-based organizations play an important role in urban environmental management. In particular, the role of civil society is key to participatory community risk assessment, local expert knowledge, and local capacity building (e.g., Krishnamurthy et al. 2011; Fazey et al. 2010; Shaw et al. 2009; Tompkins et al. 2008; Van Aalst et al. 2008).

Actor engagement matters to the quality and effectiveness of public policy decision-making, and conceptually can be organised around core, inner and outer peripheries of influence, where information and circuits of power flow inward and outward from the core to ensure legitimacy (see Figure 8-3; Corfee-Morlot et al. 2011). In this framework, governments are at the core with the central authority for policy decisions, however in climate change adaptation decisions, scientific information and expertise is also central to understanding the nature of the problem. Successful urban adaptation thus requires grappling with a complex and uncertain regional climate science as well as advancing understanding and decision making on this "new" issue across levels of government and a variety of stakeholders (e.g. businesses, households and consumers, and a wide variety government stakeholders themselves within a single level of government).

[INSERT FIGURE 8-3 HERE
Figure 8-3: Title? (adapted from Corfee-Morlot, Cochran, Teasdale, and Hallegatte, 2011).]

In urban adaptation decision making, "semi-autonomous" institutions such as local water authorities or insurance regulators (in the "inner circle") will need to engage along side of local stakeholders such as businesses, consumers or even scientific experts situated in the "outer circle". The media and other forms civil-social infrastructure act as filters of substantive knowledge and help to join expert information with local knowledge to build understanding and engagement. The credibility, legitimacy and salience of adaptation decisions will depend in part upon how well governance processes mediate across these different actors and sources of information and influence to co-produce knowledge (Wagsaether, Ziervogel 2011, Corfee-Morlot et al. 2011, Renn 2008).
The capacity to act will also vary with organisational form and of problem complexity (Habermas 98; Corfee-Morlot et al. 2011) which in turn will relate to levels of development and more generally the development context (Bicknell et al. 2009).

8.4.1.2. Building Urban Capacity to Adapt across Levels and Government across Levels, Stakeholders

Given the uncertainty and complexity of the problem, decision-making will necessarily be iterative and evolve along with scientific understanding (Dietz 2003b, Corfee-Morlot et al. 2011). Where uncertainty is high, such as in the case of future climate change, how decisions get made will be as important as what decisions are made (Funtowicz, Ravetz 1993, Liberatore, Funtowicz 2003). In the context of adaptation decision-making, this implies that both strategy and actions as well as the process through which these are determined are important (Lim et al. 2005, Mukheibir, Ziervogel 2007). Thus not only cost-effectiveness and the delivery of direct local benefits in the form of reduced vulnerability will be important, but also participatory inclusiveness, equity, awareness raising, deliberation, argument, and persuasion.

Access to sound scientific predictions and physical and economic assessments of climate change at local scale (that are rooted in understandings of local risk contexts) is a central challenge. A recent review of urban adaptation and impact assessments found that useful information about climate change at urban spatial scales is still lacking (Hunt, Watkiss 2011). For example Hunt and Watkiss (2011) found that only a small number of cities largely in high-income countries have quantified the possible costs of climate change risks under different climate and/or socio-economic scenarios and more generally that quantitative risk analysis in local contexts is rare. Sea level rise/coastal flood risk and health and water resources are among the impact sectors where urban analyses exist, while energy, transport and built infrastructure receive far less attention yet are equally important to urban development (Hunt, Watkiss 2011, Hunt, Watkiss 2011, Hunt, Watkiss 2011). Overtime, it will be 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, Carmin 2011).

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 & Winkelman 2009, Carmin, Anguelovski 2009). Experience in a handful of cities – i.e. Capetown, London, New York -- demonstrate that the benefits of engaging a wide number and variety of stakeholders at early stages in the risk assessment helping to create political support and momentum for follow-on research and ultimately adaptation planning (Hunt, Watkiss

2011, Anguelovski, Carmin 2011). Carmin and Anguelovski 2009 also highlight the importance of local leadership and the capacity to be continuously resourceful (despite resource constraints). They show that city leaders can be innovative in the absence of formal institutionalisation of the issue of climate change, often connecting the adaptation (and mitigation) agenda to other local priorities and agendas (e.g. sustainable development and comprehensive urban planning) (Carmin, Anguelovski 2009).

As a way forward, a climate change/environmental focal point or office can help to champion and coordinate climate action across government departments or line management agencies (Anguelovski, Carmin 2011; Hunt, Watkiss 2011; OECD 2011). Yet there may be downsides to that when the urban climate change function is housed by the environmental line department (e.g. Durban - Roberts, 2008 pg 523; Boston - http://www.cityofboston.gov/environment/; Sydney - Measham et al., 2020 pg 17). Roberts (2010: 401) 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 given the low or lower priority and limited resources usually assigned to environmental departments within government structures, which results in limited institutional influence.

There are also important political constraints to making adaptation decisions at the local level. Although there is growing evidence of adaptation leadership in urban contexts (Anguelovski, Carmin 2011, Lowe, Foster & Winkelman 2009, Carmin, Anguelovski 2009, Foster, Winkelman & Lowe 2011), 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). Inattention by international bilateral and multilateral donors, and tension between governments and the growing numbers of the urban poor in low and medium income developing countries, is partly what makes cities in the South highly vulnerable to climate change. Indeed an ongoing failure to provide basic services – clean water, sewerage, health services and adequate housing – for this large segment of the world's population can only aggravate vulnerability to inevitable climate change in the decades to come (Satterthwaite et al. 2009).

8.4.1.3. Need to Align Action across Levels of Government – Nested Institutions

The multilevel nature of institutional and policy interactions in the case of local adaptation governance adds another layer of complexity to the urban adaptation challenge. In particular, it highlights the need for alignment of policy incentives and actions across multiple levels of government (Corfee-Morlot et al. 2011, Mukheibir, Ziervogel 2007, Urwin, Jordan 2008, Cash et al. 2006, Young 2002, Bulkeley, Kern 2006, Kern, Gotelind 2009). From an institutional and policy perspective, local governments will have authority in some of the right domains for adaptation decisions but not in all of them. Also many of their decisions will be bounded or constrained in one way or another by national policies and infrastructure investment decisions. Urwin and Jordan examined top-down and bottom-up approaches to policy in the UK across three sectors (agriculture, nature conservation and water), demonstrating the need to both audit (pre-)existing policies and screen new policies to ensure integration of climate change adaptation concerns. Failing to do so risks mal-adaptation despite the development of pro-active adaptation policies. This can occur when long-standing sector policies do not take climate change into account and lock-in outcomes that raise the vulnerability of people, infrastructure and/or natural systems to climate change (e.g. rising sea levels and storm surge; increased levels and frequency of extreme temperatures or precipitation; risk of flooding or drought/water stress) (OECD 2009, Urwin, Jordan 2008).

Although adaptation can be guided, incentivised, mandated or constrained by top-down national policies or frameworks, its implementation will ultimately be local in nature. Opportunities for learning and accelerating action may stem from horizontal coordination and networking across actors and institutions in different municipalities – and greater metropolitan areas – many of which will face similar challenges (Lowe, Foster & Winkelman 2009, Aall, Groven & Lindseth 2007, Schroeder, Bulkeley 2008). The local implementation agenda also underscores the need for broad consultation and tailoring and any national goals and policies to local circumstances and preferences, such that they can succeed. A recent example can be found in the 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, due to lack of consultation between government experts and local citizens (Laurent 2010).

8.4.1.4 Local Government as a Central Actor in Risk Assessment and Adaptation

Given their unique access to local residents, businesses & stakeholders, local governments can be effective leaders in urban adaptation efforts. Their role includes not just political representation of local population but also essential strategic urban development and master planning functions. This includes the coordination of more localised community-based plans, and the delivery of a range of public services (e.g. water, waste and wastewater management, transport, education, land use regulation, disaster planning and management, sometimes regulation of built infrastructure and/or energy services) (Bulkeley, Kern 2006, Kern, Gotelind 2009).

The exact balance of authority for the provision and regulation of key services, land use and infrastructure provision will vary by national and sometimes even regional and local context, making it difficult to generalise notions of "good practice" across locations, however a number of key opportunities can be identified. Given their political representation and strategic planning functions, city governments may be particularly well-placed to work closely with businesses, households and civil society organisations understand and integrate climate change into a common vision for urban development (OECD 2010). As preferences of actors tend to be more homogeneous in small groups (Healy 1997; Ostrom 2009), local level decision-making may have greater potential to envisage a common approach to contentious issues raised by climate change, compared to efforts at national or international levels. With an open and participatory decision process that emphasises "governance" rather than "government", urban leaders may offer a unique opportunity to work in close proximity to stakeholders, raise awareness and create a "policy space" to create a unique vision of the future that takes climate change into account (Brunner 1996, 2005; Cash and Moser 2000; Grindle and Thomas 1991). If the goal is a resilient, safe, and clean city, having a common understanding or vision of what such a future might comprise and the influence of climate change at urban scale is a first step to achieving it (Corfee-Morlot *et al.* 2011; Moser 2006; Moser and Dilling 2006). Cities also have an opportunity to lead by doing in the way they manage the vulnerability of city-owned infrastructure and municipal operations to climate change.

A number of local actions can support climate change adaptation decisions in urban contexts. These include performance of local climate change risk assessments, risk mapping and identification of priority "most vulnerable" populations/locations at risk (Ranger et al 2009; Hallegatte et al. 2010; Bigio and Hallegatte 2011 forthcoming; Annecke – get ref Tiempo, Oct 2010). Annecke describes the LOCATE methodology (Local Options for Communities to Adaptat and Technologies to Enhance Capacity), which is being tested in 8 African countries[20]; in each country a non-governmental organisation partner is working with one or more communities to test it. The methodology steps through i) identification of local "hot spots" and an identification of a "project owner", ii) project design, iii) implementation, and iv) monitoring, evaluation and learning. Within the vulnerability identification stage, hazard and vulnerability maps are developed; overlaying the two can be a useful tool to inform assessments and choices about what target populations, infrastructure and areas may be priorities for action. Another element is to identify local stakeholders who can help design and subsequently lead implementation of adaptation efforts, in this case the "project owner" or champion on the ground. Climate change adaptation project design or planning is another distinct undertaking however, Satterthwaite et al. (2010) suggest it will remain difficult to implement such plans if they are not conceived and fully integrated with broader development planning initiatives and combined with a clear timeframe for implementation and financing strategy.

[INSERT FOOTNOTE 20 HERE: Sudan, Kenya, Tanzania, Uganda, Malawi, Zambia, Zimbabwe and South Africa.]

Where cities are growing rapidly, both challenges and opportunity lie in the routine public and private infrastructure investment that will need to accompany such growth. Provision of basic water and sanitation as well as housing services is a necessary prerequisite for adaptation to occur, however integration of climate change considerations will not occur automatically (Satterthwaite et al. 2009). Public policies that require consideration of the implications of climate change for such investment (e.g. through Environmental Impact Assessment that includes climate change, or building standards that integrate consideration of increased risk from climate hazards), or that provide robust, timely and place-based information to private sector decision makers can help deliver climate-resilient infrastructure

(OECD 2010b). Notably urban sector policies – such as water, wastewater and other natural resource management, building regulations and transportation planning, disaster management– all provide key entry points for integration of climate change considerations at urban levels of governance. A recent review suggests that this is an effective regulatory tool that requires integration of climate change into infrastructure at the design phases; it is one that is already receiving attention at sub-national government level even where national governments do not necessarily require it (e.g. in Australia). Canada and The Netherlands have also shown that they are quite far along in the use of this tool.

A number of other steps may help build institutional capacity to make urban adaptation happen. For example, budgetary integration can help ensure that climate change is addressed at urban and other levels of government by establishing resources to support decision but also by making clear who in an organisation is responsible for the decision (OECD forthcoming). In each urban governmental department that has responsibilities to address climate change issues, a separate budget line may be established both to fund relevant actions and to track progress over time. This will make the work visible and also recognise that planning for climate change is an explicit task that requires time and some amount of budget even if small at the outset.

8.4.1.5. Assessment and Delivery of Co-Benefits

A number of studies look at why and how urban climate action is advancing, asking the question: why act, what are the local near-term benefits of climate change action including adaptation? They suggest that a key to successful action is not only local leadership but also understanding and championing development and other environmental co-benefits of adaptation. Such benefits connect to the overarching goals of urban policy and development, such as delivering safer, more comfortable and healthier urban environments, poverty reduction and reducing the vulnerability of the poor (Burch 2010, Clapp et al. 2010, Hallegatte, Henriet & Corfee-Morlot 2011)(Kousky, Schneider 2003)(Carmin, Anguelovski 2009) Roberts 2010]. Some studies show that climate change considerations can help to finance investment in infrastructure that provide basic service provision and climate protection simultaneously. For example, this is the case in Rio de Janeiro where the CDM has facilitated a methane capture and waste to energy project that provides both a new low cost source of energy as well as an ongoing revenue stream which has allowed the local government to invest in local community amenities (e.g. greenspaces and parks) (Clapp et al. 2010). [Need to consider the scale of the 'new source' of energy, GHG reduction and revenue and whether it does bring local benefits; worry that these benefits may be overstated]. Numerous examples of ecosystem-based adaptation to better manage scarce water resources or limit flood risk,[21] or renovation of low cost housing to provide basic weatherisation, are receiving increased attention in development finance portfolios as "adaptation" projects or programmes but these projects also deliver multiple development co-benefits to urban areas.

[INSERT FOOTNOTE 21 HERE: See BMU May 2011, "Harnessing the Potential of Ecosystems for Climate Change Adaptation" – project operating in Brazil, Philippines, South Africa – from 2011-2015, 4.4 million Euros, implemented by Conservation International Foundation.]

