Chapter 8. Urban Areas

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Contents

Executive Summary

8.1. Introduction
- 8.1.1. Key Issues
- 8.1.2. Scope of the Chapter
- 8.1.3. Context – An Urbanizing World
- 8.1.4. Vulnerability and Resilience
  - 8.1.4.1. Differentials in Risk and Vulnerability within Urban Centres
  - 8.1.4.2. Understanding Resilience for Urban Centres in Relation to Climate Change
- 8.1.5. Conclusions from the Fourth Assessment (AR4) and New Issues Raised by this Chapter
  - 8.1.5.1. Key Uncertainties and Research Priorities
  - 8.1.5.2. What has Changed since AR4

8.2. Urbanization Processes, Climate Change Risks, and Impacts
- 8.2.1. Introduction
- 8.2.2. Urbanization – Conditions, Processes, and Systems within Cities
  - 8.2.2.1. Magnitude and Connections to Climate Change
  - 8.2.2.2. Spatiality, Physical Planning, and Climate Change
  - 8.2.2.3. Temporal Dimensions: Rapid Onset, Slow Onset, Production Cycles
  - 8.2.2.4. Urbanisation and Ecological Sustainability
  - 8.2.2.5. Regional Differences and Context-Specific Risks
- 8.2.3. Urbanization and Climate Change and Variability – Primary (Direct) and Secondary (Indirect) Impacts
  - 8.2.3.1. Urban Temperature Variation: Means and Extremes
  - 8.2.3.2. Urban Heat Islands
  - 8.2.3.3. Drought and Water Scarcity: Means and Extremes
  - 8.2.3.4. Coastal Flooding, Sea Level Rise, and Storm Surge
  - 8.2.3.5. Inland Flooding and Hydrological and Geo-Hydrological Hazards at Urban Scale
  - 8.2.3.6. Air Pollution: Means and Extremes
  - 8.2.3.7. Emerging Human Health, Disease, and Epidemiology Issues in Cities
- 8.2.4. Urban Sectors: Exposure and Sensitivity
  - 8.2.4.1. Water Supply, Wastewater, and Sanitation
  - 8.2.4.2. Energy Supply

8.2.4.3. Transportation and Telecommunications
8.2.4.4. Built Environment, and Recreation and Heritage Sites
8.2.4.5. Green Infrastructure and Ecosystem-based Adaptation
8.2.4.6. Health and Social Services
8.2.5. Urban Transition to Resilience and Sustainability
8.2.5.1. Uncertainty and Surprise
8.2.5.2. Extreme Event Probability
8.2.5.3. Transitions
8.2.5.4. Social Dynamics, Economic Tensions, and Multiple Stressors
8.2.5.5. Historical Analogues

8.3. Adapting Urban Areas
8.3.1. Introduction
8.3.2. Development Plans and Pathways
8.3.2.1. Adaptation and Development Planning
8.3.2.2. Disaster Risk Reduction and its Contribution to Climate Change Adapation
8.3.3. Adapting Key Sectors
8.3.3.1. Adapting the Economic Base of Urban Centres
8.3.3.2. Adapting Food and Biomass for Urban Populations
8.3.3.3. Adapting Housing and Urban Settlements
8.3.3.4. Adapting Urban Water, Storm, and Waste Systems
8.3.3.5. Adapting Electric Power and Energy Systems
8.3.3.6. Adapting Transport and Telecommunications Systems
8.3.3.7. Green Infrastructure and Ecosystem Services within Urban Adaptation
8.3.3.8. Adapting Public Services and Other Public Responses

8.4. Putting Urban Adaptation in Place: Governance, Planning, and Management
8.4.1. Urban Governance and Enabling Frameworks, Conditions, and Tools for Learning
8.4.1.1. Multi-Level Governance and the Unique Role of Urban Governments
8.4.1.2. Mainstreaming Adaptation into Municipal Planning
8.4.1.3. Delivering Co-Benefits
8.4.1.4. Urban Vulnerability and Risk Assessment Practices: Understanding Science, Socio-Economics, and Policy Interactions
8.4.1.5. Assessment Tools: Risk Screening, Vulnerability Mapping, and Urban Integrated Assessment
8.4.2. Engaging Citizens, Civil Society, the Private Sector, and Other Actors and Partners
8.4.2.1. Engaging Stakeholders in Urban Planning and Building Decision Processes for Learning
8.4.2.2. Supporting Household and Community-Based Adaptation
8.4.2.3. Private Sector Engagement and the Insurance Sector
8.4.2.4. Civil Society Partnerships and Philanthropic Engagement
8.4.2.5. University Partnerships and Research Initiatives
8.4.2.6. City Networks and Urban Adaptation Learning Partnerships
8.4.3. Resources for Urban Adaptation and their Management
8.4.3.1. Domestic Financing: Tapping into National or Sub-national Regional Sources of Funding and Support
8.4.3.2. Multilateral Humanitarian and Disaster Management Assistance
8.4.3.3. International Financing and Donor Assistance for Urban Adaptation
8.4.3.4. Institutional Capacity and Leadership, Staffing, and Skill Development
8.4.3.5. Monitoring and Evaluation to Assess Progress

8.5. Conclusions
8.5.1. Introduction
8.5.2. What Hinders Adaptation Progress in Urban Areas?
8.5.3. What Contributes to the Development of Effective Transformative Adaptation Plans?

Frequently Asked Questions
8.1: How does disaster risk reduction relate to climate change adaptation?
8.2: Doesn't good development produce urban adaptation?
8.3: Wouldn't urban problems be lessened by rural development?
8.4: Shouldn't urban adaptation plans wait until there is more certainty about local climate change impacts?

References

Executive Summary

Successful global climate change adaptation depends centrally on what is done in urban areas (*high agreement, medium evidence*). Urban areas house more than half the world's population and concentrate most of its assets and economic activities. They also concentrate a high proportion of the population, and economic activities most at risk from climate change. In addition, a high proportion of global greenhouse gas emissions are generated by urban-based activities. Furthermore, projections for the next few decades suggest that it is in and around urban areas that almost all the increase in the world's population and much of the increment in capital formation, economic activity, infrastructure development, ecosystem degradation and emissions will take place. [8.1] Adaptation action in urban areas that delivers mitigation co-benefits is one of the most powerful and resource-efficient means of addressing climate change, as outlined in the AR5 Working Group III report.

There has been a very large expansion in the literature of relevance to climate change adaptation in urban areas since AR4 (*very high confidence*). [8.1] This includes documents prepared by many city governments and some international agencies on their initial responses to adaptation. There is also evidence of a greater interest in climate change adaptation from certain professions (including architects, engineers and urban planners and those working on disaster risk management). There is also a new literature underlining the importance of a shift in emphasis from urban adaptation to building resilience at city and regional scale. This will support the capacity to withstand unexpected impacts, flexibility, redundancy and planning for 'safe failure' in response to increasingly extreme climate adaptation as outlined in the AR5 SREX report. [8.1] Beyond this, an emerging literature is exploring urban transformations - adaptation that helps address the key drivers of anthropogenic climate change through combined processes of sound development, disaster risk reduction, increased resilience and ecosystem adaptation. [8.5] There is also some discussion of the adaptation limits that urban centres face and difficult decisions over what can be done that might include resettlement or abandonment of previously developed land. [8.3]

Cities are complex inter-dependent systems with potential synergies that could be leveraged to support climate change adaptation (*high agreement, low evidence*). In many cities, adaptation effectiveness is constrained by complex inter-dependencies – for instance the impact of power failures or fuel shortages on water supplies, drainage, transportation, telecommunications and health care services. There is also the dependence of emergency services on all-weather roads, functioning communications systems and robust health care centres and the dependence of urban populations and economies on food and resources from beyond their boundaries. [8.2] A few cities have adaptation initiatives underway for energy systems or are considering what steps are needed to do so; energy policy discussions in the past have been dominated by mitigation concerns. [8.3] Urban enterprises developed within globalized systems of production depend on reliable supply chains which may face particular difficulties. [8.3] Conventional infrastructure investment decision-making may be interventionist or reactive and overlook more open-ended and flexible concepts such as adapting well, climate smart, sustainable adaptation and resilience. [8.5] Thus raising urban adaptive capacity in the context of climate change requires effective multi-level governance (so all levels of government work together) with institutions that facilitate coordination across multiple, nested and poly-centric authorities and have the capacity to mainstream adaptation measures. There are synergies to be encouraged in peri-urban or nearby rural areas where land-use management around a city supports rural livelihoods and protects ecosystem services. [8.3] This is yet to be built in most parts of the world. [8.4, 8.5]

The scale and concentration of urban climate risk and hence the imperative for adaption are better acknowledged now but poorly understood and rarely acted upon (*medium confidence*, characterized by *high agreement* and *medium evidence*). Increasing concentrations of population, assets and economic activities in the urban areas of almost all countries, irrespective of income-level will increase the concentration of climate-related risks for a large and growing proportion of the world's population. [8.1] This could threaten economic and development processes, poverty reduction and ecological sustainability. Awareness of these emergent risks is growing, but responses are weak except for a handful of cities largely in high-income countries. [8.3, 8.4] Three identifiable strategies to enable urban adaptation are: awareness building, evidence-based analysis and action at the appropriate level. [8.4] Most current adaptation action focuses on low-cost interventions such as infrastructure and asset-creation as a co-benefit of existing development interventions. The weak emphasis on human, institutional and ecological adaptation with long-term resilience building potential is a matter of concern. [8.5, 8.3]

Rising sea levels, associated coastal and riverbank erosion and flooding in conjunction with storm surges could all lead to widespread impacts on populations, property and coastal vegetation and ecosystems, and threats to commerce, business, and livelihoods (*very high confidence*). Sea-level rise represents one of the primary shifts in urban climate change risks, given the large and often increasing concentration of urban populations in coastal locations. [8.2] Coastal cities with extensive port facilities and large scale industries in low-elevation coastal zones including petro-chemical and energy related industries are vulnerable to climate change related increased flood exposure. [8.2] Many cities in Asian high growth economies are located on low-lying coastal areas, which are undergoing rapid urbanand economic transformation. Without adaptive measures and with rising concentrations of population, infrastructure, and industries along these coasts, there could be a non-linear increase in coastal vulnerability over the next two decades. [8.3] Many cities and smaller urban centres already experience large floods regularly and will be at greater risk of flooding if rainfall intensities increase. This 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 related diseases as noted in wide range of studies. [8.2]

Climate change can influence the dynamics of city microclimates while cities can alter a localized region's climate (*high confidence,* based on *high agreement* and *high evidence*). The dense nature of many large cities, high energy consumption, and regional climate conditions produces pronounced influences on anthropogenic heat emissions. [8.2] Reviews of megacity impact on air flow indicate that megacities, especially coastal cities, influence both internal city environmental and regional weather and air quality. [8.2] Additional environmental impacts have also been observed, such as increased levels of surface run-off. Other coupled processes includethe effect of microscale to mesoscalechanges in the built environment on Urban Heat Islands (UHI) thereby impacting mesoscale processes such as land-sea breeze effect and katabatic winds, inturnmodifyingthe spatial extent and magnitude of local urban climate change impacts resulting from radiative forcing. [8.2]

Increasing city resilience to climate change, building adaptive capacity and adequate resourcing could enable cities to 'bounce forward' (*medium confidence*, supported by *high agreement* and *low evidence*). Effective multi-level urban risk governance, alignment of multiple (potentially conflicting) policies and incentives, early and appropriate adaptation choices and implementation action could increase city resilience to climate change and build needed local and regional adaptive capacity. This would strengthen development processes, limit maladaptation, support more effective adaptation and build positive synergy with climate mitigation measures. This combined with strengthening of local ecological and built infrastructure and services, better integrated urban and adaptation planning, strengthened local government and community adaptation capacity, synergy with the private sector and appropriate financing and institutional development could enable cities (especially in low- and middle-income countries) to use their limited resources to 'bounce forward' rather than respond in a fractured, ad-hoc and poorly-resourced manner to existing or impending climate risks. [8.4, 8.5] "Bouncing forward" is enabled by building transformatory adaptive capacity and climate resilience through a mix of sound development, disaster risk reduction, and ecosystem-based adaptation rather than 'end-of-the-pipe' or incremental adaptation interventions.