Co-benefits may be particularly important in the global South, where climate change planning and adaptation suffer from low political priority as they are not perceived to be central to urban development priorities. As noted by UN-Habitat (undated: 17) when discussing the prevailing situation in Esmeraldas (Ecuador) "it is important to note that most of what has been accomplished in sanitation, infrastructure, and urban planning capacity has not been motivated by concerns over climate change, but through strategies seeking better planning processes and poverty reduction." The reality is that in the urban areas of the global South, climate change is generally of low political significance because of other pressing development needs, e.g. infrastructure, public health, education, housing and energy, which are not considered to be linked to climate change (Roberts, 2008 pg 523; Kithiia, 2009: 25 and 1). This situation is compounded by the escalating 'urbanization of poverty' that has occurred in these parts of the world, making cities the nexus where poverty and climate change compete for political attention (Kithiia, 2009: 1). Within this context the challenges posed by climate change are viewed as marginal when compared with other socio-economic problems faced by authorities responsible for urban development and security.

The potential tension between attention to poverty alleviation and development on the one hand, and climate change strategies on the other, is affirmed by other recent work by urban development practitioners from the South. A recent 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." Given this situation, local authorities in the global South often do not view climate change as a management problem requiring immediate attention due to the plethora of competing stresses and development challenges (Kithiia and Dowling, 2010 pg 470; Roberts 2008, pg 523).

Similarly in the North, development and climate change or green growth issues are often seen as separate challenges in a sub-national, regional policy context (OECD 2010, Ch. 8). A recent review of regional policy and climate change 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 also have innovative sub-national climate policies and action programmes which are incentivised and funded by the central government. For the majority of OECD countries territorial development and climate protection remain separate or parallel areas of action, raising inevitable tension and conflict between the two and limiting the ability to seek and exploit co-benefits.

As a general rule, any adaptation strategy has to be developed within "the development context of the city or country and should lead to harmonization with the country's priorities such as poverty alleviation, food security and disaster management" (UN-Habitat, undated b, pg 15; see also Satterthwaite et al. 2009). If the adaptation agenda is to be advanced, it will require the use of innovative measures that couple climate change impacts with the reduction of poverty and development more generally (Lwasa, 2010 pg 167). As concluded by Kithiia (2010: 4): "In general, without combating urban poverty and providing alternative sources of livelihood, little will be achieved towards climate change mitigation and adaptation, not just in East Africa but also in other low income countries."

8.4.1.6. Summary Points

In summary, effective urban adaptation governance will depend at least in part on regional (sub-national, multiple localities) and national institutional capacity and policy, suggesting that it will necessarily be polycentric in nature (Ostrom 2009). There is a need not only to create new urban policy and incentives for action but also to "climate proof" or audit existing policies to ensure that they do not lead to greater vulnerability and risk (Urwin and Jordan 2008). Yet 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 in many instances national governments are lagging in efforts to support local leaders on this important agenda (OECD 2010a).

Some review articles, and the foregoing discussion, suggest a number key institutional drivers of success to advance adaptation at urban levels (Anguelovski & Carmin 2011; Corfee-Morlot et al. 2011; Vogel et al. 2007;) + OECD 2010:

- Stable, local leadership and an open, iterative process that encourages stakeholder engagement;
- Sound information and continuous learning about risk and risk assessment including i) hazard assessment; ii) vulnerability assessment; iii) capacity/institutional assessment and capacity building;
- Policy level commitment to design and implement adaptation policy (integrating a long term planning perspective with short term goals), mainstream it into sector or core development principles, recognising and exploiting co-benefits between climate action and development goals
- Support from national and regional governments for local adaptation action
- Institutional reforms to establish functions/responsibilities within government (possibly through independent climate office or part of the administration) as well as clear rules and norms to take adaptation action

Further an important starting point is to establish mechanisms for information diffusion, awareness raising about climate change – both mitigation & adaptation and their interconnections -- to provide political support for action.

8.4.2. Funding and Supporting Urban Governments – Public Sector Domestic Action

Funding and other forms of support for urban adaptation action can come from the public or private sector, from domestic or international sources. Among the possible sources of funding, domestic public funding may be the most significant and sustainable source in many countries, including revenues from locally levied fiscal policies as well as revenue transfers or grants from sub-national regional and central governments (OECD 2010, Ch 9; Hedger and Bird 2011).

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 & charges. Looking across OECD countries, analysis shows that local governments are responsible for about 70% of public spending and for roughly 50% of the public spending that occurs on the environment, often operating in partnership with other levels of government (OECD 2010, ch 9). The source of funds for such spending varies widely by city and location, including not just local sources of revenues but also grants from central or higher levels of governments (OECD 2010, Ch 9). Fore example, in Melbourne, Australia, property tax is the main local tax revenue source for the city, while in Stockholm it is local income tax and in Prague it is a mix of income, sales and business tax. 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 impose other fiscal policies on local residents, property owners and businesses. In all instances there is some scope to green local fiscal policies for example through congestion charges or value-capture taxes that make visible the cost of environmental externalities and/or the benefits of infrastructure and services provided to property owners (e.g. transportation or wastewater or water services). Much less is known about local revenue sources in developing countries.

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." See for example the case of municipal financing distributed according to ecosystem quality rankings in Brazil (see Box 8-2).

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Box 8-2. Environmental indicators in allocating tax shares to local governments in Brazil

The tax on the circulation of goods and services (ICMS) is a value-added tax collected by state governments, and part of these revenues must be redistributed among municipalities. Three-quarters of this redistribution is defined by the federal constitution, but the remaining 25% is allocated to each state's legislation. The state of Paraná was the first Brazilian state to introduce the ecological ICMS (ICMS-E) in 1992, followed by the states of Minas Gerais in 1996, and several other states including São Paulo in 1996 and Rio de Janeiro in 2009. The ICMS-E was introduced against the background of state-induced land-use restrictions (protected areas) for several municipalities, which prevented them from developing land and generating value added, without being compensated for these restrictions: in the municipality of Piraquara, for example, 90% of the municipal territory was a designated protected area for conserving a major watershed to supply the Curitiba metropolitan region with drinking water (May et al., 2002).

Depending on the different states, the share of the ICMS allocated on the basis of ecological indicators ranges from 0.5% in São Paulo to 13% in Tocantins. Rio de Janeiro started with 1% in 2009, which will be gradually increased to 2.5% in 2011. Although the states have different systems in place, there are many commonalities in the allocation mechanism. The revenues are allocated according to the ecological index of a municipality, which is based on the total area set aside for protection, in relation to the total area of the municipality. The protected areas are weighted according to the different categories of conservation management, with weights ranging from 1.0 (for ecological research centres and biological reserves) to 0.1 (for special local areas of tourist interest, and buffer zones).

Some states, such as Paraná, have included an evaluation of the quality of the protected areas in the calculation of the ecological index. The quality of the protected area is assessed by regional officers of the state environmental agency on the basis of physical quality, biological quality (fauna and flora), quality of water resources, physical representativeness, and quality of planning, implementation and maintenance.

Evaluations of in Paraná and Minas Gerais show that the introduction of the ICMS-E has been associated with the creation of new protected areas and have improved environmental management and quality of these areas. In Paraná, the total area measured in conservation units increased with 165% between 1992 and 2000; the increase in Minas Gerais was 62% over 1995-2000 (May et al., 2002). The ICMS-E has also improved relations between protected areas and the surrounding inhabitants, as they start to see them 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).

Source: Ring, I. (2008), "Integrating Local Ecological Services into Intergovernmental Fiscal Transfers: The Case of the Ecological ICMS in Brazil", Land Use Policy, Vol. 25, pp. 485-497; May, P. et al. (2002), "Using Fiscal Instruments to Encourage Conservation: Municipal Responses to the 'Ecological' Value Added Tax in Paraná and Minas Gerais, Brazil", in S. Pagiola, J. Bishop and N. Landell-Mills (eds.), Selling Forest Environmental Services:Market-based Mechanisms for Conservation and Development, Earthscan, London. – as cited in OECD 2010

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Large economic and humanitarian spillovers are clearly associated with adaptation actions that limit the risk from extreme climate events in urban areas. Recent extreme events in a variety of development contexts demonstrate this – from Hurricane Katrina in New Orleans in 2005 to devastating floods in Colombia in 2010, from the deadly heat wave in Europe in 2003 to the paralysing snowstorm in China in January 2008. Failing to anticipate and plan for such events can lead to large scale disaster with national or international economic repercussions spanning multiple years if not a decade for both poor and wealthy nations (World Bank 2010b). In many locations, climate change shortens the return period of large storms, increasing their frequency. Many large, rapidly growing cities that are already ill-adapted and exposed to natural hazards and extreme weather events -- cyclones, coastal flooding due to storm surge, extended heat waves or heavy precipitation or drought. These cities will suffer significantly from increased exposure to such events in the coming decades if their vulnerability is not well managed (World Bank 2010a, Hallegatte, Corfee-Morlot 2011). That climate change increases risk of weather-related disasters in urban areas argues for increased funding and attention from national budgets for disaster planning, early warning and evacuation procedures along side of preventive measures (World Bank 2010b, World Bank 2010a, Hallegatte, Corfee-Morlot 2011).

A number of other innovative financial mechanisms exist and may be drawn upon to support urban adaptation action, including revolving funds and the energy services company (or the "esco") model (OECD 2010, Ch. 9 & Ch 8). The latter may take 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 in turn support public investments that yield adaptation benefits.

Cities and other governments in developed and in high and medium income developing 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 funds to local banks which in turn finances energy efficiency renovations in building /EIB example to support residential and commercial retrofit and renovation investments)(OECD 2010; Kfw 2011 – ppt; EIB xx)

8.4.3. Recognizing Role of and Supporting Community-Based Adaptation

8.4.3.1. Community-Based Action and Local Government

As discussed above, community based adaptation does not remove the need for extra-local interventions – including investments in infrastructure and services and support for community action. Now, it is increasingly seen as an important component of adaptation whose effectiveness depends on extra-local support and its integration within adaptation at other scales and levels (Tanner et al 2009, Burton 2008).

A study of three experiences with disaster risk reduction in informal settlements in Georgetown, Santo Domingo and Port-au-Prince highlighted the importance of support from local governments and civil defence organizations (Pelling 2011b). In the Guyanese and Haitian cases, community action was stifled by bureaucratic processes; the government was not actively hostile to community action but such action was discouraged by the lack of active support and official recognition. In Santo Domingo, a more open and diversified urban governance regime and one with a long history of local action at political and practical levels meant local activity was recognised as legitimate. This received further support from a local NGO that was respected by communities and local government and that provided continuity in support. In these cases, key actors in urban governance included the Red Cross, Civil Protection and local development committee members who sat on community committees.

This study showed how generating trust between local government and community groups takes time and external funders may under-estimate the time needed to achieve this (Pelling 2011b). Governments and international agencies often over-estimate community capacity and under-estimate the difficulties for community organizations to develop and sustain community initiatives for risk reduction (Wamsler 2007, GAR 2011, Hardoy and Pandiella 2011, Colina F et al 2004). External agencies may assume that each informal settlement (or other residential neighbourhoods) has an organized body with community leaders that are representative and also interested in working on risk reduction. But they often have other more pressing priorities or they have community organizations that are not representative.

The case studies of community based action in urban areas suggest that their effectiveness may be as much in what they can catalyze as do – for instance as community organizations or networks and federations of community organizations are successful in making demands for action within their locality and in it forming part of a larger coalition to undertake work on a larger scale or to have more influence in dealings with government and international agencies.

Douglas et al 2008 highlighted how effective action to reduce flood risks in urban areas often depended on community organizations, local government and higher levels of government working together – within different but complementary capacities. In relation to flooding, local communities were often best positioned to manage localized flooding resulting from inadequate drainage with local authorities best placed to cope with flooding from small streams with catchment areas almost entirely within the urban built up areas. Action was also required from national agencies if major rivers (with their river basins in several different administrative regions) overtop their banks.
The 2011 Global Assessment Report on Disaster Risk Reduction noted that effective local governance relies on adopting approaches to local planning, financing and investment that build on partnerships with civil society, particularly with risk-prone households and their representative organizations. "This allows for the scaling up of community initiatives. Where community organizations have only limited capacity to reduce disaster risk and to hold governments to account, meso-level partnerships with other organizations, expert institutions and government bodies can improve the success of local and community-driven disaster risk reduction" (GAR 2011, page 156)

8.4.3.2. Community-Based Risk and Vulnerability Mapping

One increasingly common method by which the residents of low-income informal settlements seek to develop their relations with local governments is by documenting and mapping their settlements (see for instance Patel 2004, Weru 2004, Karanja 2010). This has been supported by the development of national federations of slum or shack dwellers in many nations – and many national federations have prepared city-wide surveys of informal settlements and enumerations and censuses of informal settlements – the documentation needed for acting to improve conditions and install or improve infrastructure (CORC 2006, Weru 2004, Pamoja Trust and SDI 2008, Karanja 2010). Although community-based surveys, enumerations and maps were not developed with climate change adaptation in mind, some have collected detailed data about the impacts of local severe weather events and have analyzed these so they include risk and vulnerability assessments (Livengood 2012). The community mapping process in Cuttack covered over 300 informal settlements and included the preparation of digital maps at the city scale for the city authorities that showed each informal settlement. The mapping and data gathering about each informal settlement was done by the federation of women's savings groups (Mahila Milan), supported by a local NGO and local government. These maps and the data gathered about each informal settlement are being used to negotiate the support needed for upgrading (or where existing sites are too risky, land for rehousing) and thus also risk reduction to extreme weather. The first step in this mapping was to develop a complete list of informal settlements. This included the Mahila Milan savings groups identifying many informal settlements that were not on the local government list. Each informal settlement was visited by Mahila Milan representatives and staff from a support NGO to develop a profile of the settlement (including details of how they had been impacted by extreme weather. This group then walks the boundaries of the settlement, marking it with a GPS device. So this provided the basis for a digital map of the city showing the informal settlements and detailed data on each informal settlement linked to the map and so incorporated into a GIS system. This provides the information base through which the residents of informal settlements and city government discuss what needs to be done.