Sound development is a necessary, but not sufficient condition to enable urban climate resilience (*medium confidence*, supported by *high agreement* and *medium evidence*). There is a widespread assumption that sound urban development, especially universal provision of basic infrastructure and services (piped water, provision for sanitation and drainage, solid waste collection, health care, schools, emergency services, policing) are sufficient to enable urban resilience to climate change, based on the perceived experience of some high-income nations. [8.2] These provide an important base from which to build resilience. The importance of harmonization and synergy of climate adaptation and mitigation with poverty reduction, livelihood development, food security, universal access to adequate housing and basic services and disaster risk reduction is slowly being understood. But this is a complex terrain that needs more evidence and experimentation to gauge the effectiveness and limitations of current models of infrastructure and service provision – including 'social capital'-based and community-led climate adaptation and acceptance of this among national governments and mainstream development agencies. [8.3, 8.5]

City-based disaster risk reduction is a strong foundation around which to build urban climate resilience (*high confidence*, based on *high agreement* and supported by *medium evidence*). Many urban areas have long been exposed to a range of hazards and disaster risks that could be exacerbated by climate change: water shortages and droughts in urban regions, geo-hydrological hazards, inland and coastal flooding, windstorms and storm surges, high levels of air pollution, extremes in urban heat and cold and urban heat islands and novel compound and slow onset hazards that impact ecosystem resilience. [8.2] Experience in effective city-level disaster risk reduction to address these challenges largely by vulnerability reduction and exposure modification, has been built in many cities across over the last few decades via local hazard, risks and vulnerability studies and interventions. Some national governments have set up frameworks and financing mechanisms to support local government and civil society implement disaster risk reduction. This is a valuable foundation for climate change adaptation but it will need to also take account of how hazards, risks, slow onset impacts and vulnerabilities change over time and thereby seek to converge development and disaster risk reduction policies, institutional development and investmentmobilisation to meet short- to medium-run risk reduction and longer-term urban adaptation goals. [8.3]

Urban concentration and agglomeration economies can be a strategic asset in climate adaptation action (*medium confidence*, based on *medium agreement* and *low evidence*). Many of the challenges and opportunities for urban adaptation come from the concentration of people and enterprises in locations of high risk. There are agglomeration economies for much of the infrastructure and services for climate change adaptation but they need to be acted on. There is *high agreement*, supported by *high evidence*, that many urban centres are on sites that face high levels of risk with risks exacerbated by built and ecological infrastructure deficits. Many cities in low- and middle-income nations have a high proportion of their population in informal settlements that lack risk-reducing infrastructure and services and that are located on floodplains, alongside rivers, in areas prone to slips and rockfalls or on steep unstable slopes. These sites are settled because their residents cannot afford housing on safer sites. Where local governments are unable or unwilling to act on these, population concentration brings disadvantages. [8.2, 8.3] This has been seen as an argument to incentivize adaptation-led relocation but that can cause very large disruptions to both residents and economic activity. [8.2] Urban agglomeration economies are often discussed in regard to enterprises. Cities may represent a particular centre of interest for private sector engagement around climate change partly because they concentrate large infrastructure investments and related business. [8.4] There are potential urban agglomeration economies around cost-effective adaptation and resilience building via improved built and ecological infrastructure and services and bringing together people, communities and institutions to respond collectively to climate change risks. [8.3] There is also the need to take recognize potential conflicts between the adaptation and mitigation agendas, as well as the establishment of locally specific limits to adaptive interventions. [8.5] The "density conundrum" where increased urban densities could enhance climate mitigation potential can limit the possibilities of ecosystem based adaptation, cross thresholds of acceptable biodiversity change and may exacerbate urban heat island risk. [8.3]

Building climate resilience in cities can be well-served by ecosystem-based adaptation with water and food systems as foci (*medium confidence*, based on *high agreement* among practitioners and *medium evidence*). Ecosystem-based adaptation is regarded as one of the morecost-effective and sustainable approaches to urban adaptation, although the costs of needed land acquisition can be high. [8.5] This is even though climate change will impact ecosystem services by altering ecosystem functions such as temperature and precipitation regimes, evaporation, humidity and soil moisture levels. Ecosystem-based adaptation is closely linked to sustainable water management ensuring sufficient supplies, increased capacities to manage reduced freshwater availability, flood risk reduction, managing waste water flows and ensuring water quality. [8.3, 8.5] There are considerable knowledge gaps in determining the limits or thresholds to adaptation of various ecosystems and where and how ecosystem based adaptation is best integrated with other adaptation measures. [8.5] There is *high confidence* that urban food-adaptation is linked to progressive public policy on food security and livelihood development; addressing constraints in agricultural production and food supply chains and limiting food price shock impacts caused by extreme eventson the food and nutrition security of low-income groups. [8.3]

Good quality, affordable and well-located housing provides one of the bases for city-wide adaptation to climate change (*high confidence*, supported by *high agreement* and *high evidence*). Climate change adaptation in urban centres will be built on the bedrock of good quality and affordable housing that conforms to appropriate health and safety and climate-resilient building standards and has sufficient residual structural integrity over its service life to protect its occupants against extreme weather, especially heat waves and storms. Good quality housing should provide its occupants with a comfortable, healthy and secure living environment and protect them from injuries, losses and damage. This requires effectiveland-use planning and regulation to control development in flood-prone and other high risk areas. It is particularly important for vulnerable groups especially children and older residents with chronic health conditions. This can be enabled via a range of structural interventions, interventions that reduce risks to housing and support access to quality housing for low-income groups, non-structural interventions (like insurance) and disaster risk reduction measures. Well-coordinated strategies are required to address a multiplicity of agencies working at various levels, overlapping regulation and lack of committed resources. [8.3]

Reducing basic service deficits and building resilient infrastructure systems could significantly reduce global climate risk (*very high confidence*, supported by *high agreement* and *high evidence*). Around one billion people live in informal settlements in urban areas with inadequate or no provision for infrastructure and services that provides a foundation for adaptation. Here, poverty and social inequality may be aggravated by climate change and the lack of adaptive capacity. The adaptive capacity of an urban centre is much influenced by the quality and coverage of infrastructure (piped water supplies, sewers or other forms of provision for sanitation, drains, all weather roads and electricity provision) and services that include solid waste collection (vital for keeping drains functioning), policing, health care, emergency services and measures to reduce disaster risk. The extent to which urban and higher levels of governments are able to mobilize resources, choose the most appropriate technical and institutional systems for service delivery influences adaptive capacity and deepens climate resilience. [8.3] The rate and magnitude of urban development in some low- and middle-income countries also brings great challenges that many high-income nations do not have to deal with.

Urban governments are the fulcrum of successful urban climate adaptation (*high confidence*). Local governments are responsible for many of the needed measures for climate change adaptation in urban areas. This makes sense since most risks and vulnerabilities are rooted in local contexts and much of the risk reducing infrastructure and services are within their jurisdictions. [8.3] The incorporation of climate change adaptation into each urban centre's development planning and investments is well served by an iterative process of learning about changing risks and opportunities and drawing in different stakeholders, to inform a balanced assessment of policy options and decisions. Engagement with local stakeholders, built upon openness and transparency about climate change information and its risks, can ensure the needs and priorities of low-income and vulnerable groups get attention and that the private sector is brought into discussions. The role of urban governments in climate adaptation is now more widely recognized, but in many nations, local governments need a stronger financial and institutional base to be able to act on this, including land use management and infrastructure investment. [8.4] Operationalisation will also need a redirection of current priorities, investment and capacity building plans including those that strengthen the investment capacity of urban, city and metropolitan governments. [8.2, 8.3]

City governments are slowly learning from climate change adaptation implementation experience (*medium confidence*, based on *high agreement* and *medium evidence*). The last five years have brought many examples of city governments assessing urban adaptation needs and responding. [8.3] These have often included the designation of a unit within city government with responsibility for adaptation, measures to involve key sectors so they understand why they need to engage with adaptation, the importance of local champions to initiate measures and ensure continuity and the importance of dialogue and discussion with all key stakeholders. [8.4, 8.5] There is also recognition of the need to review building codes, the climate data on which the codes are founded, infrastructure standards and land-use management thereby developing scalable approaches to local adaptation planning. [8.3] City governments that have taken adaptation seriously have drawn in other institutions for support, including local universities and research centres and representative organizations of those living in informal settlements. [8.4]

Effective ways to engage local government attention have been the demonstration of climate change adaptation's importance for a city's continuing economic success, improved service delivery, job creation and risk management. [8.5]

The process of city-based climate adaptation learning is slow, complex and fraught with multiple interlinked challenges (*very high confidence*). Although some city governments have developed innovative adaptation plans, the scale and scope of what is needed is still poorly appreciated. Multiple changes across legal and regulatory frameworks, jurisdictions, policies and intergovernmental flows are needed to mainstream urban climate adaptation. These can be slow to be accepted and slower to implement. The capacity to integrate climate risk, disaster risk reduction, urban infrastructure and planning are being slowly built in some parts of the world. Sector policies need to take account of climate change. Many such policies will require changes to prevent increases in the vulnerabilities of urban populations, infrastructure and natural systems. In most urban centres, these include policies on water, wastewater, solid waste, natural resource management, building regulations, land-use management, transport planning, and disaster management. [8.4] Other challenges that need addressing include: reducing the lack of clarity of multi-level governance mandates; addressing the tension between local and higher-level and sometimes international agency driven priorities; the competition that long-term climate adaptation horizons will face from short-cycle electoral processes, a focus only on growth and competitiveness and local short-run priorities; overcoming the lack of human and financial resources and compartmentalisation and fragmentation of urban government. An openness to emergent and uncertain climate risks via awareness and institutional development can bridge the gap between the need for phased adaptation interventions and the many years it would take for their benefits to become visible. [8.3, 8.4, 8.5] The practice of effective monitoring of development and of the implementation of adaptation plans is still evolving, given the localized nature of most urban adaptation action. [8.5]