Some of these surveys and maps have had an explicit focus on identifying settlements at high risk from extreme weather. In the Philippines, as described in Box 8-3, this now includes an interest in documenting and mapping vulnerabilities and risks to extreme weather in ways that identify how to reduce these and build resilience.

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Box 8-3. Shifting from community-driven disaster response to disaster risk reduction in the Philippines

The Philippines Homeless People's Federation is a national network of 161 urban poor community associations and savings groups with more than 70,000 members from 18 cities and 15 municipalities. The national federation and member local federations are engaged in many initiatives to secure land tenure, build or improve homes and increase economic opportunities, working wherever possible with local governments. They have also been working in locations impacted by disasters, building community-capacity to take action to meet immediate and long-term needs (refs). Drawing from this experience, the Federations is also developing initiatives for risk reduction to extreme weather as it identifies at-risk communities in cities and municipalities and supports the design and implementation of risk reduction. City-wide enumerations identify and support at-risk communities and help provide documentation on informal settlements for which there is little or no official data. The Federation and PACSII (an NGO that supports the Federation) are identifying and profiling at-risk communities in 12 cities and 10 municipalities located in Luzon, Visayas and Mindanao. This focuses on informal settlements located under bridges, on cliffs and other landslide prone areas, coastal shorelines and riverbanks, public cemeteries, near open dumpsites and those in flood-prone locations.

The Federation works with The Environmental Science for Social Change (ESSC) that is knowledgeable in disaster mapping and risk assessment and this helps to capacitate communities to undertake a community-driven risk assessment. The Federation overlays the data from these assessments with local maps which the ESSC helped develop for the selected high risk communities. This provides the basis for the federation to negotiate with local government in planning for disaster risk reduction. The Climate Change Act of 2009 (RA 9729) and the Philippine Risk Reduction and Management Act of 2010 encourage neighbourhood level (barangay) and city government to take the results of enumerations into consideration in their disaster response and risk reduction plans.

A review of the work of the federation to date with many local governments on disaster response and disaster risk reduction suggests the possibilities for this to develop to include climate change adaptation will be supported and sustained by four factors: strong community networks (that can lobby for risk reduction policies that are community-driven), alternative financial facilities (including support for insurance for low income households and loans for reconstruction or rehabilitation and upgrading), technical support (to advise on site selection, land acquisition, housing and settlement designs, zoning based on geo-hazard maps and easy-to-comply building standards) and community-based information systems (including community enumeration and risk assessment).

Source: Carcellar, Rayos Co and Hipolito 2011

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8.4.4. Role of Private Sector (including Market-Driven Responses) and Civil Society

8.4.4.1. Introduction

Some analysts argue that adaptation investments will be largely undertaken by the private sector (Bowen , OECD 2008), while in international discussions it is often assumed that the public goods nature of adaptation will require a major public investment to cover the principal needs in the South (AGF 2010 CHECK). Another way to look at the need for private sector engagement in adaptation is to note that the scope for adaptation investments will far exceed available funds from public budgets (Hedger 2011)(OECD 2008, World Bank 2010). Both public and private investment will be required to address adaptation. Where markets are well functioning, reliable information and good awareness of climate change risks should be sufficient to incentivize individuals, households, businesses to make pro-active adaptation decisions. However the heightened risk of disaster due to increased climate change cannot be easily addressed through private action alone, where the poorest and most vulnerable populations will be the least able to protect themselves through private action and where insurers may be reluctant to act.

8.4.4.2. Incentivizing Private Investment and Action – Policy Frameworks, Information

Private sector engagement in adaptation can help to limit climate impacts and risks. The majority of the investment required for sound adaptation is likely to come from a multitude of small scale private decisions spanning individuals, households and firms (Bowen , Fankhauser et al. 2008). If reliable information about climate change is available, adaptation will occur where markets are well functioning, even without policy incentives. For private autonomous adaptation to occur however, a pre-condition is well-functioning property markets where individuals and businesses are responding to economic signals and information about past weather events and climate, as well as future reliable predictions of climate change. Eakin et al. 2010 and Chu and Schroeder 2010 suggest that the private sector role may become more prominent when the local governments and/or other civil society component of the governance structure are limited [need to discuss, is this likely?]

Public policy will be needed to establish enabling conditions for markets to function and allocate scarce resources most efficiently to highest adaptation options with the highest benefits. For example, where information is highly uncertain or not consistent with past experience, such as is the case for the prediction of extreme weather events and potential losses from these, public policy may also play a role to facilitate what will inevitably be gaps in insurance markets (Fankhauser et al. 2008, Mills 2007). Public policy will also be needed to establish markets and valuation of relevant market externalities; for example policy is needed to value ecosystem services that provide adaptation benefits such as storm buffering and flood protection delivered through mangrove protection in coastal zones (Fankhauser 2008).

For markets to work in favour of urban adaptation, businesses and consumers will need access to reliable downscaled projections of climate change and tools for risk screening and management (AGF 2010; UNEP-FI – SBI/jan 2011). A recent UNEP-FI survey of the financial business sector underscores the need for regional and local climate predictions and hazard mapping, as well as risk screening tools; it suggests that there is both a public and a private role to invest in and provide such information (UNEP-FI, 2011). Local information on other possible stress factors in an urban context that intertwine to affect the impacts of climate change is also necessary to help understand possible climate change impacts; these include socio-economic factors such as urban population growth, age distribution, and wealth as well as natural resource profiles such as urban water supply and management practices, land use and building regulations, and energy sources and institutional structure in the urban context (Hallegatte, Henriet & Corfee-Morlot 2011).

Global trends in losses from weather-related climate change, averaged yearly from 1980 to 2004, show that they continue to climb at a pace that exceeds socio-economic growth trends and that the variability in losses is also increasing in the same period (Mills 2007; see Figure 8-4). Mills also cites available data to show that: "… ''all'' weather-related natural disasters totalled $1 trillion ($2003), divided approximately 40/60 between wealthy and poor countries, respectively. Between 1980 and 2003, insurance covered four percent of the total costs of weather-related disasters in low-income countries and 40 percent in high-income countries" (Mills 2007: 812; citing Munich Re 2004).

[INSERT FIGURE 8-4 HERE
Figure 8-4: Title? (Mills, 2007).]

Despite the low level of insurance coverage available today in low-income countries, Mills (2007) considers the insurance sector to have high capacity to assist with adaptation, with the potential to compensate for disasters in these countries far exceeding the capacity of international aid. Ultimately the largest source of financing for disaster recovery remains domestic budgets and individuals, estimated to cover 99% and 60% of disaster costs in low-income and high-income countries respectively. [Consider introducing figure from Mills 2007]

[INSERT FIGURE 8-5 HERE
Figure 8-5: Title? (Mills, 2007).]

Insurance mechanisms provide a means for private sector to support individual and business adaptation. The role of the insurance industry is widely acknowledged for risk management in flood prone areas (Rosenzweig and Solecki 2010), however a variety of different types of insurance are relevant to adaptation ranging from health and life insurance to property insurance (Mills) as well as micro insurance mechanisms (see below). Insurance markets play a role in adaptation both by sharing and spreading risk from climate change, thus directly reducing the damage costs from climate change, and by sending market signals to individuals, households and firms about the nature of climate change risks and how to better manage it (Fankhauser ; Mills). For example, insurers could in theory signal climate change risk homeowners by raising the premiums for insurance in areas that are at increasing risk of fire damage or flooding given to regional predictions of climate change, or simply refuse to insure houses that are not meeting high standards of weatherisation to withstand storms and extreme heat (Mills - LBL; Germanwatch; UNEP-FI). However in practice it may be difficult to predict increased risk due to climate change and there is uncertainty around how climate change will unfold in any one location. Thus insurance markets are inevitably constrained both by both information and how insurance companies access and use the information about climate change.

Insurance companies themselves are also vulnerable to climate change and in many ways have become a constructive pro-active force in the fight against it (Mills 2007). They are investing large sums in their own research to raise awareness about the risks of climate change and have long been active in national and regional regulatory processes that institutionalise actions to lower the risks, such as through strengthened building standards. Innovative insurance mechanisms are also being explored and may play a role to support adaptation on a regional scale in the future.

Private investment or standard insurance markets will not however protect marginalised population whether in poor developing countries or developed countries, where there is no money to be made (or lost) – here public funding will be needed (Ranger, Muir-Wood & Priya 2009, Hallegatte et al. 2010). In particular, where risks are high (as they are in most informal settlements) and capacity to pay is low, insurance will play little if any role to spread risk. In an analysis of Mumbai adaptation options to flood risk, researchers demonstrated that while insurance could potentially limit mitigate some of the damages to built infrastructure, property and the economy from the flood hazards, a large population of urban poor are already at risk to urban flooding. Around half of Mumbai's population live in 'slums' most of which have inadequate provision of basic infrastructure (REF) The risk profile for this marginalised population working in the informal economy is set to increase under most scenarios of climate change and this population will not be assisted by insurance mechanisms. People and businesses operating in the informal economy will rely instead upon government assistance and local solidarity (family and community support) to respond when disaster hits and to prepare for the next event (Hallegatte et al. 2010). In informal settlements in many nations in Africa and Asia, informal savings groups where most savers and most savings managers are women have particular importance for providing their members with rapid access to emergency loans (Mitlin 2008).

Microfinance schemes (MFS) have potential to support pro-poor adaptation through a variety of different instruments including micro-credit, micro-insurance and micro-savings schemes. Microfinance is a means to help families and individuals that hover around the poverty line to build and diversify assets, and in doing so it is also a means to reduce vulnerability to climate change and extreme events such that the impact is not as immediately damaging as it would have been otherwise (Hammill, Matthew & McCarter 2008). 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 the only formal means to share risk in poor areas at high risk to weather events.

Although typically more costly than commercial bank loans[22], such financing can be used to support entrepreneurial undertakings that are not otherwise eligible for bank loans, for example, due to their small size or lack of credit history. In doing so, microfinance may be one tool to help to diversify the economy; it may also help employ and empower women in particular, which can in turn contribute to adaptive capacity in a local context (World Bank 2010a, Agrawala, Carraro 2010). Linking provision and favourable terms of microfinance to environmental performance is possible and helps to deliver environmental protection and ecosystem services that in term limit vulnerability of the poor to climate change. For example, Hammill et al (2008:120) report that in Nicaragua a local microfinance schemes offered lower interest rates to farmers who undertook soil and water management practices. While documenting the potential for microfinance to make a positive contribution to adaptation, an empirical analysis of MFS in Bangladesh and Nepal also identifies cases where it can aggravate vulnerability to climate change at local levels (Agrawala and Carraro 2010). For example, it may emphasise short-term gains by encouraging growth in hazard prone areas and sustaining livelihoods in a status quo pattern, when taking longer term climate change into account would argue for diversification and shifting of settlements and type of livelihood strategies. This evidence argues for a "climate-proofing" of microfinance practices to ensure it delivers on the potential to strengthen adaptation amongst the poor. There is also potential to target its use to priority tasks that will deliver adaptation and development benefits in the nearer term e.g. disaster planning and early warning systems or community based technical training and education (Agrawala, Carraro 2010). Microfinance also provides a means for donors to deliver support to among the most vulnerable communities without creating an ongoing dependence on aid (Agrawala and Carraro 2010; Hammill et al. 2008).

[INSERT FOOTNOTE 22 HERE: Interest rates associated with microfinance are typically significantly above market rates – see discussion in Agrawala and Carraro 2010.]

One limitation of micro-finance for adaptation is that it provides credit to individuals for their use and so it is not easily used to help finance collective investments – for instance to improve drainage or provision for sanitation within communities. In many nations, the savings groups mentioned earlier that are formed by (mostly women) slum or shack dwellers have pooled their savings and use 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 (see for instance Manda 2007, Mitlin and Muller 2004)

[Limitations of micro-finance for buying or building housing for low-income groups as this is too expensive – but its contribution to improving or extending existing housing, if low-income households have their own home]

Another innovative insurance and risk management mechanism that is currently being piloted is an insurance pool that is operating across the Caribbean as a risk management mechanism (Germanwatch 2010 – Climate Risk Index paper). The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is the only multi-country risk pool that exists today, and aims to serve as a regional risk management facility for the adaptation and insurance programme in the Caribbean. Between 2011 and 2014, the CCRIF has planned to "… design and implement products that combine risk reduction and insurance for low income groups such as small-holding farmers and day labourers in the Caribbean." [Possible to add box on CCRIF] It is a form of public-private partnership, which centres on both new instruments and information provision to guide adaptation decisions, including but not limited to policies, in the region. Emerging from a 2007 ministerial meeting, it pools resources from Bermuda, Canada, France, the UK, the Caribbean Development Bank and the World Bank with a total of US $47 million pledged to date [Check]. Lessons learnt from this experience will undoubtedly prove useful for other regions.