Locally-relevant adaptation plans, data and feedback mechanisms are important for building urban climate resilience (*high agreement* and *medium evidence*). Governments, households and the private sector need relevant, reliable local information, including climate projections, to encourage them to act and inform their actions. Despite growing attention, much-needed information and assessment of climate change at urban spatial scales is generally still lacking. Unlike mitigation planning, adaptation programmes are less open to a standard set of requirements, given that actions are oftenrooted in local circumstances, involve multiple stakeholders, are cross-sectoral, multi-scalar and multi-synchronous, and include a high level of uncertainty. [8.5] Only a small number of cities, largely in high-income countries, have quantified risks in local contexts and even fewer have quantified possible costs of climate change risks under different climate and/or socio-economic scenarios. First and second order impacts such as sea level rise and coastal and riverine flood risk and health and water resources are among the most studied sectors, while third order impacts on energy, transport and built infrastructure receive far less attention, and yet these sectors are often targeted for mitigation-focused interventions. While science and climate change information is increasingly available, socio-economic drivers of vulnerability and impacts, such as an increasing health risk and disease burdens are less well understood. [8.2, 8.4] Tools for risk screening and management, which draw on detailed data and projectionsboth from physical science and the socio-economic domains, can help engage the interest of local governments, businesses and civil society organizations. They can also help the translation into information useful for decision-making. City experience is slowly developing around multi-stakeholder adaptation engagement and awareness generation to build broad based support; mainstreaming climate adaptation processes into municipal planning, land use management and building and infrastructure codes. Improved feedback, monitoring and reporting capacity supported by new generation risk screening, vulnerability mapping and integrated urban climate assessment tools are helping catalyse social-learning to help mainstream climate adaptation into urban policies and planning. [8.4] Assessment tools such as scenario-planning that go beyond spatial and multi-criteria assessment to consider the urban environment as a system to better understand the inter-connections, cascading impacts and vulnerabilities are also recommended [8.4, 8.5)]

Enabling the agency of low-income households and vulnerable communities is a powerful adaptation strategy (*high confidence*). Informal settlements in low- and middle-income nations are among the largest existing and emerging concentrations of climate vulnerable urban populations, assets, infrastructure and ecosystem services. [8.1, 8.2, 8.3] Many urban governments are unable to extend a full range of entitlements, services and the institutional support necessary for effective adaptation to these settlements. For most cities and smaller urban centres in low- and middle-income nations, poverty reduction needs more attention because of the strong association between poverty and environmental health, disaster and climate change risks. [8.5] In many high climate risk locations, community and household-led adaptation have intervened with their limited resources to fill this gap. In informal settlements, engagement with community learning provides a means for participatory community risk assessment, where local capacity to adapt is built in part through accessing their knowledge. The scale and range of what this can achieve is increased with local governments' support; simply shifting the burden of adaptation to the community level is unlikely to bring success. [8.4] It is now more common for local and national governments to work with the inhabitants of informal settlements to install or upgrade infrastructure and services and address insecure tenure; this can strengthen social capital creation processes and build their resilience to climate change impacts. [8.4] Enabling community-led adaptation can be challenging and depends on a number of factors including representativeness of leadership, supportive local governance, community organizations' ability to pressure government and other stakeholders to respond to their concerns, as well as a recognition of the limits of community-based intervention. [8.4, 8.5]

Effective local action requires coordinated support from higher levels of governments and other stakeholders (*medium agreement* supported by *medium evidence*). To be effective adaptors, urban governments need a mandate around climate change adaptation via supportive policy and enabling legislative frameworks from higher levels of governments (including national, supra-national and state/provincial levels). Universities and research institutions, multilateral and bilateral agencies, financial and insurance and other private sector agencies have successfully assisted urban governments and households to mobilize around climate adaptation. Since effective adaptation for urban centres needs local responses and includes major roles for local governments and civil society (especially those representing those most at risk), consideration needs to be given to mechanisms by which international support for adaptation can work at scale while supporting local processes [8.4, 8.5] Large metropolitan areas and their rapid growth raise the level of complexity of managing adaptation, requiring action to be coordinated across multiple urban jurisdictions. The role of local government champions has often proved critical in providing initial leadership towards promoting and sustaining an adaptation agenda. [8.5] Although there is some evidence of innovative responses at the sub-national levels to plan for extreme weather events and climate change, limited local government capacity and experience suggests a need for support from higher levels of government. [8.4] A phased approach, whereby the most urgent matters, such as rapid-onset disasters, are prioritized first, leaving a longer time period to plan for slow-onset impactswhich may be associated with greater uncertainty, is most likely to attract local government attention. [8.5]

Building human and institutional capacity for urban climate resilience will accelerate implementation and improveoutcomes (*high confidence*). A binding constraint to effective and timely urban adaptation and building resilience is effective institutions and leadership across government, communities, civil society, knowledge institutions and the media. This can be addressed by a number of structural interventions to enable city-wide alliances and frameworks to be built, institutionalization of processes, building a culture of exchange between learning organizations and a strong emphasis on capacity building. [8.4] The locus of the climate change focal point in government has a strong bearing on its success. There is evidence of expanding urban adaptation leadership, but building a wide support base for adaptation across many sectors, in and outside of government to de-risk the impact of slow institutional development and leadership change is an important priority. Local or regional boundary organisations such as nearby academic or research communities have been shown to have influence and support policy decisions. Networking and sharing experiences among adaptation practitioners and between cities is also an important vehicle to improve city-level outcomes. [8.4, 8.5]

Adapting urban centres' economic base can enhance comparative advantage, deepen climate resilience and limit disadvantage (*high agreement*, supported by *medium evidence*). Climate change will shift the comparative advantages of cities and regions and differentially threaten or enhance the resource, asset and economic base and so lead to significant structural changes and impacts on local, national and potentially the global economy. Effective adaptation can protect a city's economic base via a mix of strategies. These include extreme weather exposure reduction via effective land-use planning, selective relocation and structural measures; reduction in the vulnerability of lifeline infrastructure and services (water, energy, waste management, food, biomass, mobility, local ecosystems and telecommunications) and measures to assist vulnerable sectors and households; mitigation of business interruption and capital stock losses and support to the 'waste economy' and the 'green economy'. These may be easier and cheaper to implement in new and peri-urban developments. [8.3]

There is limited commitment to and development of urban climate adaptation finance (*high agreement* and *low evidence*). Available finance for urban adaptation span domestic and external public and private sources. Domestic public funding can be raised through a variety of measures ranging from urban fiscal policies (where there is capacity to do this) to revenue transfers from national (and often provincial or state) government. External public funding can come from traditional development finance sources (i.e. multilateral development banks and bilateral development co-operation partners). The need for urban adaptation investments will far exceed available public funding. Smaller cities and other urban centres with weak and fragmented governance structures may be least equipped to access available climate change funding, even as they house some of the most vulnerable populations. Domestic private investment by individuals, households and businesses is expected to be the most sustainable and significant source of funding for adaptation. Its effectiveness depends on what local and higher-level governments do to encourage and support this, as well as helping deliver infrastructure and services. Hence, a range of innovative fiscal instruments, measures to attract 'climate-smart 'public and private investment and micro-insurance coverage of lower-income households, risk transfer mechanisms and innovative market-based insurance coverage, will be needed to address climate adaptation finance needs. This will need a supportive public policy environment to enable efficient market resource allocation to promote adaptation and overcome persistent market barriers. It also needs frameworks for land-use management to ensure appropriate economic and livelihood development incentives, avoid high-risk zones and implement appropriate building and infrastructure standards. A growing share of current development finance is being committed (in principle) to adaptation, especially towards technological investment and capital projects. However, mechanisms are not yet in place to ensure that it supports locally-driven adaptation practice in urban centres. There is a need to reconcile top-down and bottom-up planning, enabling structured planning, programming and outcome monitoring. A key to improving effectiveness of international public finance will be building the capacity for country-led planning processes that include urban adaptation and are backed by adaptation monitoring and data collection, designed specifically for the complexity of urban projects. The systematic programming of adaptation into international humanitarian and disaster response funding is still to develop. In addition, most national Action Plans under the UNFCCC have little emphasis on urban adaptation. Thus, urban climate adaptation financing and structuring remains an area where innovation and improvement are much needed to deliver demand-driven and responsive solutions, while catering to local contexts and possibilities. [8.4, 8.5]

8.1. Introduction

8.1.1. Key Issues

Successful adaptation to climate change depends centrally on what is done in urban centres – that now house more than half the world's population and concentrate most of its assets and economic activities. As 8.4 emphasizes, this needs to include responses by multiple levels of government, individuals and communities, the private sector and civil society. The serious impactsof extreme weather on many urban centres each year show risks and vulnerabilities that need to be addressed and climate change will usually add to these. What is done in urban centres also has major implications for mitigation, especiallyfuture levels of greenhouse gas emissions and for delivering co-benefits, as discussed in WGIII. This chapter focuses on the connections between urban centres and climate change and on the possibilities for governments, enterprises and populations to adapt to and develop resilience to its direct and indirect impacts.

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

In reviewing adaptation needs and options for urban areas, the documentation points to two key conclusions. The first is how much the adaptive capacity of a city depends on: past plans and investments in infrastructure and services; existing capacities for such investments and land-use management; and for ensuring buildings meet health and safety standards. This provides the foundation for city resilience on which adaptation can be built. For almost all urban centres in low-income and many in middle-income nations; there is little of this foundation of resilience. The second is the importance of city and municipal governments acting now to incorporate climate change adaptation into their development plans and policies. But to do so requires not only building the foundation of resilience (and its institutional and financial underpinnings) but also to mobilize new resources and continuously develop local capacities to respond. This is not to diminish the key roles of other actors including the private sector, the demands and priorities of residents, civil society and higher levels of government. But it will fall to city and municipal government to provide the scaffolding and regulatory framework within which all other stakeholders contribute and collaborate. Thus, adaptation in urban areas depends heavily upon the competence and capacity of local governments and a locally rooted iterative process of learning about changing risks and opportunities, identifying and evaluating options, making decisions, and revising strategies in collaboration with a range of actors (see Chapter 2 for more discussion of this).

8.1.2. Scope of the Chapter

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

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

8.1.3. Context – An Urbanizing World

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

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

There is an economic logic underpinning most urbanization as all wealthy nations are predominantly urbanized and as rapid urbanization in low- and middle-income nations is usually associated with rapid economic growth (ibid). Most of the world's largest cities are in its largest economies (ibid). If rapid urbanization and rapid city population growth is associated with economic success, it suggests that more resources can be drawn on to support adaptation. But in most urban centres in low- and middle-income nations, including many successful cities, local governments have been unable to keep up with the economic and physical expansion and there are large deficits in provision for infrastructure and services that have relevance for climate change adaptation. Around one in seven of the world's population live in poor quality, overcrowded accommodation in urban areas with inadequate or no provision for basic infrastructure and services and mostly in informal settlements (UN-Habitat 2003, Mitlin and Satterthwaite 2013). Within the world's urban population, it is in these settlements that much of the risk and vulnerability to climate change is concentrated. And a substantial proportion of these settlements are in economically successful cities (Mitlin and Satterthwaite 2013). So this chapter is concerned not only with an adaptation deficit for urban centres but also with a development deficit that has relevance for risk and vulnerability to climate change.

Many aspects of urban change in recent decades have been so rapid that they have overwhelmed government capacity to manage it. Of the world's cities with 750,000 plus inhabitants in 2010, 52 had populations growing more than twenty fold since 1960 and 116 had populations growing more than tenfold (statistics in this paragraph drawn from data in United Nations 2012). The increasing concentration of the world's urban population and its largest cities outside the nations with the highest incomes that Table 8-1 shows represents an important change. Over the 19th and 20th centuries, most of the world's urban population and most of its largest cities were in its most prosperous nations. Urban areas in low- and middle-income nations now have close to two-fifths of the world's total population and close to three-quarters of its urban population. They also have most of the world's large cities. Of the 23 'mega-cities' (cities whose population was reported to exceed 10 million) by 2011, only 5 were in high-income nations (two in Japan, two in USA, one in France). Of the remaining 18, four were in China; three were in India and two in Brazil. However, over three fifths of the world's urban population is in urban centres with less than 1 million inhabitants and it is in these that much of the growth in urban population is occurring.

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

One difficulty that this chapter faces is in providing a summary of trends for settlements that have more than half the world's population when there is such diversity among these in terms of their current vulnerability to extreme weather, the scale and nature of risks that climate change is bringing or will bring (and who is most at risk), the extent to which their population lives in good quality homes served with conventional infrastructure and services that provides the basis for adaptation (what this chapter terms accumulated resilience) and the extent to which their governments are acting or able to act on adaptation and being supported to do so by higher levels of government and where needed international agencies. Table 8-2 illustrates this diversity and how each urban centre falls within a spectrum in at least four key factors that influence adaptation: local government capacity, the proportion of the population served with risk-reducing infrastructure and services; the proportion of the population living in housing built to appropriate health and safety standards; and the levels of risk from climate change's direct and indirect impacts. This chapter also draws on detailed case studies of three cities to illustrate this diversity – New York (Solecki 2012a), Durban (Roberts and O'Donoghue, 2013) and Dar es Salaam (Kiunsi, 2013).

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

Many attributes of urban centres can be measured and compared. Populations vary from a few thousand inhabitants (or a few hundred in some nations) to the largest cities with 20-36 million inhabitants. Areas vary from less than one to thousands of square kilometres. Average life expectancy at birth for urban centres varies from over 80 years to under 40 years – and under-five mortality rates vary by a factor of 20 or more (Mitlin and Satterthwaite 2013). Average per capita incomes vary by a factor of at least 300; so too do the investment capacities of urban governments (UCLG 2011). Greenhouse gas emissions per person vary by more than 100 (Dodman 2009, Hoornweg et al. 2011). There are large differences between urban centres in the extent to which their economies are dependent on climate-sensitive resources (including commercial agriculture, water and tourism).There are also large variations in the scale and nature of impacts from extreme weather. As Table 8-2 suggests, there are urban indicators that are relevant for accumulated resilience to climate change impacts (the proportion of the population with water piped to their homes, sewers, drains, health care and emergency services) but less so for the scale and nature of climate change related risks and for the quality and capacity of government.

Recent analyses of disaster impacts show that urban centres concentrate a high proportion of theworld's population most affected by extreme weather events (United Nations 2009, 2011, IFRC 2010). As shown in Table 8-2, a high proportion of such urban centres have local governments that lack the capacity to reduce such disaster risk and very large deficits in the infrastructure and institutions needed to do so. Their low-income households may require particular assistance due to greater exposure to hazards, lower adaptive capacity, more limited access to infrastructure or insurance, and fewer possibilities to relocate to safer accommodation as compared to wealthier residents. There are also many cities that have high resilience to extreme weather and have the infrastructure and institutions that can provide resilience to the exacerbation of extreme weather events and change in resource availabilities associated with climate change.

All successful urban centres have had to adapt to environmental conditions and resource availabilities, although local resource constraints have often been overcome by drawing resources and using sinks from 'distant elsewheres' (Rees 1992, McGranahan 2007); this includes importing goods that are resource intensive and whose fabrication involves high greenhouse gas emissions. The growth of urban population over the last century has also caused a very large anthropogenic transformation of terrestrial biomes. Urban centres cover only a small proportion of the world's land surface; Schneider et al 2009 suggested that they cover only 0.51 per cent of the total land area and among the world's regions only in Western Europe did they cover more than 1 per cent. However, their physical and ecological footprints are much larger, as urban based enterprises and consumers draw on a much larger land area. The net ecological impact includes the decline in the share of wild and semi natural areas from about 70 per cent to under 50 per cent of the land area. This was largely to accommodate the demand for crop and pastoral land to support human consumption, leading not only to a decrease in biodiversity but a threat to ecological services that support both rural and urban areas. Future projections (Seto et al 2012) suggest that if current trends continue, that urban land cover will increase by 1.2 million square kilometres by 2030. This would represent nearly tripling the global urban land from around 2000 and would result in a "considerable loss of habitats in key biodiversity hotspots" destroying the green infrastructure that will be key in helping areas adapt to the impacts of climate change (ibid page 16083)

Many of the challenges and opportunities for urban adaptation are derived from the central features of city life – the concentration of people, buildings, economic activities and social and cultural institutions (Romero-Lankao and Dodman 2011). A key part of urban centres' adaptive capacity is related to agglomeration economies. These are usually discussed in relation to the advantages for enterprises locating there. But the concentrations of people, enterprises and institutions in urban areas also provides potential agglomeration economies in lower unit costs for providing each building with piped water, sewers, drains and a range of services (solid waste collection, schools, health care, emergency services, policing) and bringing together people, communities and institutions to respond collectively (Hardoy et al. 2001). But these need to be acted on and to have local governments capable of acting on them. In most urban centres in low- and middle-income nations, these are not acted upon and the result is very large deficiencies in infrastructure and services. Although urban centres in high-income nations are much better served, there may also be particular challenges – for instance in addressing aging infrastructure and in adapting energy systems, the building stock and infrastructure and services to the altered risk set that climate change's direct and indirect impacts will bring (see Zimmerman and Faris 2010 and Solecki 2012a for discussions of this for New York).

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

8.1.4. Vulnerability and Resilience

For each of the direct and indirect impacts of climate change, there are groups of urban dwellers that face higher health and other risks (illness, injury, mortality, damage to or loss of homes and assets). This can be on the basis of age (for instance infants or elderly people's greater susceptibility to particular hazards such as heat waves) or health status (for instance those with particular diseases, injuries or disabilities that make them more susceptible to these impacts). Or it may be because they live in locations that face greater risks – for instance on coasts or by rivers where flood risks have increased or will increase. These are often termed vulnerable groups – although to state the obvious, these are only vulnerable to climate change impacts if the hazard poses a risk. Remove the vulnerable population's exposure to the hazard (e.g. drains preventing flooding) and there is no impact. Infants may face serious health risks when water supplies are contaminated by flooding but rapid and effective treatment for diarrhoea and quickly re-establishing availability of drinking quality water greatly reduces impacts (Bartlett 2008). There are also adaptations by individuals, households, communities, private enterprises or government service providers that may reduce risks or reduce exposure.

Although there are many definitions of vulnerability (see for instance Füssel 2007), these agree that it centres on an inability to avoid harm when exposed to a hazard – including an inability to avoid the hazard, anticipate it (and take measures to avoid it or limit its impact), cope with it and recover from it (bounce back) (see also the report Glossary). So vulnerable groups may be identified on the basis of any of these four factors. Adaptation can also include 'bouncing forward' as resilience is increased and so built to protect against future hazards and uncertainty about such hazards.

The term vulnerability is also applied to sectors that may includefood processing, tourism, water, energy and mobility infrastructure and their cross-linkages e.g. perishable commodities dependent on efficient transport. Much tourismissensitive to climate change as it may damage key tourist assets e.g. coral reefs and beaches or make particular locations less attractive to tourists because of changes in temperatures or increases in extreme weather. Oil price changes will affect travel costs.

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

8.1.4.1. Differentials in Risk and Vulnerability within Urban Centres

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

Where provision for adequate housing, infrastructure and services is most lacking, the capacity of individuals, households and community organizations to anticipate, cope and recover from the direct and indirect losses and impact of disasters (of which climate-related events are a sub-set) becomes increasingly important (see 8.4).Here, the speed of response and effectiveness of post-disaster response is especially important to those who are more susceptible and have less coping capacity. Their effectiveness depends on understanding the specific vulnerabilities, needs and priorities of different income-groups, age groups and groups that face discrimination, including that faced by women and by particular social or ethnic groups.

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

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

A literature discussing resilience to climate change for urban centres and what contributes to this has emerged in recent years - and this section draws on this literature (Miller 2007, Pelling 2011a, Leichenko 2011, da Silva et al. 2012, Tyler and Moench 2012, Brown et al. 2012). Although resilience is usually considered to be the opposite of vulnerability, vulnerability is often discussed in relation to particular groups within the population whereas resilience is more often discussed in relation to what helps protect them such as infrastructure or climate-risk sensitive land-use management. Addressing resilience for cities is also more than identifying and acting on specific climate change impacts as it looks to the performance of each city's complex and interconnected infrastructure and institutional systems and includes a capacity to withstand unexpected or unpredicted changes. When considered for cities, it is common for certain characteristics of resilience to be identified – for instance flexibility, redundancy, responsiveness, capacity to learn and safe failure (Moench et al., 2012, Tyler et al. 2012, da Silva et al. 2012, Brown et al. 2012). There is also recognition of the complexities of urban systems and the multiple inter-dependencies between different sectors that were noted above.

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

Cities in high-income nations and many in middle-income nations have become more resilient to extreme weather (and most other potential catalysts for disasters) through a range of measures that have responded to risks and to the political processes that demanded such responses (Satterthwaite 2011). This resilience has been built over many decades and often required intense political negotiation. The resilience accumulated through this in what was built and in the capacity of institutions provides resilience to some climate change impacts, even though the measures that built resilience were not in response to climate change impacts (see for instance Hardoy and Ruete 2013 on Rosario, Argentina).What strongly influences resilience to extreme weather for urban dwellers is the quality of buildings (homes and workplaces), the effectiveness of land-use planning and regulation to control development in flood-prone and other high risk areas, the quality and coverage for key infrastructure and services, early warning systems for extreme weather and adequate public response measures, whether their incomes are sufficient to invest part in resilience (living in healthy homes, life insurance, insurance for possessions and home, savings, pensions, asset ownership…), what safety nets are available if income is insufficient and the regulatory framework for ensuring the application of the above. Urban governments have importance for most or all of these, although their provision usually depended on changes at national level – for instance in legislation and in financial support (although political change at national level was also in part driven by political pressure from urban dwellers and innovation by city governments). Private companies or non-profit institutions may provide some of the key services and private companies have key roles in provision and often maintenance of infrastructure -but the framework for provision and quality control is provided by local government or local offices or national or provincial government.

A city's accumulated resilience can be assessed by the extent to which it has reduced hazards, reduced risk and reduced exposure, with particular attention to how this serves or protects vulnerable groups and at-risk areas. Also by the measures in place to enhance capacity to cope and adapt. Such an assessment can also consider how well this 'accumulated resilience' will serve climate change adaptation. Of course, there are hazards that city governments cannot reduce (for instance earthquakes) or that need global action (eg reducing greenhouse gas emissions).

Although the components of accumulated resilience were not in response to risks from climate change, the web of institutions and finances that produced and maintain them provide a base for climate change adaptation (and more broadly for resilience). Building and infrastructure standards can be adjusted if needed (there is infrastructure in place that can be adjusted - for instance increasing capacity for storm and surface water drainage systems), existing service provision can be adjusted for new risks or risk levels (measures to reach populations vulnerable to heat stress during heat waves and within heat islands) and city planning and land-use management can be adjusted to any new or heightened risk (keeping building and city expansion away from areas facing new risk levels).This can be supported by changes in private sector investments (over time shifting away from high-risk areas) and changes in insurance premiums and coverage. So the web of institutions and the buildings, infrastructure and services that have developed in response to non-climate change risks provide a foundation for developing resilience to climate change.They provide the basis on which to build adaptive capacity to withstand climate-change related direct and indirect disturbances. They can also go beyond this and "bounce forward" by building climate resilience through a mix of sound development, disaster risk reduction and ecosystem-based adaptation, rather than incremental adaptation interventions..