8.4.5. Role of International (Development) Assistance Agencies and Humanitarian Sector

[will need to look for urban angle here; hard enough to monitor adaptation finance; impossible to monitor urban adaptation finance. Worth discussing reluctance of many bilateral agencies to invest in urban areas or even to have an urban policy]

Multilateral humanitarian assistance, disaster management and the MDGs

- Multitude of different channels to funnel funding for adaptation, e.g. Humanitarian Hyogo framework for action 2005-2015; MDGs – how they relate to urban adaptation:
  - Key outcomes – recent international commitments to climate change and disaster risk reduction financing.
- Other Disaster management funds – are there any – urban dimensions?
  (Satterthwaite et al. 2007)

Multilateral development and bilateral climate finance channels

The UNFCCC decisions at COP16 in Cancun committed developed countries to a scaling up of financial support for climate change, with balanced attention to mitigation and adaptation. For the first time, adaptation is expected to receive relatively large sums of funding through both multilateral and bilateral channels. In the Cancun Agreements, developed countries committed to provide 30 bn USD of new and additional funding between 2010 and 2012, and to the goal of mobilizing 100 bn USD per year (from both public and private sources) by 2020.

In general there are no consistent and complete data sets available yet to track adaptation funds as part of the emerging international effort to direct public finance to support climate change, however some data and evidence is emerging. For example, an initial review of progress made to deliver "fast start finance" (FSF) is available from Parties' recent submissions to the UNFCCC. These submissions suggest that significantly more public funding is available for adaptation from bilateral donors and their multilateral partners than ever before documented.[23] [need to cite submissions; also to review submissions & add detail – how much is committed in FSF to adaptation?] One study across 5 development cooperation agencies[24] suggests that just under one-third of climate change funding in 2009 was committed to adaptation, representing close to 4 bn USD per year, of which about 95% is estimated to be concessional or aid (largely loans with about 14% of the total being grants) (UNEP 2010). This is estimated to represent about a 30% increase by the same agencies in funds committed to adaptation compared to 2008. While the data reported do not allow separation of the concessional and non-concessional financing at a sector level, it is interesting to note that three-quarters of adaptation funding identified by these donors is in the water supply and treatment sector[25] and another 20% is directed to sectors that are urban relevant (i.e. transport, policy loans, disaster risk reduction) (see Figure 8-6; UNEP, 2010). Interestingly health and energy have not received any attention to date from these donors despite the fact that these sectors are amongst the most exposed to climate change.

[INSERT FIGURE 8-6 HERE
Figure 8-6: Title? (based on data from UNEP 2010, Bilateral Finance Institutions and Climate Change: A Mapping of 2009 Climate Financial Flows to Developing Countries).]

[INSERT FOOTNOTE 23 HERE: This ignores the question of "new and additional", for which a technical definition and means of measurement does not exist. Estimates from these submissions as well as from a recent studies suggest growing attention to climate change and within this adaptation within development assistance portfolios.]

[INSERT FOOTNOTE 24 HERE: The study covers three bilateral agencies: Japan's JICA, French AFD, German KFW; and 2 multilateral or regional development agencies: the European Union's European Investment Bank and the five Nordic country donor organisation of the Nordic Environmental Finance Corporation (NEFCO).]

[INSERT FOOTNOTE 25 HERE: Interestingly about half of all adaptation funds in 2009 from this cluster of donors are from a single donor – JICA –the water supply/treatment area.]

One of the newest developments in climate change financing is the large number of vertical (dedicated) climate change funds operated by the World Bank and other multilateral financial institutions (cite WBCSD brochure; ODI website; AGF). These have potential to shift the balance of climate change funding somewhat towards adaptation and away from what has been more dominantly attention to the mitigation agenda. However action is slow and design features of these vertical funds, with direct access, may exacerbate problems such as lack of access to funds for the poorest of nations as well as lack of integration with country systems for development and ownership of resulting programmes or projects (Germanwatch 2010; WB; ODI website; Oxfam …).

- To add some detail on the vertical funds as they pertain to adaptation
- Adaptation fund – unfccc – what role urban?
- Cancun; Green Climate Fund – a new mechanism – different windows including adaptation; Cancun commitment to balanced treatment of adaptation and mitigation

Conventional delivery institutions – through multilateral and bilateral channels – appear to be playing the biggest role in adaptation financing, though new vertical funds have also been created and will be tested in the coming years. Available data, though still partial and limited in scope, do suggest that significant financial support has begun to flow to adaptation, scaling up from previous estimates, with current annual commitments from multilateral and bilateral donors currently amounting to at least several billion USD per year. Despite the encouraging growth in funding available to support adaptation, the proliferation of multiple, single purpose funding mechanisms runs contrary to long-standing principles of sound development cooperation notably harmonisation and alignment (Hedger, 2011; UNDP/OECD Bangkok reports).

In particular in the face of the proliferation of delivery channels, there is a risk of lack of country ownership and full integration of climate funded programmes with national development planning and goals. In an in-depth assessment of development assistance and adaptation funding in Bangladesh, ODI points to the need for consolidation and convergence across the new funding channels and highlights opportunities for piloting and learning phases where early lessons are reaped to informed next phases of programme design and implementation on the ground (Hedger 2011a & b - opinion). Hedger notes that it is clear current commitments fall significantly short of the needs for adaptation support, pointing to the need to ensure that funds are not wasted in initial years. It will also be necessary to mobilise domestic public and private investment to ensure delivery of adaptation in a timely manner to abate climate change risk to development itself. For example, one study suggests that 2.7 bn USD of investment in Bangladesh is now at risk from climate change.[26]

[INSERT FOOTNOTE 26 HERE: Asian Tiger Capital Partners 2010. A strategy to engage the private sector in climate change adaptation in Bangladesh. Prepared for the International Finance Corporation. September 2010. – as cited in Hedger, 2011 (opinion)]

Partner countries will also need assistance to design national systems to effectively direct and utilise climate change finance. An emerging literature in this area highlights that countries lack defined priorities for the use of funds (Peskett and Brown, 2011). When combined with donor tendency to "control" funds to ensure short term results through a large variety of different funding instruments, the result is highly fragmented delivery systems that lead to unclear outcomes (Peskett and Brown, 2011). This raises fundamental questions about the capacity in either the donor or the partner country to effectively manage the magnitude of the funds currently available for adaptation, yet alone scaled up funds. In some medium income developing 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.

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. This would present an opportunity for urban adaptation programmes to be identified as a national priority. Even where national climate strategies exist to guide action – such as in the case of Bangladesh which is an "early mover" on adaptation planning – the plan is not yet costed nor is it sequenced and thus proves difficult to be used as a framework for delivery of international climate finance (Hedger 2011, opinion).

A further challenge is to raise the profile and the attention to urban or local adaptation within national adaptation planning. Currently 45 LDCs have prepared and submitted NAPAs (National Adaptation Programmes of Action) and submitted these to the Least Developed Country Fund managed by GEF (Oxfam 2011 – " Owning Adaptation"). A process is now in place under the Adaptation Fund of the UNFCCC to support LDCs to formulation National Action Plans. Other countries area also formulating responses at a national level.

Whether and how urban adaptation needs and efforts figure into those plans remains a question.[Need to look at NAPAs and see if urban is being taken seriously] As a whole, these international public funding and the planning exercises that they have supported remain essentially "top down" and are led by the national government. Urban governments have access to such funds and planning processes only through their national governments, where routine institutional mechanisms for multilevel adaptation planning and risk governance do not yet exist.
Multilateral or regional development banks

- Other dedicated funds for climate adaptation – what role urban? (i.e. World Bank's Pilot Program for Climate Resilience (PPCR), which is part of the Strategic Climate Fund, where the objective is to build resilience to climate change by integrating adaptation into national development planning and policy. PPCR will support capacity building, awareness raising, coordination and planning in its first design phase of funding and provide technical and financial assistance in a second implementation phase.
- regional cooperation and financing mechanisms (i.e. Caribbean, Pacific ?) – these regions have been invited to participate in the PPCR
  [other refs: AGF – MDB, IFI paper – 2010]

Assessing progress

Steps for consistently and internationally harmonised data collection are urgently needed to support monitoring, reporting and verification of both delivery and use of climate finance to ensure that lessons are learnt and funds are being directed in an effective manner (Hedger 2011; Buchner et al. 2011).

Beyond measurement of flows of climate finance commitments and disbursements, tools for monitoring and evaluation of adaptation are needed to assist both donors and partner countries to assess outcomes and effects of climate finance. In the adaptation area this is particularly difficult …as well as interim indicators of progress overtime. (Lamhauge et al. 2011)

While urban development and adaptation has not necessarily received much attention in climate finance to date, there is clearly a link and a need for this on both the adaptation and mitigation side given the close linkages between urban resilience to climate change and development itself, particularly in rapidly urbanising medium and high income developing countries of the world.

8.4.6. Learning Cycles and Systems

8.4.6.1. Science-Policy Exchange: Expert – Policy – Stakeholder 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 of climate risks and vulnerability demands a continuous re-assessment of the scientific knowledge about local climate conditions and translating this information into local decision-making. This will depend upon local capacity to monitor and use climate change as it becomes available.

Climate science refers to the ability to predict future changes in local temperature, sea level and precipitation sufficiently well such that people and governments can plan for and adapt these changes. How climate predictions alter local climatic conditions 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 an vegetation conditions, proximity to the sea or river basins of the area, etc). Combined with the dimension of time which often brings rapid socio-economic change in urban areas, the complexity and uncertainty of climate change impacts increase over time and at smaller scales (Figure 8-1). Both dimensions are important to predicting how climate change might impact local population, economies and infrastructure) (Hallegatte et al. 2011 – concept paper).

A broad literature on the use of science in policy assessments – from local to global – points to the need for credibility, legitimacy and salience in such processes (Cash et al. 2006; NRC 2007). Boundary work or organisations can play a key role to negotiate between political and scientific endpoints – interpreting scientific inputs such that they become more useable in a political context (Jasanoff 1990, Gieryn 1999, Vogel et al. 2007, Guston 2001). In a local and regional context, boundary organisations may take a variety of institutional forms and have been shown to actively help advance adaptation decision-making at local and regional levels (Vogel et al. 2007; Tribbia & Moser; NRC 2009; Corfee-Morlot et al. 2011). Another important area for urban adaptation is how decision makers actually access or use scientific information, what sources do they rely upon and are they reliable? One study shows that resource managers are more likely to rely upon informal sources such as maps or in-house experts, media and internet rather than turning to scientific journals; rendering information useable for coastal zone and water resource managers or city planners extends beyond technical boundaries for science-policy assessment venturing into the world of communications (Tribbia & Moser 2006). Other research has shown that even where ongoing boundary organisations and support exists for urban decision-making, economic analysis is often missing (Corfee-Morlot et al. 2011, Hunt, Watkiss 2011). Building economic analytical capacity and communications efforts to generate policy relevant local information may be critical gaps to fill if urban adaptation is to become more effective and widespread.

8.4.6.2. Risk Assessment, Planning Tools

A variety of climate risk and vulnerability decision-support tools have been developed in recent years. These tools are designed around a variety of methods and objectives. A central element of tools that organize and rank information on vulnerability in different locations is to identify relative and absolute differences in risk and vulnerability and resilience capacity (e.g., Manuel-Navarrete et al. 2011; Hahna et al. 2009; Posey 2009; Milman and Short 2008). Hammill and Tanner (2011, forthcoming OECD) review and compare risk screening and assessment tools, and current experience with their use across six different donors and their partner countries. These tools span various functions ranging from a quick screening to identify risks to a risk analysis and/or adaptation options evaluation. Although the diversity of approaches may be confusing, it can also be helpful to fit diverse local contexts. Nevertheless Hammill and Tanner suggest that harmonisation may be valuable, particularly for the screening tools. Another theme within decision-support or planning tools is to make climate scenarios and modelling results more useful for local decision-making (e.g., Van Vuuren 2007; Hallegatte, Henriet and Corfee-Morlot 2011).

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

Horizontally, there is also increasing evidence of multilevel governance through transnational networks on climate change, where actors work across organisational boundaries to influence outcomes (Bulkeley and Betsill, 2005; Bulkeley & 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, among others. 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 & Bulkeley 2004, 2006; Lindseth 2004). The focus of such networks has typically been on mitigation however attention to adaptation is growing. See for example Foster et al. 2011 on the US Urban Leaders Adaptation Initiative. These groups have given an institutional foundation to concerted effort and collaboration on climate change at city level (Aall et al. 2007). (Kern, Gotelind 2009, Romero-Lankao 2007).

Interactions between research institutions and urban governments and stakeholders

[see Mehotra et al. 2009; Anguelovski & Carmin 2011 – see refs there]

8.5. Draft Conclusions: What has been Learned from City Adaptation Strategies to Date

8.5.1. Introduction

In recent years, as more city governments have begun to discuss and develop adaptation strategies (as described in 8.3.x), so too has a discussion developed on what factors contribute to or hinder effective adaptation strategies. Part of this discussion comes from researchers external to these strategies, part from reflections by those engaged in particular city processes (researchers, government officials, civil society organizations). This discussion focuses mostly on the local (city-scale) institutional and political basis for adaptation, rather than on assessing what is proposed. This section draws from these discussions as they have begun to identify a range of factors that have been important in introducing, developing and implementing a local level adaptation agenda and also factors that constrain this agenda

Because of the inherent complexities and uncertainties associated with local level adaptation there has been a tendency for most urban interventions to begin with 'low hanging institutional fruit', for example, focusing on existing city initiatives where climate change adaptation can be achieved as a co-benefit rather than creating new work streams with climate change adaptation as the sole driver. Priority is often given to 'no-risk' options and soft solutions that can be implemented at a reasonable cost, and produce a variety of real benefits under a range of potential future scenarios (Roberts, 2008 pg 401, Toronto Environment Office, 2008 pg 9). Another characteristic of these early adaptation initiatives is the strong initial reliance on risk and vulnerability assessments, linked in most cases to down-scaled climate change projections (e.g. Greater London Authority, 2010 pg 22; MWH, 2008 pg 5; City of Boston, 2011 pg 10; Roberts, 2008 pg 528; UN-Habitat, undated b pg 6).

This focus on risk assessment and business-as-usual (but with climate benefits) has meant more focus on infrastructural adaptation i.e. "hard" (Lwasa, 2010, pg 168) or "asset-oriented" (Jones *et al*. 2010, pg 1) adaptation, particularly given the concern around aging urban infrastructure in the Global North and the often very large infrastructure deficits in the Global South (UN-Habitat, 2011 pg 130). This approach to adaptation has to a certain extent masked the importance of the "soft" or process (i.e. human and ecological) elements of adaptation such as governance, links to poverty reduction and livelihood systems, social cohesion and ecosystem based adaptation (Lwasa, 2010 pg 168; Jones *et al*. 2010 pg 1).

As pointed out by Kithiia (2009, pg 19) "understanding the difference between taking adaptation measures and building adaptive capacity is very crucial for city decision-makers" especially in the global South where "adaptive capacity is limited by resources, weak institutions, poor/inadequate infrastructure and poor governance." This means that adaptation planning has to be able to address these constraints. Also, as Jones et al 2010 notes, adaptation has to recognise various intangible processes such as "decision-making and governance; the fostering of innovation, experimentation and opportunity exploitation; and the structure of institutions and entitlements" and moving away "from simply looking at what a system *has* that enables it to adapt, to recognising what a system *does* to enable it to adapt" (page 1).

This implies the need for interventions that facilitate a "bouncing forward" in resilience and risk reduction rather than the more conventional meaning of resilience as an ability to return to the initial state (Shaw and Theobald, 2011 pg 2 Lowe *et al*., 2009, pg 2; UN-Habitat, 2011 pg 130; Fünfgeld and McEvoy 2011, pg 45)). The conceptualisation of adaptation as being a transformative process that changes the way urban areas are understood, planned and managed also answers the question of: "how is adaptation different from good development?" and links well with the idea of adaptation as a proactive solution rather than just being reactive to the climate change problem (Foster *et al*., 2011b pg 18). For example, such transformation would include the prioritisation of the kinds of "green infrastructure" initiatives described in section 8.3.x - such as green, blue, and white roofs; hard and soft permeable surfaces; green streets; urban forestry; green open spaces such as parks; and biodiversity networks of indigenous ecosystems (Roberts, 2008 pg 533; Roberts, 2010 pg 401). These go alongside the conventional infrastructure, that is, the more traditional approaches of building wastewater treatment facilities to deal with increased runoff from more intense precipitation events, or building dams to deal with the greater irregularity in precipitation events (Foster *et al.,* 2011a pg 3). Some progress on this is already evident in some cities.

8.5.2. What Contributes to Cities Developing Adaptation Plans?

The importance of senior government staff becoming champions for adaptation (Lowe *et al*., 2009, pg 4; Roberts, 2008 pg 527; Parzen, 2009 pg 7; Shaw and Theobald, 2011 pg 10, Anguelovski, I and J.Carmin, 2011 pg 4). These have proved important in providing initial leadership and promoting and sustaining the adaptation agenda. Measham *et al*. (2010) in their discussion of barriers and opportunities for adapting to climate change through municipal planning highlighted how in Sydney, the opinions and value system of the Mayor and CEO (or General Manager) had influenced the opinions held by others. But such leadership may lack needed continuity as the champions change positions or leaving office; Tyler *et al*., 2010, pg v and Roberts 2010 note the importance of developing a broad base of support for adaptation so that progress is not stalled or undermined by leadership changes.

Institutional changes were needed to support and give continuity to city adaptation strategies (Lowe *et al*., 2009 pg 4; Roberts, 2008 pg 529). Section 8.3.x discussed how climate change adaptation requires working across departmental lines and jurisdictions. Lowe *et al*. (2009) note that "Because of the complex nature of the impacts, proper departmental organization can help to make or break adaptation efforts" (page 4). In this regard, for Durban, the development of adaptation strategies has been facilitated by having champions from different sectors within city government (Mather *et al*., 2011). Another important institutional reform is establishing functions and responsibilities within government – possibly through a climate change office. In the development of adaptation plans for Chicago and Durban, an important factor has been dedicated city staff assigned to undertake the work (Roberts, 2008 pg 535; Parzen, 2009 pg 7); without this, adaptation can be sidelined by the many developmental pressures facing local governments and their staff. The experience with developing an adaptation strategy in Durban has also shown how this is not a linear process of identifying impact and acting in response; the approach has often been more circuitous and iterative in order to deal with institutional limitations, such as leadership change, lack of resources and buy-in and competing powerbases (Roberts 2010, pg 405; Anguelovski, I and J.Carmin 2011, pg 3; Fünfgeld and McEvoy (2011pg 57).

Scientific support for adaptation, both in access to reliable, accurate and useable science and to relevant research institutions (Lowe *et al.,* 2009, pg 4; Roberts, 2008 pg 528). Section 3.x discussed the lack of data available to most local governments and the difficulties in establishing what climate change is likely to bring for each locality. Other barriers include the fact that official data may be difficult to access due to bureaucratic difficulties or financial limitations, or local government staff cannot utilize it because of the language gap between the information producers (scientists) and the information users (local decision makers) (Lowe *et al*., 2009 pg 4; Opitz-Stapleton, 2010 pg iv). Where there is a lack of "useful, relevant and credible information" about the nature of climate risk (Measham *et al*., 2010 pg 14), the experience to date in a range of cities suggests that it may be preferable to start local level risk assessments with an assessment of existing hazards, challenges and vulnerabilities that are likely to be exacerbated by climate change (Tyler *et al.,* 2010, pg vi). This allows the development of adaptation strategies, without detailed down-scaled climate impact data. It is also important to acknowledge that while scientific information is important, adaptation decisions will also be affected by local cultural, environmental, economic and political values and priorities and governance patterns (Opitz-Stapleton, 2010 pg v).

In Chicago (MWH, 2008 pg 5) and Durban (Roberts, 2008 pg 528), city government partnerships with local research institutions have proved valuable in developing adaptation strategies. Lowe et al 2009 notes that "Because of the importance of accurate and specific climate data and projections, creating partnerships with academic institutions can be a useful tool for gaining knowledge about climate impacts from a trusted source. Collaborating with universities also allows for more efficient expenditure of local resources while utilizing local expertise" (page 5). Generally the more locally specific the information, the more powerful it becomes (Measham *et al*., 2010 pg 15).

Networking and sharing experiences amongst practitioners: there are various examples of support for the sharing of experiences and practices amongst practitioners – including the Urban Leader Adaptation Initiative (Lowe *et al.,* 2009 pg 5) Asian Cities Climate Change Resilience Network (Tyler *et al*., 2010 pg v) and the Cities for Climate Protection Australia Adaptation Initiative (ICLEI Oceania, 2008 pg 12). DETAILS OF OTHER NETWORKS NEED TO BE ADDED? Peer influence and learning as well as reputational issues have also proven to be powerful motivators for local governments beginning to tackle climate adaptation (Foster *et al*., 2011b pg 4; Greater London Authority, 2010 pg 5).

Engaging Stakeholders: Experiences to date in developing city adaptation strategies highlight the importance of creating the necessary dialogue and political and institutional platform required to advance the adaptation agenda – although the forms and processes for engaging stakeholders vary between cities depending on institutional, political and social contexts. These range from cross-cutting technical advisory groups often with sectoral or task group focal areas (Lowe *et al.,* 2009 pg 5; Parzen, 2009 pg 10; City of Boston, 2011 pg 8; City of New York, 2011 pg 150; Anguelovski, I and J.Carmin, 2011 pg 3; Carter, 2011 pg 195) to more broadly representative multistakeholder groups with a core working group (Tyler *et al.,* 2010, pg v; Roberts, 2010 pg 411; Boston, 2010 pg 10; Anguelovski and Carmin, 2011 pg 3). The importance of broad outreach to build public awareness and support is also recognized" above all, the adaptation story will need to be a local one that is told locally with actions undertaken neighborhood by neighborhood" (Foster *et al.,* 2011b pg 17). As discussed in sections 8.3 and 8.4 on community-based adaptation, the issue of stakeholder engagement becomes all the more important where significant sections of the population currently live and work in informal settlements (and include a high proportion of those most at risk from climate change; section 8.4 also gave examples of a more active stakeholder engagement where community organizations formed by those living in informal settlements worked in partnership with local governments to identify and address risks and vulnerabilities.

Getting local attention to adaptation. In some cities, local government attention to adaptation has been triggered by extreme weather events that have shown the vulnerability of that locality to such events (Roberts 2008, Lowe *et al*., 2009 pg 6). Some of the innovations in disaster risk reduction in city governments in Central America were in response to the damage caused by hurricanes and these also serve to build resilience to hurricanes – although with mixed outcomes in terms of how much they managed to embed disaster risk reduction within local development and thus address the structural causes of vulnerability (Gavidia 2006). Section 8.x noted the creation of a municipal system for disaster prevention and response in the city of Medellin in response to a landslide in 1987 and cold spells in 1988 and 1989 (Cardona et al 2007). The availability of new research findings that focus on local impacts and possibilities (or support for such research) has also been important in some cities (Roberts, 2008 pg 536; Hamin, 2011 pg 132). In some instances, the attention of local governments was stimulated by the identification of local economic, social, and environmental co-benefits that will result from adaptation interventions (Foster *et al*., 2011b pg 6; Roberts 2010 pg 410) such as the reforestation projects in Durban which offer the opportunities to improve water quality and quantity, protect important recreational and economic assets and create community wide opportunities for job-creation and skills development. Benefits and protecting and enhancing competitiveness have been a principal framing element in adaptation strategies for cities such as London (Greater London Authority, 2010 pg 5) New York (City of New York, 2011 pg 3) and Copenhagen (City of Copenhagen, 2011 pg 11).

Phased approaches that prioritize the more urgent issues have helped encourage city government engagement with adaptation: Such approaches allows the most urgent matters or near term impacts to be dealt with first and a longer time period to plan for those impacts that may occur in the future and be associated with greater uncertainty (Foster *et al*., 2011b pg 10; City of Copenhagen, 2011 pg 11; City of Boston, 2011 pg 8; Wajih et al, 2010 pg 27). "There are often good reasons for local governments not to act prematurely in the face of climate change impacts but preparing ahead to act in the future is a robust risk management strategy offering 'no-regrets' for a range of future conditions" (Foster *et al.,* 2011b pg 11). In addition, in the Global South, given the complex mix of physical, social and institutional systems with varying levels of capacity and a generally resource poor environment, an evolving approach to strategy development allows greater flexibility and responsiveness (Roberts, 2008 pg 528; Wajih et al 2010 pg 27). This phased approach is also important when considering the different types of responses required to sudden versus slow onset climate impacts. Fünfgeld and McEvoy (2011pg 25) note: "For sudden, short-term events such as storms and flooding, adaptation efforts may need to focus on improved disaster prevention, establishing early warning systems, and effective disaster response. For slow-onset, continuous impacts such as sea-level rise, however, strategic forward planning is critical, and existing planning instruments such as land use planning may need to be altered to take gradual changes in climatic stressors into account."

The importance of mainstreaming climate change adaption requirements into municipal planning systems, building codes and land-use management. 8.3.2.2 noted how it makes little sense to introduce an additional layer of climate change planning to already complex and often fragmented and inadequate planning systems in the Global South. It also noted how such mainstreaming faces significant challenges such as lack of information, institutional constraints, resource limitations (Measham *et al*., 2010 pg 4). Climate change issues need local development plans to be spent "with adaptation needs in mind" (Lowe *et al.,* 2009 pg 6) and move towards a new approach of risk-based design for a range of climate conditions projected in the future" (Kithiia, 2010, pg 3).

Some city adaptation strategies got the attention of senior politicians and civil servants by focusing on improved service delivery, economic resilience (and success) and risk management. In others, mainstreaming was enhanced 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, pg 401; UN-Habitat, 2011 pg 147; Anguelovski and Carmin 2011 pg 2). Most city adaptation strategies included some pilot projects and these can root the (often vague) concept of adaptation in reality and allow a practical demonstration of the gains to be achieved (Roberts, 2010 pg 408, Tyler *et al*., 2010 pg 21). But a major challenge encountered with adaptation pilot projects was that they did not provide the evidence for how to scale them up

Institutional learning: Adaptation planning requires that urban areas plan for an uncertain future using variable projections about the future and often with limited and unreliable data about the past. As a result "municipalities and businesses need to continually incorporate new data and reassess decisions. The successful adaptation to climate change requires a learning organization, one that adapts to changing environmental factors" (MWH 2008, pg 7). It is difficult to see how this can be achieved in most city or municipal governments in low- and middle-income nations given their weakness, lack of funding and lack of trained staff - and what Kithiia 2009 notes as a situation of " 'organized' chaos, where decisions are delayed, correspondences lost in bureaucratic black-holes and ascription of responsibility is obfuscated" (page 23).

Leading with ecosystem based adaptation: Ecosystem based adaptation has been put forward as one of the more cost effective approaches to adaptation (Nature Conservancy, 2009 pg 8) given what needs to be spent to manage and preserve ecosystems and the climate adaptation value derived from that spend. But there are many knowledge gaps here on determining where the limits or thresholds to adaptation of various ecosystems lie; also on where and how they can integrate with other adaptation measures.