Whether they will do so depends on whether urban governments take this on – and whether the demands of their inhabitants and these inhabitants' capacity to organize and get change promote this; also whether the institutions and their complex inter-relationships have the capacity to learn. Obviously, the extent to which these provide or can provide resilience in the future also depends on global agreements that slow and stop the increases in risk from GHG emissions and other drivers of climate change.

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

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

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

Thus, resilience can be considered in relation to individuals/households, communities and urban centres. In each, it includes the capacity to take action that avoids a climate change impact (live in safe location, have a safe house, have risk reducing infrastructure), to take action before climate impact takes place to reduce its impact (especially relevant for extreme weather events), to cope with the impact and to bounce back (to the previous state) and to 'bounce forward' to a more resilient state that would lay the ground for transformative adaptation.For urban centres, bounce back includes a government capacity to rapidly restore key services and repair infrastructure and 'bounce forward' is building the socio-institutional processes and capacities that enable the accumulation of resilience.

8.1.5. Conclusions from the Fourth Assessment (AR4) and New Issues Raised by this Chapter

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

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

AR4 described how the interactions between climate change and global urbanization has led to concentrations of urban populations in low-income nations with weak adaptive capacity. It also described the interactions between climate change and a globalized economy that include long supply chains and impacts spreading from directly impacted areas and sectors to other areas and sectors through complex linkages. Many impacts will be unanticipated and total impacts are also poorly estimated by considering only direct impacts. Key global vulnerabilities include interregional trade and migration patterns.AR4's Chapter 7 also described how climate change impacts and most key vulnerabilities are influenced by local contexts including geographic location, the sensitivity to climate of enterprises located there, development pathways and population groups unable to avoid dangerous sites and homes.

Key risks 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 reduce risk and cope (development context). Climate change will increase demands on water and energy supplies and often on health care and emergency response systems.

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

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

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

8.1.5.1. Key Uncertainties and Research Priorities

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

- The limits to understanding and predicting impacts of climate change at a fine grained geographic and sectoral scale
- Inadequate knowledge on the vulnerabilities of urban citizens, enterprises and centres to the direct impacts of climate change, to second and third order impacts and to the interdependence between systems
- Inadequate knowledge on the adaptation potentials for each urban centre (and its government) and their costs and on the limits on what adaptation can achieve (informed by a new literature on loss and damage)
- Serious limitations on geophysical, biological and socio-economic data needed for adaptation including data on nature-society links and local (fine-scale) contexts (see for instance WMO 2008)
- Uncertainties about trends in societal, economic and technological change with or without climate change including the social and political underpinnings of effective adaptation
- Understanding the different impacts and adaptation responses required to rapid and slow onset disasters

8.1.5.2. What has Changed since AR4

There is now a much larger and more diverse literature on current and potential climate change risks for urban populations and centres and the vulnerabilities of different urban centres and their structure and functioning. There has also been a very large expansion in the literature on urban 'adaptation,' and on building resilience at city and regional scales. This includes a large increase in the number of city governments that have published documents on adaptation. There is more engagement with urban adaptation by some professions (including architects, engineers, urban planners and disaster risk reduction specialists). There are also books that focus specifically in climate change and cities with a strong focus on adaptation (see Bicknell et al 2009, Rosenzweig et al 2011a and UN-Habitat 2011a, Cartwright et al 2012). This makes a concise and comprehensive summary more difficult. But this has also produced more clarity in what contributes to resilience in urban centres and systems. Specifically:

- A more detailed understanding of key urban climate processes and improved analytical and down-scaled integrated assessment models at regional and city scale
- A more detailed understanding on the governance of adaptation in urban centres and the adaptation responses being considered or taken (including a large and important grey literature produced by or for city governments and some international agencies) and in many high-income and some middle-income nations, support for this from higher levels of government

- More nuanced understanding of the many ways by which poverty and discrimination exacerbates vulnerability to climate impacts (see also Chapter 13)
- More detailed studies for particular issues of built environment responses to promote adaptation (see for instance the growth in the literature on green and white roofs)
- More case studies of community-based adaptation in its potential contributions and in its limitations
- More consideration of the role of ecosystem services and of green and blue infrastructure in adaptation
- More considerations on the financing, enabling and supporting of adaptation for households and enterprises
- More on learning from innovation in disaster risk reduction
- A greater appreciation of the inter-dependencies between different infrastructure networks and of the need for adaptation both in 'hard' infrastructure and in the 'soft' institutions that plan and manage it.
- More examples of city governments and their networks contributing to national and global discussions of climate change adaptation (and mitigation) including establishing voluntary commitments (see for instance the Durban Adaptation Charter for local governments) and engaging with the Conference of Parties

8.2. Urbanization Processes, Climate Change Risks, and Impacts

8.2.1. Introduction

This section assesses the connections between ongoing urbanization and climate change in relation to patterns and conditions of climate risk, impact, and vulnerability. The focus is on urbanization and its local, regional and global environmental consequences and the processes that maylead to increased risk exposure, constrain people in high-risk livelihoods and residences, and generate vulnerabilities in critical infrastructure. Understanding urbanization and associated risk and vulnerability distributions is critical for an effective response to climate change threats and their impacts (Romero Lankao and Qin, 2011; Bulkeley, 2010;Solnit, 2008; Satterthwaite, et al., 2009; Vale and Campanella, 2005), promotion of sustainable urban habitats and the transition to increased urban resilience. There is a particular interest in the ability of cities to respond to environmental crises, and the resilience and sustainability of cities (Solecki et al., 2011, Solecki, 2012).

The section assesses the direct impacts of climate change on urban populations and urban systems. Together, direct climate impacts and shifts in urbanization change the profile of societal risk and vulnerability. Both can alter transition pathways that lead towards greater resilience and sustainable practices and the basis of how such practices are managed within a community. Understanding and acting on the connections between climate change and urbanization is crucial since changes in one can affect the other. We investigate a range of direct impacts including those on physical and ecological systems, social and economic systems, and coupled human-natural systems. Where relevant and fundamental to the understanding, cascading impacts (where systems are tightly coupled) and secondary (indirect) impacts also are noted.

8.2.2. Urbanization – Conditions, Processes, and Systems within Cities

8.2.2.1. Magnitude and Connections to Climate Change

Section 8.1 emphasizes how much conditions in urban centres vary, how they are influenced by the proportion of the population with incomes too low to allow them to afford food and non-food needs, the extent to which the whole population (and vulnerable groups within this population) are served by the basic infrastructure and network of services that should serve as the main reducers of risk, the extent to which their site is at risk from climate change impacts, and the competence, capacity and accountability of their government (Pelling,2003; Moser and Satterthwaite, 2008; Hardoy and Pandiella, 2009). Variations in these factors have important consequences for the process of climate change, for how climate change contributes to global environmental change, shaping impacts in urban areas, and for how cities might be able to respond (Stone, 2012; Rosenzweig et al., 2011a; Seto and Satterthwaite, 2010; Seto and Shepherd, 2009; US NAS, 2012; Güneralp and Seto, 2008).

Urbanization can be considered in relation to key qualities and parameters (spatial, temporal, and sustainability) to capture the shifting, complex interactions between climate change and urban growth within a global toregional context. Giventhe significant and usually rising levels of urbanization (see 8.1.3), more people will be exposed to impacts of climate change in urban areas, with a growing proportion being exposed in large centres and megacities (de Sherbinin et. al., 2007; Revi, 2007). Additionally, many smaller urban centres in Africa, Latin America and Asia are growing rapidly but are "often institutionally weak and unable to promote effective mitigation and adaptation actions" (Romero Lankao and Dodman, 2011: 14). It is in the urban centres in these regions with less than a million inhabitants where most population growth is expected (United Nations 2012). It is largely these that have limited institutional and financial capacity to address development challenges and incorporate adaptation and mitigation as elements of urban development.

Urbanization alters local environments via a series of physical phenomena that can result in problems such as heat islands and local flooding that can be exacerbated by climate change. It is critical to understand the interplay between the urbanization process, current local environmental change and accelerating climate change. For example, the past long-term trend in surface air temperature in urban centres has been found to be associated with the intensity of urbanization (Kalnay et al 2006; Ren et al., 2007; Fujibe, 2009; Kolokotroni et al., 2010; Chen et al., 2011; Iqbal and Quamar 2011; Fujibe, 2011; Rim, 2009; Santos and Leite 2009; Tayanc et al., 2009; Sajjad et al., 2009; Jung, 2008; He et al., 2007; Stone, 2007). Climate change can influence the dynamics of the microclimate associated with a given city and a city may likewise alter a localized region's climate. Some coupled processes that may be influenced by the interaction of urbanization and climate change include: changing the effect of urbanization (microscale to mesoscale) by strengthening and/or increasing the range of a UHI, altering small scale processes, such as a land-sea breeze effect, katabatic winds, etc.,modifyingsynoptic scale meteorology (e.g. changes in the position of high pressure systems in relation to UHI events), and the spatial extent and magnitude of climate change (on a city) resulting from global radiative forcing from GHGs.

The dense nature of many large cities (including megacities) produces pronounced urban influences on anthropogenic heat emissions and surface roughness. The level of this impact is linked to the level of wealth, energy consumption and micro and regional climate conditions. Anthropogenic heat fluxes for large cities can be very high: up to 50-500 W m^{-2} has been observed in a global analysis (Flanner, 2009; Allen et al., 2011) in London (Iamarino et al., 2011) and Singapore (Quah and Roth, 2012), with values locally reaching 1500 W m^{-2} in Tokyo (Ichinose et al., 1999). Under clear skies and light wind conditions, large cities can be more than 10°C warmer than surrounding rural environments (Oke, 1982). There is strong seasonal, diurnal, and meteorological variability in temperature which influences the level of significance that these urbanization related changes have on a specific city.

In a review of relationships between coastal megacities and environmental change, Grimmond (2011) found increasing evidence that cities can influence weather (e.g. rainfall, lightning) through complex urban land use–weather–climate feedbacks (see also Ohashi and Kida, 2002). Megacity impact on air flows, especially for coastal cities has been modelled, for New York and Tokyo (Holt et al., 2009; Holt and Pullen, 2007; Thompson et al., 2007). Megacities influence both internal city environmental and regional weather and air quality. Megacity-coastal interactions may also impact the hydrological cycle and pollutant removal processes through the development of fog, clouds, and precipitation in and around megacities and coastal areas (Landsberg, 1970; Ohashi and Kida, 2002; Shepherd et al., 2002). Other modelling efforts define building density and design and the scale of urban development are important local determinants of the influence of urbanization on local temperature shifts (Oleson et al., 2012; Trusilova et al., 2008).