A growing number of cities around the world are recognizing the value of biodiversity (particularly indigenous and endemic biodiversity) and recognizing that nature's resilience to the impacts of climate change can be used to protect people and infrastructure (e.g. flood control, preventing coastal erosion) and meet basic needs (e.g. assist with energy and food security) (Greater London Authority, 2010 pg 95; Roberts, 2010 pg 411; City of New York, 2011 pg 163; Institute for Sustainable Communities, undated pg 14; Carter, 2011 pg 194; Zimmerman and Faris, 2011 pg.183) in a cost effective and sustainable way. The TEEB study concluded that "ecosystem conservation and restoration should be regarded as a viable investment option in support of a range of policy goals including food security, urban development, water purification and waste water treatment, regional development, as well as climate change mitigation and adaption" (TEEB, 2010 pg 28).

Such ecosystem-based approaches in urban areas are "not simply about saving ecosystems, but rather about using ecosystems to help 'save' people and the resources on which they depend" (Burgiel and Muir, 2010 pg 4). Shaw and Theobald (2011) suggest that these approaches characterize forward-thinking and responsive local governments that are capable of "bouncing forward" (pg 2). For example in London, there is a strong focus on ecosystem services as being "essential to the wellbeing of Londoners and London's resilience to climate change. Improving the quality, quantity, connectivity and diversity of London's green spaces will increase their resilience and therefore increase the capacity of London and London's biodiversity to adapt to a changing climate" (Greater London Authority, 2010 pg 95). This ecosystem services based approach is particularly important in the Global South where the livelihood systems of the peri-urban and urban population is heavily dependent on natural resources. For example in Kampala, many people in the urban and peri-urban areas "rely on natural resources for some or all of their household livelihood strategies." (UN-Habitat, undated c, pg 9). In Durban in 2002 it was calculated that the replacement value of the ecosystem services supplied by the city's (largely indigenous) open space system was R3.1 billion per annum, approximately half the value of the city's operating budget at the time (EThekwini Municipality, 2007 pg 15).

Water as an early focal point for action: Many urban adaptation plans focus strongly on the issue of water management. As observed by Pickett *et al*. (2010 pg 355) "sustainability has become a concern of many cities, and vegetation and water will play key roles in advancing this goal." Water (i.e. issues of quantity and quality, runoff, waste water etc.) features prominently in the adaptation thinking and planning of a diverse range of cities e.g., Seattle (EPA, 2011 pg 23), New York (EPA, 2011 pg. 37), Chicago (Zimmerman and Faris, 2011 pg.183), London (GLA, 2010 pg 7), Durban (2010, pg 402), Semerang (Tyler et al., 2010, pg 37) and Indore (TARU 2010 pg 28). Copenhagen's adaptation strategy notes that "In our society, rainwater is considered something we must get rid of. Water is however, also a resource we cannot do without. So, there is much to be gained by using rainwater to make the city a better place to live in. This can be achieved by managing rainwater locally with the help of green, low-tech solutions which can absorb the rainwater or clean it" (City of Copenhagen 2011, page 6). The city's planners have also acknowledged that preemptive action is required to deal with changes which may still be in the future, such as sea level rise: "Changes in sea water levels take place slowly. We expect that the risk of serious damage to Copenhagen as a result of rising seas will first begin to change significantly in about 30 years…For this reason, preparations are starting now. It takes time to find the right solutions, and the sooner we start the easier it will be to implement the necessary actions in conjunction with other construction projects, so we can keep costs down" (ibid page 9). 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 through highlighting the job creation and investment promotion advantages of adaptation (Copenhagen, 2011 pg 3; Roberts 2010, pg 410; City of Boston 210, pg 43).

Links between adaptation and mitigation: In reviewing the role of urban governments in climate change over the last decade, mitigation got more attention than adaptation (e.g. Satterthwaite 2008, Hardoy and Romero Lankao, 2011 pg 160; Carter. 2011 pg 195) – and it is often seen as competing with adaptation. In part, this was sustained by the political fear that pursuing adaptation might undermine the importance of the mitigation agenda. The identification of co-benefits between adaptation and mitigation may help encourage more attention to adaptation – for instance green roofs that cool the city and retain water during storms, promote local biodiversity and food production (all adaptation) while also helping to increase the energy efficiency of buildings (mitigation). Increasing the size of urban open space networks and tree plantings can also provide shade to decrease the urban heat island effect (adaptation) and reduce energy demand to cool buildings (mitigation) (Lowe *et al.,* 2009 pg 6; MWH, 2008 pg 5; City of Boston, 2011 pg 13).

NEED CONCLUSIONS HERE ON LESSONS FROM SECTIONS 8.3 AND 8.4 FOR NATIONAL AND REGIONAL LEVEL ACTION AND INSTITUTIONAL CHANGE IN SUPPORT OF URBAN ADAPTATION

8.5.3. What Hinders Adaptation Progress in Urban Areas?

The complexities of developing adaptation: Mitigation-focused interventions provided the early experiential training ground for most cities and local governments engaging with climate change for the first time (Anguelovski and Carmin, 2011pg 4)– and a series of steps for developing mitigation strategies were developed. Experience with adaptation programmes to date show that these are less open to a standard set of steps – as they are complex and often chaotic, cross-sectoral, cross-institutional, operate across a range of scales and timelines, involve more stakeholders and include a high level of uncertainty. The realities of this more organic and complex type of process is acknowledged by ICLEI Oceania who acknowledge that in addressing adaptation local level staff must demonstrate clarity, creativity and courage (ICLEI Oceania, 2008 pg 2) if they are to successfully balance the tension between short-term and long-term needs, engage a broad range of stakeholders and lead through action, even in the face of uncertainty.

The weakness of the climate change focal points within local governments: The climate change function within urban areas is often housed or championed by the environmental line department (e.g. Durban - Roberts, 2008 pg 523; Boston - http://www.cityofboston.gov/environment/; Sydney - Measham *et al.*, 2020 pg 17; Anguelovski and Carmin 2011 pg 2). This can lead to a marginalisation of the climate function (Roberts, 2010 pg 401) particularly given the low or lower priority usually assigned to environmental departments within government structures, and the resulting limited institutional influence and access to resources.

Lack of mandate: As noted by Measham *et al.* (2010 pg 16) "without the legal basis for adjusting local environmental planning in terms of climate change, it is difficult to do so in the face of competing planning interests". The jurisdictional issues relating to which sphere of government has the legal mandate to act on climate change issues poses a significant barrier to action if local government is not empowered to act through the appropriate allocation and assignment of constitutional and legal powers. Without these formal mandates, adaptation action becomes an optional and discretionary extra, dependent largely on local level interest and resources and is particularly vulnerable to leadership change, as opposed to a situation where it is a mainstreamed and institutionalised commitment. Difficulties also arise when the need for adaptation action extends beyond the boundaries over which cities and their local governments have jurisdiction e.g. in sectors such as coastal planning and catchment management (Anguelovski and Carmin, 2011 pg4; Carter, 2011 pg 196). This requires that a high level of co-operative governance is established and maintained, which is often difficult in given problematic governance systems and institutional issues, particularly in the Global South (Hardoy and Romero Lankao, 2011 pg 161).

Political obstacles: "The political nature of local government means that all decisions, including climate adaptation, are affected by political interests and competing preferences vying for support at the municipal scale" (Measham *et al.*, 2010 pg 19). This means that addressing constraints such as information and resources alone will not necessarily enable local adaptation if there is political resistance, particularly as political leaders control local level resources (Roberts, 2008 pg 535). There is also the disjuncture between political and climate time lines, which set the short-term (often personal advancement) priorities of political terms against the generational, public good impacts of climate change.

The assumption that development produces adaptation. Although this chapter has stressed how adaptation is served when city populations and enterprise are comprehensively served by have adequate provision for infrastructure and services, Lowe *et al.*, 2009 and TARU 2010 note that the assumption that adaptation requires little more than the expansion of existing efforts (e.g. Carter, 2011 pg 195) using existing skills and institutional forms, is too simplistic and could generate a false sense of complacency. There is some evidence (especially in the urban areas of the Global South) that new patterns and forms of urban development and new management skills (e.g. restoring previously deforested areas to sequester carbon, protect catchments and create employment or identifying new staple food crops Roberts, 2010 pgs 409 and 408) may be required to compensate for the adaptation deficit that currently exists in these cities. New approaches will in turn generate the need for new information, new technical skills, new funding (or the use of existing funding in new and creative ways) new understanding of what might constitute progress and new ways to set targets for and to measure this progress (Foster *et al.*, 2011b pg 4; Shaw and Theobald, 2011 pg 5; Roberts 201, pg 412).

The constraints on transformative approaches: Initiating system transformation is beset by a range of challenges. Even under existing patterns of climate variability there are many competing priorities at the local government level. Most local governments are already "involved with everything from babies to bitumen" (Measham *et al.,* 2010 pg 11). There are also concerns that in the current recessionary environment that local authorities will have to prioritise traditional and untransformed service delivery, and that the climate change agenda will become an additional burden that will be displaced by seemingly more urgent, short-term priorities (Shaw and Theobald, 2011 pg 5).

Dealing with uncertainty: The uncertainty associated with climate change projections and impacts contrasts strongly with the immediate nature of adaptation costs and the fact that benefits are likely to be delayed (OECD, 2010 pg 23). A key question is how can planners "make effective use of available climate information despite large uncertainties and unfamiliar or unhelpful data formats"? (Tyler *et al*., 2010, pg vi). A pragmatic approach suggests a stepwise approach of focusing initially on existing vulnerabilities (as "adaptation to present climate variability and extreme events forms the basis for reducing vulnerability to future climate change" - UN-Habitat undated c, pg 15) identifying no-regrets options that have near and long-term co-benefits, using scenario planning instead of trying to precisely predict future climate change through down scaled projections, undertaking further studies to develop better local data, avoiding maladaptation and increasing awareness (Tyler *et al*., 2010, pg vi; OECD, 2010 pg 23; TARU, 2010 pg 18). Understanding the cost of inaction is also an important mechanism for dealing with the institutional hesitancy that can result from confronting the challenges of uncertainty.

The issue of thresholds and conflicting agendas: Despite the fact that most urban areas acknowledge the value of both mitigation and adaptation - Toronto for example defines mitigation as "the globally responsible thing to do" and adaptation as the "locally responsible thing to do" (Toronto Environment Office, 2008 pg 3) - there is often the tendency for cities to treat adaptation and mitigation separately, and to lead with one or the other depending on their circumstances, priorities, resources and institutional affiliations (Roberts, 2010 pg 397; Carmin *et al*., 2009 pg 1; Hamin, 2011 pg 133). As a result little progress has been made in ensuring that adaptation and mitigation policy goals are not in conflict (Hamin and Gurran, 2009 pg 238). A key nexus for both is the issue of densification. It is generally accepted that mitigating climate change will require a denser urban form in order to maximize economies of scale, reduce the need for motorized transport and to reduce building energy use. Adaptation alternatively speaks to an urban form that favours green infrastructure such as the provision of open space for stormwater management, species migration, and urban cooling (Hamin and Garrun, 2009 pg 242). This raises the question of thresholds i.e. when will densities be so high that they create negative feedbacks such as the inability to maintain ecologically viable and biodiverse systems, or positive feedbacks such as the exacerbation of 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. Hamin and Garrun (2009 pg 242) refer to this as the "density conundrum".

The dangers to biodiversity particularly are highlighted by Hamin and Garrun's (2009 pg 242) assertion that an appropriate response to the density conundrum would be to provide multi-use greenspace within settlements along linear features (such as transportation routes and rivers and floodplains) while larger open areas are limited to the urban periphery. While this may make sense from a climate perspective – it makes little biological sense, especially in situations where urban areas are located in areas of high biodiversity and endemism. Under these conditions it is often necessary to protect and 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. Such is the case in South African cities such as Durban and Cape Town, both of which are both located within global biodiversity hotspots (EThekwini Municipality, 2007 pg 4; Holmes *et al*., 2008 pg 4). A not insignificant number of cities in the Global South are likely to face similar dilemmas given that the three most biodiverse countries in the world are Brazil, Indonesia and South Africa (Endangered Wildlife Trust, 2002 pg 2). Such an approach is also counter to long-accepted conservation network design principles which favour larger, rounded areas over smaller fragmented or linear areas (Diamond, 1975 pg 143) and also does not acknowledge the higher costs and per unit effort associated with maintaining and managing smaller and linear areas. These are important considerations given that the impacts of climate change on biodiversity (even without the additional pressures of urban development) are likely to be "disastrous" and that current protected area systems (including those in urban areas) are already unlikely to be sufficient to deal with the projected impacts of climate change (Lovejoy and Karsh, 2008 pg 3). 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 pg 9) it is critical not only that adaptation and mitigation agendas are not in conflict, but that climate protection actions do not undermine other agendas such as biodiversity. This will require that research is undertaken to determine the thresholds for unacceptable biodiversity change in urban areas and that this information is used to determine acceptable limits to urban densification. Similarly it will be necessary to carefully analyse the negative impacts of planned mitigation and adaptation activities on biodiversity in urban areas such as has recently occurred in London (Gill *et al*., 2009, pg 71).

The issue of thresholds is pertinent not only to biodiversity concerns, but will also be of general relevance in other areas. For example, in determining when and where adaptation is no longer possible, due either to technical difficulties or cost (or both) – so called residual damage (UN-Habitat, 2011 pg 130; Parry et al, 2009 pg). This knowledge about limits within existing systems will be vital in developing appropriate planning responses to future climate challenges.