The results of climate modelling exercises indicate an 'urban effect' that leads locally to higher temperatures and reduced humidity while additional warming also marginally increases rainfall over large cities. The replacement of vegetation with urban surface outweighs this positive impact to reduce the overall land carbon sink (Grimmond, 2011). With respect to temperature specifically, Jackson et al. (2010 and 2012) confirm that building material properties are influential in creating different urban climate temperature regimes, which have the potential to alter energy demand for climate control systems in buildings. These results suggest that climate impacts of large cities, including the megacities, are open to change should they be redesigned and use of energy-efficient building materials, passive design technologies and appropriate land-use are scaled up. Urbanization and climate change also will lead to other environmental impacts such as increased levels of surface runoff(Hamdi et al., 2011).

8.2.2.2. Spatiality, Physical Planning, and Climate Change

The pattern of urban spatial development is a critical factor in the interactions between urbanization, climate-related risks, and vulnerability. Urban form densities range from concentrated to dispersed, while most planned urban settlements exhibit declining population density outward from the urban core (Seto et al., 2010; Leichenko and Solecki, 2008). In cities with large fringe and unplanned settlements, this pattern can be reversed. In both cases urban growth is experienced through horizontal expansion and sprawl (United Nations2012; Hasse and Lathrop, 2003). Rapid urban population growth in the last decade has been increasingly marked by growth in vertical density (high-rise living, and working) in many nations, especially in Asia. Higher density living can offer opportunities for resource conservation but also challenges for planning and urban management (see 8.3.3.7).

Many large cities have developed into extended metropolitan regions across a wide range of settlement conditions from low, middle and high-income nations (Seto et al., 2010; Leichenko and Solecki, 2005). In such regions, this can force a multiplication of loci for economic activity, industry, educational excellence, and concentrations of poverty. It is often problematic for these multiple centres to interact in planned ways that can benefit from traditional scale economies, creating pressures for geographical, social, administrative and political fragmentation – leading to a transition from a city with a single centre to city metropolitan region with multiple centres and uni-polarity to multi-polarity which is typically observed in most large city development (Laquian, 2011).

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

Settlement patterns strongly shape conditions for climate change adaptation and mitigation (Stone et al., 2010; Biesbroek et al., 2009). For instance, within Toronto, per capita greenhouse gas emissions from housing and transport varied from 1.3 to 13 tCO_2 equivalent when comparing a dense inner-city neighbourhood with good access to public transport with a sprawling outer suburb (VandeWeghe et al., 2007, Hoornweg et al.,2011). Cities generate challenges for adaptation by concentrating people and assets in ways that increase climate-related risks and vulnerabilities. By the same token, urban areas create advantages to support resilience through the "economies of scale and proximity that they present for key protective infrastructure and services for risk-reducing governance innovations..." (Satterthwaite, 2009: 560). Higher-density development with adequate transport links can promote social integration and equity, particularly in cities where low-income households live in peripheral settlements (Dulal et al., 2011). Physical planning interventions can be combined with command-and-control measures (e.g. zoning), land use taxes, price mechanisms, and public education campaigns to promote sustainable transport and settlement patterns (Grazi and van den Bergh, 2008).

8.2.2.3. Temporal Dimensions: Rapid Onset, Slow Onset, Production Cycles

For any city or region, it is important to understand the connections between climate risk and vulnerability and the rate of change in aspects of urbanization including populations and households, urban spatial expansion, and redevelopment of existing urbanized areas. Urbanization is associated with changing dimensions of migration and materials flows both into and out of cities and within them (Grimm et al., 2008). The level of increase or in some cases decrease of these conditions, create a dynamic quality in cities. Urban risks are not static and will continue to change in the future. 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. For example in sub-Saharan Africa, the combination of relatively high population growth rates and increasing levels of urbanization (projected to reach 46 percent by 2030) will bring a corresponding rise in exposure to climate change impacts. The conflation of local environmental change resulting from urbanization with climate change shifts make the identification and implementation of effective adaptation strategies more difficult. For example, water shortages are already a chronic concern for many cities in low and middle income nations and this typically worsensas the population and demand continue to grow (Muller, 2007).Overlaying climate change-related reductions in supply or heightened uncertainties facing water managers with this existing instability creates the conditions for greater management and governance crises (Gober, 2010, Milly et al., 2008*)*.

8.2.2.4. Urbanisation and Ecological Sustainability

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

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

8.2.2.5. Regional Differences and Context-Specific Risks

Case studies and regional reviews assessing urban vulnerabilities to climate change have revealed diverse challenges and large differences in levels of adaptive capacity (Rosenzweig et al., 2011a; Hunt and Watkiss, 2011). For instance, discussions in African cities (Castan Broto et al., 2013; Simon, 2010; Kithiia, 2011) have highlighted the lack of capacity and awareness of climate change, as well as often extremely high levels of vulnerability among the continent's large and rapidly growing urban poor populations. Other reviews have considered cities in Latin America (Luque et al., 2013; Hardoy and Romero-Lankao, 2011), North America (Zimmerman and Faris, 2011), Europe (Carter, 2011), and China (Liu and Deng, 2011). Studies have analyzed Asian cities' health risks due to climate change (Kovats and Akhtar, 2008) and other urban vulnerabilities in South and Southeast Asia (Birkmann et al.,2010; Alam and Rabbani, 2009; Revi, 2009).

The global distribution of urban risks is highly context-specific, dynamic, and uneven between and within regions. Absolute exposure to extreme events over the next few decades will be concentrated in large cities and countries with urban populations in low-lying coastal areas, as in many Asian nations (McGranahan, Balk, and Anderson, 2007). Settlements located in river flood plains also are prone to flooding during extreme or persistent precipitation / severe storm conditions. Urban populations' exposure to climate change related risks is influenced by the scale of the population concentration in cities and the proportion of the population in urban areas. However, recent improvements in urban governance and rising wealth in Latin America (one of the world's most urbanized regions) have helped to strengthen adaptive capacity (Hardoy and Romero-Lankao, 2011).

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

8.2.3. Urbanization and Climate Change and Variability – Primary (Direct) and Secondary (Indirect) Impacts

Climate change will lead to increased occurrences and intensity of extreme weather events such as heavy rainfall, warm spells and heat events, drought, intense storm surges and associated sea-level rise (see SREX IPCC 2012; Hunt and Watkiss, 2011; Romero-Lankao and Dodman, 2011; Rosenzweig et al., 2011a). Physical factors such as topography and geo-hydrological conditions typically differentiate variations in the distribution of impacts within an urban area. Social (e.g. equity and justice issues), geographic (e.g. high density locations, suburban, exurban locations) and temporal (e.g. short, medium, and long term shifts) contexts should also be considered.

8.2.3.1. Urban Temperature Variation: Means and Extremes

Heat waves and warm spells will connect with urban heat island effects resulting in increased air pollution (Blake et al., 2011; Campbell-Lendrum and Corvalán, 2007) and may cause heat-related health problems (Hajat et al., 2010; see also 8.2.3.7). Conversely, widespread reduction in cold waves will induce shifts in heating demands (Mideksa and Kallbekken, 2010) and potential reduction in mortality from cold waves. Increased warming is predicted in a wide variety of cities including sub-tropical, semi-arid, and temperate sites with respect to human thermal comfort level (Thorsson et. al., 2011). For more discussion on cities and impacts of increased warming in specific regions refer to the regional chapters of this report. It is still unclear whether or not climate change will exacerbate the UHI phenomenon in cities (Oleson et al., 2012).

8.2.3.2. Urban Heat Islands

Urban heat islands are difficult to quantify and there is debate within the literature on how to define them (Stewart, 2011). Many studies indicate that the UHI will decrease or at least stay constant in the future (Oleson et al., 2012). In London, urban heat islands were observed with recorded night-time temperatures up to 7ºC higher in central London than in Wisley, a rural location 32 km to the southwest (Wilby, 2007). Although small urban centres may also experience the UHI, the extent of urban-rural temperature different are not linearally related to urban population size (Smith and Levermore, 2008). Studies have also linked the extent and expansion of urbanization with past UHI trends, urban heating, current variability, and projected climate change. Recent studies with physically based models such as Oleson (2012) and McCarthy et al. (2010) show mixed signals with reductions in UHI in many areas of the world and increases in some areas in response to climate change simulations. McCarthy et al. (2011) looks specifically at London and Manchester and does not find an increase in UHI in the 2050s.

Future projections of UHI under global warming conditions were conducted for Tokyo. The air temperature of Tokyo in August is projected to increase about 2ºC by the 2070s according to an average of 5 GCMs under the SRES A1b scenario (the range of uncertainty in GCMs is about 2ºC). Another warming of about 0.5ºC is projected due to the maximum possible land-use change. As a result, total UHI intensity is projected to increase from 1.5ºC to 2.0ºC through the 2070s (Adachi et al., 2012).

London's annual number of nights with heat islands stronger than 4ºC has increased by 4 days/decade since the late 1950s; meanwhile, the average nocturnal heat island intensity rose by just ~0.1ºC/decade over the same period (Wilby, 2007). Projections suggest that by 2050, London's nocturnal UHI in August could rise another 0.5°C, representing a 40 percent increase in the number of nights with intense UHI episodes (*ibid*). For New York City, climate change is expected to exacerbate the existing UHI conditions via increase of extended heat waves (Rosenzweig et al., 2009).

For cities in India, connections between urbanization and the development of UHI, and the implications with future climate have been defined (Mohan et al., 2011a; 2011b; 2012). Overall, there is evidence that a current trend of increasingly frequent extreme events will increase with climate change (Manton, 2010). The inter-comparison of the annual mean minimum temperatures of two stations within Delhi (Safdarjung and Palam) post 1970's onwards show that night time temperature trends are synchronized with the city's pace of urban expansion (Mohan et al., 2011b).

8.2.3.3. Drought and Water Scarcity: Means and Extremes

Drought can cause many impacts in urban areas, including increases in food prices and food insecurity because of reduced supply, water shortages, electricity power shortages for urban areas that depend mostly on hydropower and an increase in water related diseases; these may also lead to a wide set of economic impacts as well as increased rural to urban migration (Farley et al., 2011; Herrfahrdt-Pahle, 2010; Vairavamoorthy et al., 2008). Averaging across all climate changescenarios, recent findings suggest that nearly 100 million more city-dwellers "will live under perennial water shortage under climate change conditions than under current climate" (McDonald et al., 2011:2). The study also notes the role of demographic growth: The model results show that currently 150 million people live in cities with perennial water shortage, defined as having less than 100 L per person per day of sustainable surface and groundwater flow within their urban extent" and by 2050, this figure could increase to almost 1 billion (ibid.). Drought and water scarcity also affect cities in high-income countries. A detailed economy-wide, 70-industry analysis of the economic impacts of climate change on water availability in the USA for 2010 through 2050 highlighted the interacting industry-level effects, employment impacts, consequences to personal income, and ramifications for the U.S. Gross Domestic Product (GDP). When compared to a baseline economic forecast, the calculations produced an average risk of damage of $1 trillion to the U.S. economy from climate change over the 40 years, with losses in employment equivalent to nearly 7 million full-time jobs (Backus et al., 2012).