Prioritising poverty within the climate change debate: A dichotomy exists between the Global North and South regarding the level of emphasis placed on the issue of poverty and poverty alleviation in the adaptation debate. While cities such as Boston (City of Boston, 2011 pg 8) and London (Greater London Authority, 2010 pg 7) acknowledge the need to consider vulnerable groups in their planning, for most cities in low and middle income nations, poverty reduction is a central item of any adaptation agenda. As noted by UN-Habitat (undated b, pg 17) when discussing the prevailing situation in Esmeraldas (Ecuador) "it is important to note that most of what has been accomplished in sanitation, infrastructure, and urban planning capacity has not been motivated by concerns over climate change, but through strategies seeking better planning processes and poverty reduction." In urban areas of the Global South climate change is generally of low political significance because of pressing development needs e.g. infrastructure, public health, education, housing and energy (Roberts, 2008 pg 523; Kithiia, 2009 pg 25 and 1). This situation is compounded by the escalating 'urbanization of poverty' that has occurred in these parts of the world, making cities the nexus where poverty and climate change compete for political attention (Kithiia, 2009 pg 1). Within this context the challenges posed by climate change are viewed as marginal when compared with other socio-economic problems. If the adaptation agenda is to be advanced, it will require the use of innovative measures that couple climate change impacts with the reduction of poverty (Lwasa, 2010 pg 167). As concluded by Kithiia (2010 pg 4): "In general, without combating urban poverty and providing alternative sources of livelihood, little will be achieved towards climate change mitigation and adaptation, not just in East Africa but also in other low income countries."

Role of international institutions: Despite the fact that in many instances the adaptation efforts of local governments are a response to internal motivations (e.g. the perception of threat, city agendas, leadership, improving city image) rather than external pressures (Anguelovski and Carmin , 2011 pg 2), in the Global South, because of the lack of skills and resources, international institutions still play a significant role in initiating and shaping the adaptation agenda. This occurs through programmes such as UN-Habitat's Cities and City Change Initiative (CCCI), ICLEI-Local Governments for Sustainability's Sub-Saharan African Cities Adaptation Initiative (SSACAI) and the Asian Cities Climate Change Resilience Network (ACCCRN). These initiatives (and others like them) often constitute the main form of encouragement and institutional and financial support to mitigation and adaptation work at the local level (UN-Habitat, undated b pg 16; Kithiia 2010, pg 2; Roberts 2008, pg 524). The danger of the donor driven model approach is that the resulting programmes tend to focus on the funding agency's agenda, which may or may not coincide with local priorities, often with little lasting ownership by the local participants once the support is withdrawn (Roberts, 2008 pg 525; Kithiia and Dowling, 2010 pg 468). Furthermore, the manner in which information is delivered by international agencies during the course of these programmes is critical in determining the efficacy of the intervention, as local decision-makers access and use scientific and expert information about climate change in a manner that is different to the research community. For example, instead of relying on scientific journals they tend to rely on more informal sources and formats such as colleagues and the internet (Corfee-Morlot et al 2011 pg 183). Failure to note this distinction can result in a significant waste of effort and resources and experience has shown that "without developing a meaningful understanding of the science, climate change and its significance are unlikely to be effectively understood at the local government level" (Roberts, 2008 pg 525).

Different risk reduction priorities Local authorities in the Global South often do not view climate change as a management problem requiring immediate attention due to the plethora of competing stresses and development challenges (Kithiia and Dowling, 2010 pg 470; Roberts 2008, pg 523). As a result any adaptation strategy has to be developed within "the development context of the city or country and should lead to harmonization with the country's priorities such as poverty alleviation, food security and disaster management" (UN-Habitat, undated c, pg 15).

Undervaluing social capital: There is limited work available on adaptive capacity at the community or household levels (Jones *et al*., 2010 pg 2). This is a critical gap given that social capital may provide a key 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 to climate variability and change (Kithiia, 2009 pg 17). The issue of social capacity has been identified as important to urban resilience in a number of urban areas (TARU 2011, pg 38; UN-Habitat undated d, pg 22; Roberts 2010, pg. 408). However, as with ecosystem based adaptation, it is necessary to determine the limits of community based intervention, as communities may be able to restore and protect mangrove forests but they are unable to install, maintain and fund infrastructure and services at scale (UN-Habitat, 2011 pg 136). The issue of scaling up community level interventions, nevertheless remains an ongoing challenge (Lwasa 2010 pg 168) as does addressing the gender aspect of social capital.

Finally, 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 and are as yet not adequately addressed. These include:

- Does it reduce mortality?
- Does it help reduce illness and injury and/or their impacts, especially for vulnerable groups?
- Does it make livelihoods more resilient and improve choices on employment and livelihoods?
- Does it reduce negative impacts on economic output and 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 with other adaptation and mitigation interventions?

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Table 8-1: The distribution of the world's urban population by region, 1950–2010 and projected for 2030.

Region or country	1950	1970	1990	2010	Projected for 2030
Urban populations (millions of inhabitants)					
WORLD	729	1,330	2,255	3,486	4,900
High-income nations	427	652	812	930	1,037
Low- and middle-income nations	302	678	1,443	2,556	3,863
"Least developed nations"	15	41	110	249	520
Africa	33	87	205	413	761
Asia	229	483	1,003	1,757	2,598
Europe	281	412	503	533	567
Latin America and the Caribbean	69	163	311	469	585
Northern America	110	171	213	289	355
Oceania	8	14	19	25	25
Urbanization level (percentage of population living in urban areas)					
WORLD	28.8	36.1	42.6	50.5	59.0
High-income nations	52.6	64.7	70.8	75.2	80.9
Low- and middle-income nations	17.6	25.3	34.8	45.1	55.0
"Least developed nations"	7.3	13.1	21.0	29.2	40.8
Africa	14.4	23.6	32.1	40.0	50.0
Asia	16.3	22.7	31.5	42.2	52.9
Europe	51.3	62.8	69.8	72.9	78.4
Latin America and the Caribbean	41.4	57.1	70.3	79.6	84.9
Northern America	63.9	73.8	75.4	82.1	86.7
Oceania	62.0	70.8	70.7	70.2	71.4

* The statistics for 2010 are an aggregation of national statistics, many of which draw on national censuses held in 1999, 2000 or 2001 – but some are based on estimates or projections from statistics drawn from censuses held around 1990. There are also some nations (mostly in Africa) for which there are no census data since the 1970s or early 1980s so all figures for their urban (and rural) populations are based on estimates and projections.
SOURCE: United Nations 2010

Table 8-2

	Urban Pop. 2010 (2050)	Heat Wave / Warming	Drought / Water Supply	Wildfire	Inland Flooding	Coastal Flooding Sea Level Rise	Key References
Africa							Kithila 2011
Europe		**X**			**X**		Carter 2011
Southwest, Central Asia							
South Asia			**X**				Revi 2008
East Asia		**X**					Liu and Deng 2011
Australasia		**X**	**X**	**X**			
North America		**X**			**X**	**X**	Zimmerman and Faris 2011
Central and South America, Caribbean							Hardoy and Romero-Lankao 2011
Small Islands						**X**	
Polar Regions		**X**					

To be completed

Table 8-3

9.3.4 Adaptation measures – long term

The following potential long term adaptation measures are proposed for the City of Melbourne in managing the scenario of extreme heat.

Proposed potential adaptation measures	Risks influenced / controlled													
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14
Implement changes to urban form to reduce heat island affect; urban and rooftop gardens; lighter building; roof and road colours; more extensive network of stormwater fed urban wetlands	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Revised building standards incorporating passive cooling, ventilation, and suitably rated materials	✓	✓	✓	✓	✓			✓		✓	✓			
Storm water street sprinkling/cooling mist facility	✓	✓	✓	✓				✓		✓				
Emergency/grid independent generation (e.g. solar) for ventilation	✓	✓		✓				✓		✓				
PT system improvements to reduce knock-on effects of individual breakdowns or service failures e.g. rail tunnel, bus service expansion	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	
Continued long term replacement of aged train/tram stock to provide greater resilience to hot conditions	✓			✓				✓		✓				
Development and implementation of revised engineering standards for infrastructure	✓			✓			✓	✓						
Ongoing efforts to redesign design public realm for comfort and enjoyment of all in hotter conditions: shading; cool places; public water facilities	✓			✓										

Legend ✓ Control Critical ✓ Active Management ✓ Periodic Monitoring ✓ No Major Concern

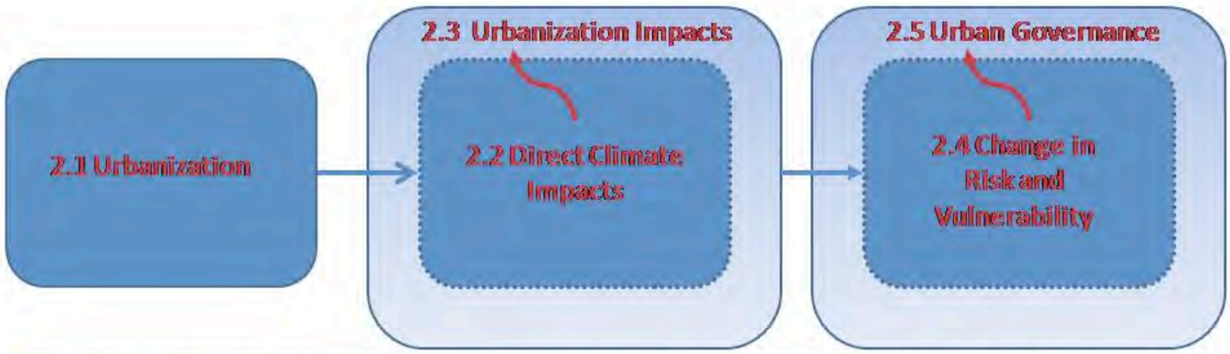
Table 16: Adaptation measures: extreme heat - long term

Table 8-4: The role of city/municipal governments in preventing disasters from extreme weather, limiting their impact and post-disaster responses.

Role for city/municipal government	Long term protection	Pre-disaster damage limitation	Immediate post-disaster response	Rebuilding
Built environment				
Building codes	High		High*	High
Land use regulations and property registration	High	Some		High
Public building construction and maintenance	High	Some		High
Urban planning (including zoning and development controls)	High		High*	High
Infrastructure				
Piped water provision including treatment	High	Some	High	High
Sanitation	High	Some	High	High
Drainage	High	High**	High	High
Roads, bridges, pavements	High		High	High
Electricity supply	High	Some?	High	High
Solid waste disposal facilities	High	Some?		High
Waste water treatment	High			High
Services				
Fire-protection	High	Some	High	Some
Public order/police/delivery of early warning	Medium	High	High	Some
Solid waste collection	High	High**	High	High
Schools	Medium	Medium	Medium***	
Health care/public health/environmental health/ambulances	Medium	Medium	High	High
Public transport	Medium	High	High	High
Social welfare (includes provision for child care and old-age care)	Medium	High	High	High
Disaster response (over and above those listed above)			High	High

The extent to which the roles listed above are the responsibilities of city or municipal governments obviously varies; this table is intended to illustrate the wide range of relevant responsibilities that they usually have.
* Obviously it is important that these do not inhibit rapid responses
** Clearing/desilting drains and ensuring collection of solid wastes have particular importance just prior to extreme rainfall; many cities face serious flooding from extreme rainfall that is expected (for instance the monsoon rains) and this is often caused or exacerbated by the failure to keep storm and surface drains in good order.
*** Rebuilding/repairing schools quickly to allow them to serve as community meeting points and also get the children back to school as soon as possible (that helps restore aspects of normality for the children and provides more time for parents in rebuilding homes and livelihoods)

Source: Satterthwaite, Dodman and Bicknell 2009



2.1 Urbanization	2.2 Direct Climate Impacts	2.3 Urbanization Impacts	2.4. Change in Risk and Vulnerability	2.5 Urban Governance
2.11 Magnitude and Connections to Climate Change	2.21 Water and Sanitation	2.31 Uncertainty and Surprise	2.41 Inland Flooding	2.51 Institutional Environment
2.12 Spatial	2.22 Energy	2.32 Extreme Event Probability	2.42 Coastal Flooding, Sea Level Rise and Storm Surge	2.52 Governance and Civil Society
2.13 Temporal	2.23 Transportation and Teleconnections	2.33 Transitions	2.43 Urban Heat and Cold	2.53 Science-Policy Linkages
2.14 Sustainability and Ecological Habitat	2.24 Built Environment, and Recreation and Heritage Sites	2.34 Social Dynamics and Economic Tensions	2.44 Drought and Water Scarcity	2.54 Decision-Support Tools
2.15 Regional Patterns	2.25 Ecosystem Services and Green Infrastructure	2.35 Historical Analogs	2.45 Air Pollution and Public Health	2.55 Development as Risk and Vulnerability Reduction
	2.26 Social and Public Services		2.46 Geohydrological Hazards	2.56 Private Sector

Figure 8-1: The structure of this section.