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

Sea-level rise represents one of the primary shifts in urban climate change risks, given the increasing concentration of urban populations in coastal locations and within low-elevation zones (McGranahan et al., 2007). Rising sea levels, the associated coastal and riverbank erosion, or flooding in conjunction with storm surge could all lead to widespread impacts on populations, property and coastal vegetation and ecosystems, and threats to commerce, business, and livelihoods (Nicholls 2004, Hanson et al., 2011; Carbognin et al., 2010; Pavri et al., 2010; El Banna and Frihy, 2009; Zanchetting, 2007; Dossou and Glehouenou-Dossou, 2009). It is the lowland areas in coastal cities such as Lagos, Mombasa, or Mumbai that are usually more at risk of flooding, especially if a city also has less provisions for drainage (Adelekan, 2010; Awuor et al., 2008; Revi, 2009). Structures constructed on infilled soils in the lowlands of Lagos, Mumbai and Shanghai are more exposed to risks of flood hazards than similar structures built on consolidated materials (*ibid.*). Many coastal cities have sites at risk from both riverine and coastal storm surge (Mehrotra et al., 2011a).

Cities with extensive port facilities and large scale petro-chemical and energy related industries are vulnerable to climate change's increased flooding potential. Hanson et al. (2011) estimate the change in flooding, by the 2070s in the exposure of large port cities to coastal flooding with scenarios of socio-economic growth, sea level rise and heightened storm surge, and subsidence. They find that population at risk could more than triple while asset exposure is expected to increase more than ten-fold with a 0.5 meter rise in sea-level. The study identifies the "top-20" cities for both population and asset exposure to coastal flooding. The high risk cities in both the current and 2070 rankings are spread across low, middle, and high-income nations, but are concentrated in Asian deltaic cities.

The cities include: Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, New York, Osaka-Kobe, Alexandria, Tokyo, Tianjin, Bangkok, Dhaka, and Hai Phong. Using asset exposure as the metric, cities in high-income nations and in China figure prominently - Miami, New York City, Tokyo and New Orleans as well as Guangzhou, Shanghai and Tianjin. These analyses which highlight the large number of assets and population which will be exposed and vulnerable underscores the need for long-term urban risk reduction measures.

8.2.3.5. Inland Flooding and Hydrological and Geo-Hydrological Hazards at Urban Scale

The exposure to climate related hazards will vary due to differences in the geomorphologic characteristics of the city (Luino and Castaldini, 2010). Heavy rainfall and storms surges would impact urban areas through flooding which in turn could lead to the destruction of properties and public infrastructure, contamination of water sources, water logging, loss of business and livelihood options and increase in water borne and water-related diseases as noted in wide range of studies (Revi, 2007; Dossou and Glehouenou-Dossou, 2007; Kovats and Akhtar, 2008; Sharma and Tomar, 2010; Adelekan, 2010; Hardoy and Pandiella, 2009; de Sherbinin et. al., 2007; Douglas et al., 2008; Roberts, 2008; Nie et al., 2009; Shepherd et al., 2011). Case studies of inland cities have considered the elevated risk of flooding due to climate change, such as in Kampala (Lwasa, 2010; Lwasa, 2013) and travel disruptions in Portland (Chang et al.,2010). Significant research focus has been on attempts to improve modeling of the frequency and condition of extreme precipitation events and resulting flooding (Ranger et al., 2011; Onof and Arnbjerg-Nielsen, 2009; Nelson et al., 2009; Olsson et al., 2009; Sen, 2009).

8.2.3.6. Air Pollution: Means and Extremes

Climate change is associated withimplications for urban air quality (Athassiadou et al., 2010), air pollution, and health policy (see Chapter 11 of WGI AR5 for more discussion). Urban air quality in most cities already is compromised by localized air pollution from industry andtransportation, and often commercial and residential sources. Air quality can be adversely affected by limited ventilation within and aroundstructures. Emerging literature on climate change and air quality shows that there is strong evidence that climate change would generally increase ozone in the US and Europe, but that the pattern of that change is not clear, with some areas increasing and some decreasing. The effects on particulate matter (PM) are also unclear, as are the effects on ozone and PM outside of the US and Europe. Effects on particular urban areas are highly uncertain and may include increases and decreases of certain pollutants (Weaver, 2009; Jacob and Winner, 2009).

8.2.3.7. Emerging Human Health, Disease, and Epidemiology Issues in Cities

Good evidence exists that temperature extremes (heat and cold) affect health, particularly mortality (see 11.2.2). The impacts vary by setting, but populations in urban areas appear more sensitive to heat effects than rural areas in temperate zone countries. Since AR4, there have been more studies on urban populations in low and middle income countries (see for instance Burkart et al 2011 for urban populations in Bangladesh and Egondi et al 2012 for children and non-communicable disease deaths in Nairobi's informal settlements). Heat waves are known to have significant impacts on health that can be exacerbated by drought conditions or high humidity. Studies in high-income countries suggest a greater vulnerability among the elderly to heat-related mortality (see Åström et al 2011 for a review of this). In urban settings where child mortality is high, high and low temperatures have been shown to have an impact on mortality (e.g. Egondi et al. 2012). Furthermore, some occupations are more at risk as they are exposed to higher temperatures for long durations and low-income households are more at risk when heat waves disrupt or limit income-earning opportunities (Kovats and Akhtar 2008) (see also 11.2.7 for more detailed discussion of occupational heat stress).

WHO (2012) notes that climate change may affect the future social and environmental determinants of health, including clean air, safe drinking water, sufficient food and secure shelter. All these are relevant to urban areas. Increased risks from water scarcity, heat waves and flooding were discussed ready. The incidence of asthma exacerbation may be affected by any climate-change related increases in ground level ozone exposures (Barata et al., 2011; O'Neill and Ebi, 2009; Reid et al., 2009; Gamble, 2009b; Kinney, 2008); other pollutants may also be affected particularly in those cities with PM10 and ozone levels far above WHO guidelines (WHO 2011b). Climate change may affect the distribution, quantity, and quality of pollen in urban areas, as well as altering the timing and duration of pollen seasons. WHO (2012) also noted that diarrhoeal diseases, malnutrition, malaria and dengue are climate-sensitive and in the absence of appropriate adaptation responses, could be adversely affected by climate change (see chapter 11).

8.2.4. Urban Sectors: Exposure and Sensitivity

This section assesses how the observed and forecasted direct impacts of climate change influence the exposure of city residents, infrastructure, and systems to risk by considering key affected sectors and populations and possible interrelations. Direct impacts 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 (see UN-ECLAC 1991). Both the temporal and spatial scale of the shifts in climate risk across cities and urbanizing sites in the next few decades are considered. In addition, we analyze how the scale and character of risks change and grow in cities as shifts in climate extremes, means and long-term trends (e.g. sea-level rise) take place.

Climate change will have profound impacts on a broad spectrum of city functions, infrastructure, and services and will interact with and potentially exacerbate many existing stresses. These impacts can occur both *in situ* and through long-distance connections with other cities and with rural locations, such as sites of resource production and extraction (Seto et al., 2012; Satterthwaite et al., 2010). The interaction between climate change and existing environmental stresses can lead to a range of synergies, challenges, and opportunities for adaptation with complex interlinkages and often highly uncertain or non-linear processes (Ernston et al., 2010). For example, the 2007 floods in the city of Villahermosa covered two thirds of Tabasco State in Mexico with serious consequences for the city’s economic base. Regional damages and asset and infrastructure losses amounted to US$ 3.1 billion, equivalent to 30 percent of the state annual GDP (CEPAL, 2008). The flood that struck the Chao Phraya River in 2011 not only caused a high loss of life and damages to many companies and several industrial estates in Bangkok but also had a wider economic impact because of the disruption to industrial supply chains (Komori et al 2012).Urban centres serving prosperous agricultural regions are particularly sensitive to climate change if water supply or particular crops may be at risk. In Naivasha, Kenya, drought threatens high-value export oriented horticulture (Simon, 2010). Urban centres that serve as major tourism destinations may suffer when the weather becomes stormy or excessively hot and lead to a loss of revenue.

Similarly, infrastructure will be impacted by systemic and cascading climate risks (Hunt and Watkiss, 2011). Climate stresses, particularly extreme events, will have effects across interconnected urban systems – both within and across multiple sectors (Gasper et al. 2011). The cascading effects of climate change are especially evident in the water, sanitation, energy and transportsectors, due to the often tightly-coupled character of urban infrastructure systems (see Rosenzweig and Solecki 2010 for a discussion of this for New York City). The U.S. National Climate Assessment effort has looked at the impacts of climate change on infrastructure considering the water, land, and energy nexus, as well as on a large number of industries (Skaggs et al., 2011; Wilbanks et al., 2012). These systemic cascades can have both direct and indirect economic impacts (Hallegatte et al., 2011; Ranger et al., 2011) which can extend from the built environment to urban public health (Frumkin et al., 2008; Keim, 2008).

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

Recent assessments have projected the rising population and asset exposure in large port cities (see 8.2.3.4; also Hanson et al.,2011; 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).

8.2.4.1. Water Supply, Wastewater, and Sanitation

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). Climate change will impact residential water demand and supply and its management (O'Hara and Georgakakos, 2008).Among the projected impacts of climate change on water are: altered precipitation and runoff patterns in cities, sea level rise and resulting saline ingress, constraints in water availability and quality, and heightened uncertainty in the assumptions that underpin long-term planning and investment in water and waste water systems (Muller, 2007; Fane and Turner, 2010; Major et al., 2011).Local government departments and water utilities responsible for water supply and waste water management must confront these new climatic patterns and major uncertainties in availabilities and learn to respond to a dynamics and evolving sets of constraints (Milly et al.,2008).

Climate change will increase the risk and vulnerability of urban populations to groundwater and aquifer quality reduction (e.g. Praskievicz and Chang, 2009; Taylor and Stefan, 2009) and subsidence and increased salinity intrusion. High levels of groundwater extraction have led to serious problems of subsidence in cities such as Bangkok (Babel et al 2006) and Mexico City (Romero-Lankao 2010) that damages buildings and fractures pipes and can increase flood risks (see also Jha et al., 2012). This problem can be compounded in coastal cities when saline intrusion reduces ground water quality and erodes structures.

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

In Shanghai, climate change is expected to bring decreased water availability, as well as flooding, groundwater salinization and coastal subsidence. The city's population of 17 million is projected to continue expanding, often within areas that are "likely increasingly flood-prone" (de Sherbinin et al. 2007: 60). Groundwater depletion has contributed to land subsidence in these already vulnerable areas, reinforcing the water stresses and risks of erosion, but Shanghai's wealth and correspondingly greater adaptive capacity may help to manage these complex risks *(ibid.)*. In several large Andean cities, declining volumes of glacial melt water and expected further declines have been observed for several cities (Chevallier et al. 2011; Buytaert et al. 2010).

Several studies estimate how climate change will alter the relationship among water users and the implied tensions over the supply and the demand for water (Tidwell et al., 2011; Roy et al., 2012). Large-scale critical infrastructure such as sanitation systems for cities (e.g. Cape Town – Ziervogel et al., 2010) may also be affected. In small and mid-sized African cities, threats from floods on drinking water quality taken fromwells, is a growing concern (Cisse et al., 2010).

Water shortages will exacerbate existing tensions and conflicts between the various end-uses (residential, commercial, industrial, agricultural, and infrastructural) (Tidwell et al., 2011; Roy et al., 2012).Floods, droughts and heavy rainfall have also impacted agriculture and urban food sources, and climate change can exacerbate food and water scarcity in urban areas (Gasper et al., 2011). Some water systems, under some scenarios and short-term time frames, are not projected to experience negative impacts. For instance, Chicago's Metropolitan Water Reclamation District (MWRD) found that reduced precipitation due to climate change would decrease pumping and general operations costs, since sewers will contain less rainwater in drier seasons (Hayhoe et al.,2010).