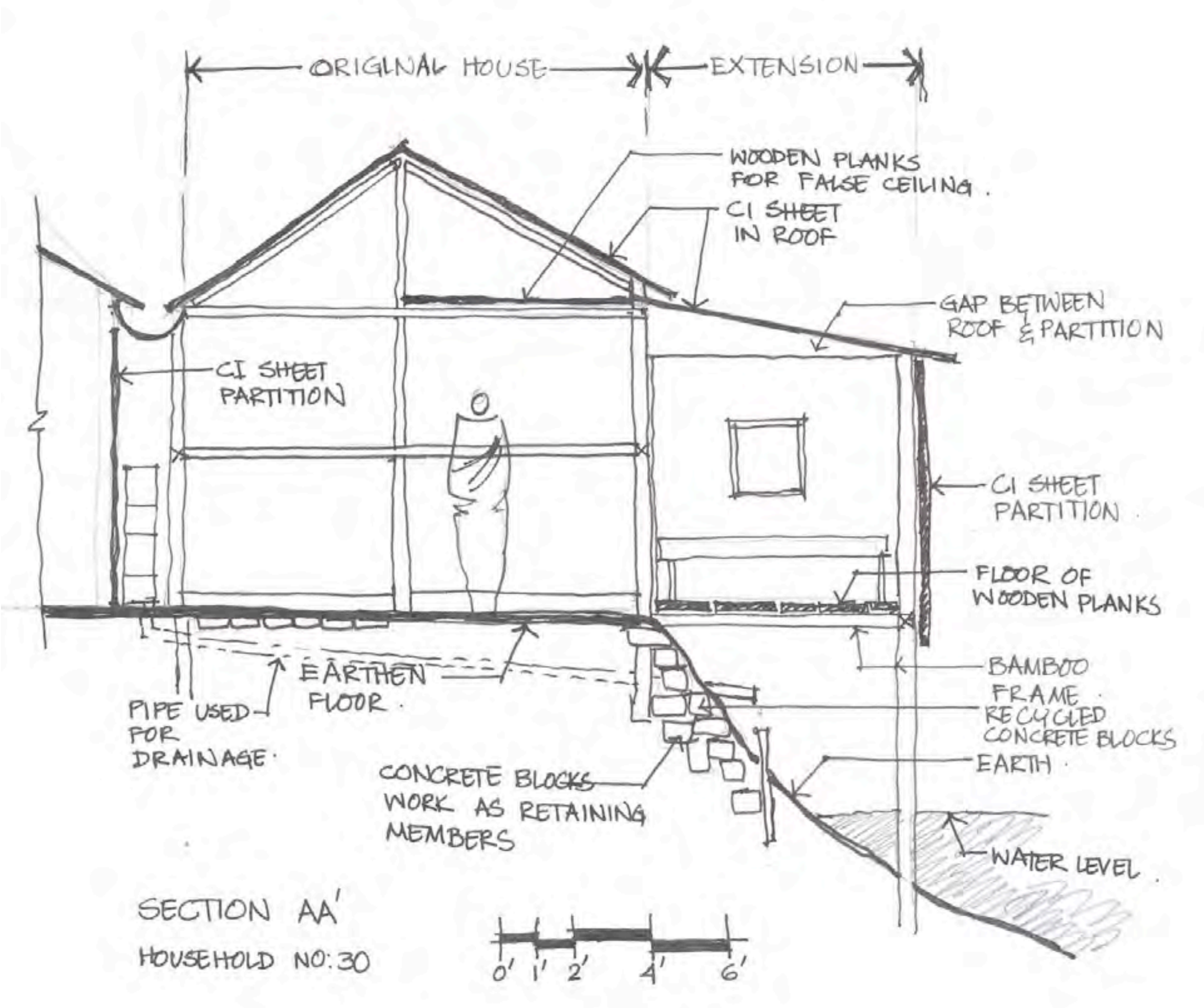


Figure 8-2: A cross-section of a house in Korail showing measures taken to cope with flooding and high temperatures (Jabeen, Johnson, and Allen, 2011).

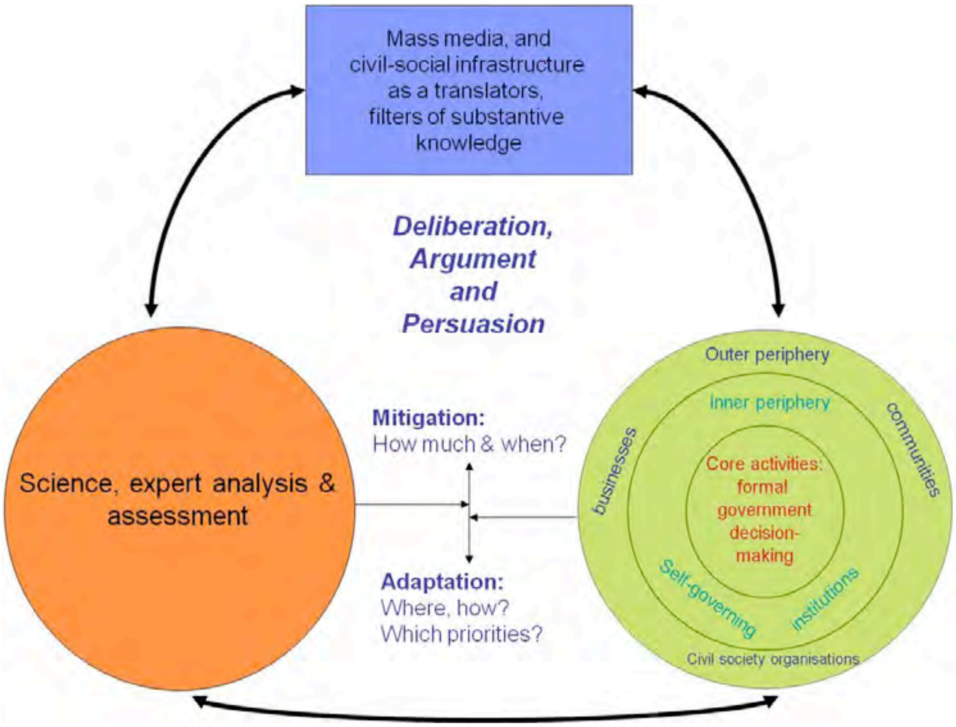
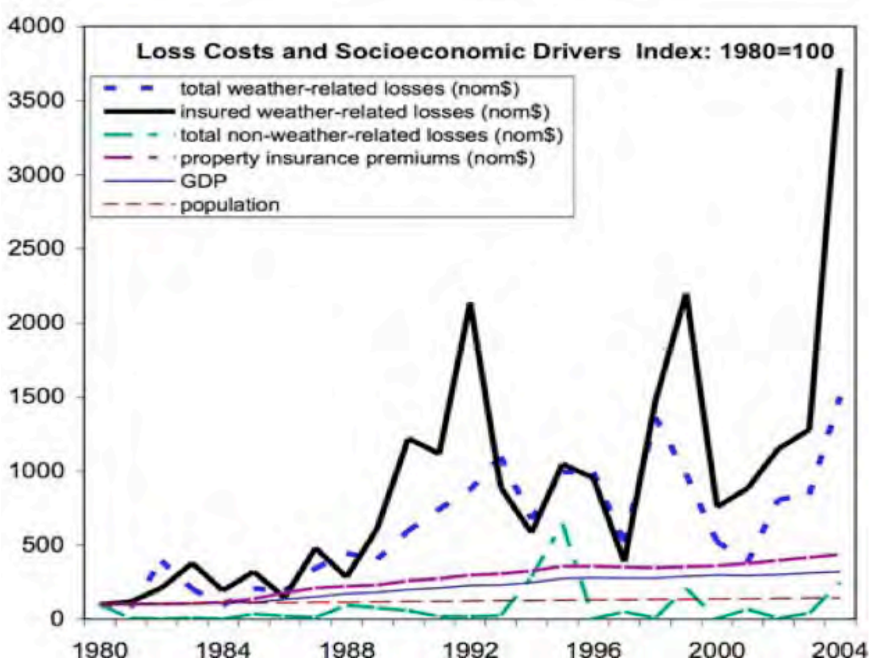


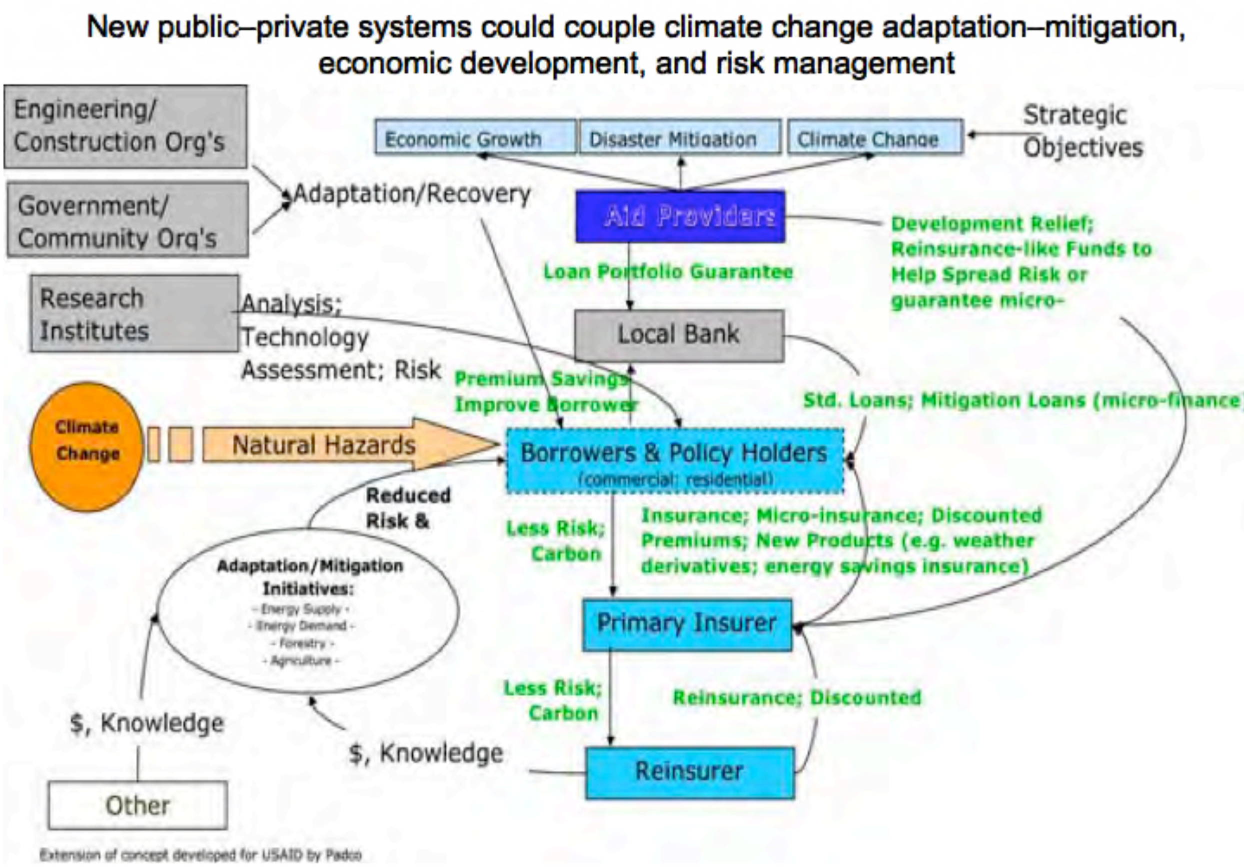
Figure 8-3: Title? Adapted from Corfee-Morlot, Cochran, Teasdale and Hallegatte 2011.

Figure 8-4



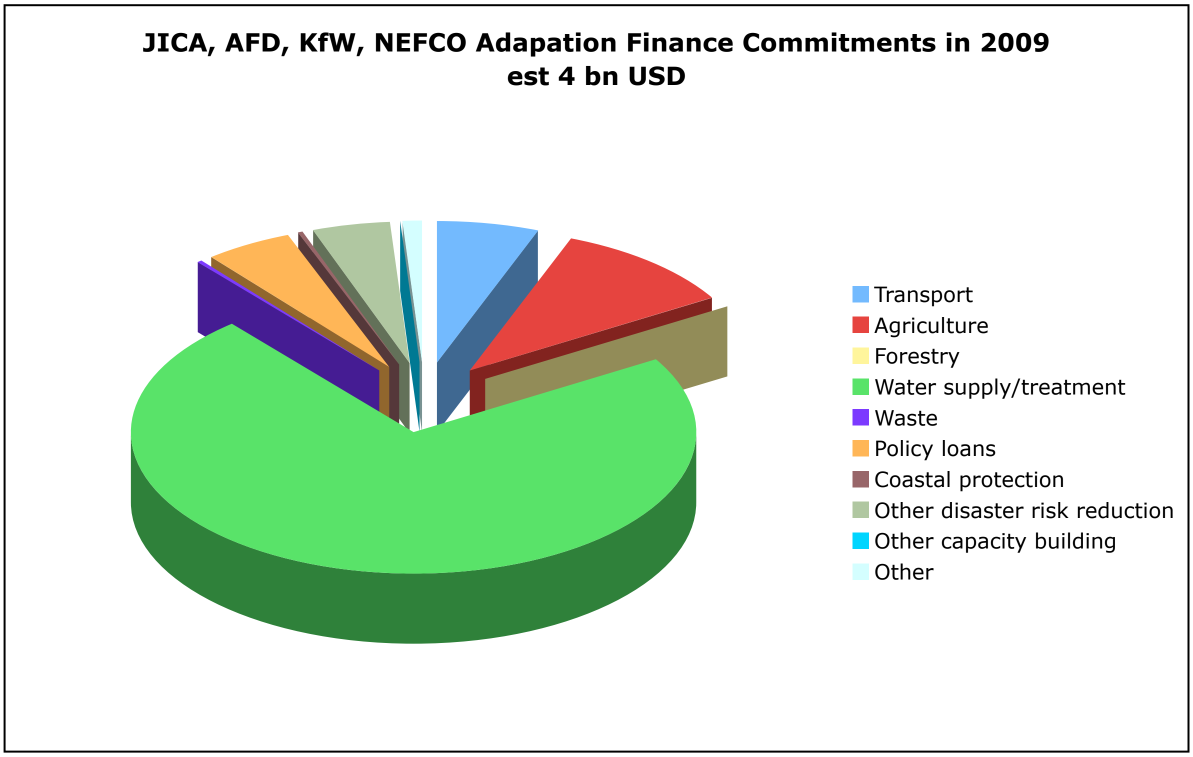
Source: Mills 2007 from Mills 2006

Figure 8-5



Source: Mills 2007

Figure 8-6



Source: based on data from UNEP 2010, Bilateral Finance Institutions and Climate Change: A Mapping of 2009 Climate Financial Flows to Developing Countries