Wastewater and sanitation systems will be increasingly overburdened during extreme precipitation events if attention is not paid to maintenance, the limited capacity of drainage systems in old cities, or the lack of any provision for drainage in most unplanned settlements and in many urban centres (Howard et al., 2010; Wong and Brown, 2009, Mitlin and Satterthwaite 2013). In the city of La Ceiba in Honduras, stakeholders concluded that addressing urban drainage and improved management of the Rio Cangrejal watershed were top priority for protecting the population against projected climate change impacts; the city lacks a stormwater drainage system but experiences regular flooding from heavy rainfall and storm surges (Smith et al., 2011). Flooding is often made worse by uncontrolled city development that cause natural drainage channels and flood plains to be built over and a failure to maintain drainage channels (and their blockage by solid wastes where there is no waste collection service). These problems are most evident in urban centres in low- and middle-income nations and where there are no drains or sewers that can help cope with heavy precipitation (see Douglas et al 2008) and no service to collect solid wastes (many cities in low-income nations have less than half their population with a regular solid waste collections service – see Hoornweg and Bhada-Tata 2012). Many cities in high-income nations also face challenges. An analysis of three cities in Washington State sought to assess future streamflows and the magnitudes of peak discharges, concluding that “concern over present (drainage) design standards is warranted” (Rosenberg et al., 2010: 347). Climate change was identified as one of the key drivers affecting Britain’s future sewer systems (Tait et al., 2008). According to a model of urbanisation and climate change impacts in an urban catchment, the volume of sewage released to the environment by combined sewage overflow spills and flooding was projected to increase by 40% (ibid).

8.2.4.2. Energy Supply

Since energy exerts a major influence on economic development, health, and quality of life, any disruption or unreliability in power or fuel supplies due to climate change can have far-reaching consequences. Most urban businesses (from the largest to many home-based enterprises), infrastructure, services (including healthcare and emergency services) and residents rely heavily on power supplies (Findland Safety Investigations Authority, 2011; Halsnaes and Garg, 2011; Hammer et al., 2011). This is also true for water treatment and supply, rail-based public transport, road traffic management and often flood-protection measures (Jollands et al.,2007). Power interruptions in communication networks can pose problems for rescue and emergency services that rely on telecommunications for their operations (Safety Investigations Authority of Finland, 2011).

Past experiences with power outages indicate some of the knock-on effects (Chang et al., 2007). 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). Low-income households in Chittagong utilize candles or kerosene lamps during the city’s frequent power outages, which were found to disturb children’s studies, increase expenses, and overheat homes (Rahman et al., 2010). A review of climate change impacts on the electricity sector (Mideksa and Kallbekken, 2010) projects reductions in the efficiency of cooling for thermal power, changes in hydropower and wind power potential, and changing demand for heating or cooling in the US and Europe.

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

Climate change will alter the patterns of urban energy consumption, particularly with respect to electricity demand and/or energy needed for cooling or heating (for a review see Mideksa and Kallbekken, 2010). In settings with extensive air conditioning use, climate change will bring increases in air conditioning demand and in turn heightened electricity demand (Radhi,2009; see also Hayhoe et al.,2010 for a discussion of this in relation to Chicago). In temperate and more northern regions, winter temperature increases will bring decreases in energy demand for heating (Mideksa and Kallbekken, 2010). In most cases within individual cities, potential increases in summertime electricity demand from climate change will exceed reductions in winter energy demand reductions (Hammer et al., 2011).

Many cities' economies will be impacted if climate change induces water scarcity and variability that interrupt hydropower supplies. If climate changereduces Brazil's hydroelectric generation, this will have negative impacts on the economies of the many urban centres supplied in Brazil as well as across national to neighboring counties(Lucena et al., 2009; Lucena 2010; Schaeffer et al., 2009). Cities in sub-Saharan Africa often rely on hydropower for their electricity, and failures in hydropower supplies "can lead to a more general 'urban failure' " (Muller, 2007). Discussing supply side concerns, Laube et al. (2006) identify water shortages in Ghana following low precipitation periods and competition with hydropower between energy and water provision including to downstream urban centres as a possible impact. 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).

Summer heat waves are associated with spikes in demand with extensive use of air conditioning,resulting in brownouts or blackouts (Mideksa and Kallbekken, 2010; Mirasgedis et al., 2007).Cities in the temperate regions of Australia are already experiencing regular blackouts on hot summer days, largely due to increased residential air-conditioner use (Maller and Strengers, 2011). Research in Boston (Kirshen et al., 2008) suggested that rising energy demands in Boston's hotter summers have a "disproportional impact on (the) elderly and poor,increased energy expenditures; loss of productivity and quality of life" (*ibid:*241). Any increase in the frequency or intensity of storms may disrupt electricity distribution systems because of the collapse of power lines and other infrastructure (see for instance Rosenzweig et al., 2011a; 2011b; 2011c; see also Chapter 10).

8.2.4.3. Transportation and Telecommunications

Climate change related extreme events will affect transportation and telecommunication infrastructure including a variety of capital stock in urban areas such as bridges, roads, railways, pipelines, and port facilities, data sensors, and wire and wireless networks (Major et al., 2011; Jacob et al., 2011; Hallegatte et al., 2011; Koetse and Rietveld, 2009). Assessing possible disruptions of transport networks within cities and urban systems is critical. Loss of telecommunication access during extreme weather events can inhibit disaster response and recovery efforts because of its critical role in providing logistical support for such activity (Jacob et al., 2011).

The literature on transport and climate change focuses more on mitigation, with limited attention within the urban literature to adaptation (Hunt and Watkiss, 2011). Existing studies on climate change impacts are often limited to the short term demand side, particularly in passenger transport (Koetse and Rietveld, 2009). However climate change creates several challenges for transport systems. The daily functioning of most transport systems is already sensitive to weather fluctuations including extreme precipitation, temperature, winds, visibility, and for coastal cities, rising sea levels with the associated risks of flooding and damages (Mehrotra et al., 2011b; Love et al., 2010). Transport is thus highly vulnerable to climate variability and change, and the economic importance of transport systems has increased with the rise of just-in-time delivery methods, heightening the risk of losses due to extreme weather (Gasper et al., 2010). In addition to adapting road transport, it will be necessary to ensure bridges, railway cuttings, and other hard infrastructure are resilient to climate change over their service lifespan (Jaroszweski et al., 2010). For railways, few studies have examined the effects of climate change but weatherrelated rail system failures may be caused by high temperatures, icing, and storms (Koetse and Rietveld, 2009; see also Dobney et al 2010 for future heat related delays in UK railways). Very few studies have examined the vulnerability of air and seaborne transport and infrastructure. The impacts of climate change could translate into a greater number and longevity of weather-related delays with extreme weather possibly occurring more frequently and more severely. This would bring further disruptions for aviation (Eurocontrol, 2008) and maritime transport (Becker et al., 2012).

Most cities in low and middle-income nations are still developing their transport systems (Dimitriou and Gakenheimer, 2011), especially in their largerand more rapidly growing cities.For example, Asian cities and the transportation networks located within and around them are often at risk from extreme weather events (Regmi and Hanaoka, 2011). India's transportation 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) to maximise co-benefits and synergies and minimise trade-offs (Biesbroek et al., 2009; Hamin and Gurran, 2008).

Loss of sea ice can benefit some cities as it increases opportunities for developing road networks or ports, although it may be costly to adapt the road, air and water transport networks in addition to the known environmental risks associated with such redevelopment (Larsen et al., 2008). For industries and communities in Northern Canada, reduced freshwater-ice levels creates economic benefits such as longer shipping seasons (Prowse et al.,2009). Lost sea ice could also promote new seaports in marine environments, but inland towns require sizable investments in land-based roads to replace winter ice roads that formerly utilised small lakes and stream networks (ibid.). Thawing of permafrost can result in instability and major damage to roads, infrastructure, and buildings in and around northern cities and towns (ibid.).

The direct impacts of extreme weather on transportare often more easily assessed than the indirect impacts or possible knock-on effects between systems. Studies have often examined the direct impacts of flooding upon transport infrastructure, but the indirect costs of delays, detours, and trip cancellation “may also be substantial” (Koetse and Rietveld, 2009). During Mumbai’s 2005 floods, there were serious direct impacts in terms of injuries, deaths and property damage but also serious indirect impacts as most city services were shut down for 5 days without contact via rail, road or air (Revi, 2005). Transport and other urban infrastructure networks are often interdependent and located in close physical proximity to one another (Kirshen et al., 2008). Yet only a few assessments have jointly considered the impacts upon transport and other associated sectors (Hayhoe et al.,2010 for Chicago, Kirshen et al.,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).

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

8.2.4.4. Built Environment, and Recreation and Heritage Sites

Good quality housing should provide its occupants with a comfortable, healthy and secure living environment and protect them from injuries, losses and damage (Haines et al. 2013). For many low-income households, home-based enterprises are also important components of livelihoods. As such, housing has a key role in protecting urban populations and their assets – and has particular importance for protecting vulnerable groups including infants and young children (Bartlett 2008), older residents or those with disabilities or chronic health conditions. This also means protection against displacement since low-income urban dwellers are particularly at risk from disruptions to household income.

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

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

The increased risks that climate change is bringing to the built environment (Wilby, 2007;Spennemann and Look, 1998) also means risks to the built heritage. This has led to the Venice Declaration on Building Resilience at the Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies which brings together UNESCO, UN-HABITAT, EC and individual city mayors. One example of this is Saint-Louis in Senegal, a coastal city that is also on the mouth of the Senegal river that has frequent floods and large areas at risk from river and coastal flooding. It is a World Heritage Site and there are initiatives to reduce flooding risks and to relocate families from locations most at risk but the local authority has very limited investment capacity (Diagne 2007, Silver et al., 2013).

8.2.4.5. Green Infrastructure and Ecosystem-based Adaptation

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 utilized for flood protection, food and urban agriculture and overall biomass production. Mombasa will experience more variable rainfall as a result of climate change, making initiating and expanding green infrastructure more difficult (Kithiia and Lyth, 2011). Trees in British cities will be increasingly prone to heat stress and to attacks by pests, including non-native pathogens and pests that could survive for the first time under warmer or wetter conditions (Tubby and Webber, 2010). Urban coastal wetlands will be inundated with sea level rise. In New York City, remnant coastal wetlands will be lost to sea-level rise because the wetlands will not be able to migrate inland due to bulk heading and intensive coastal development (Rosenzweig et al., 2012).

8.2.4.6. Health and Social Services

The effects of climate change will also be evident across several urban social and public services such as health and social care provision, education, police and emergency services including firefighting and ambulances (see Health, Chapter 11 in this volume for more discussion). Many low and middle-income cities lack adequate social and public service provision (Bartlett, 2008; Satterthwaite et al,2007) while higher-income cities are only beginning to consider climate change in their health or disaster management plans (Brody et al.,2010).Although there are few studies on adapting education, police, or other key services, a growing public health literature has discussed multi-sectoral adaptation strategies (Huang et al., 2011). Cities' existing public health measures provide a foundation for adapting to climate change, such as heat warning systems or disease surveillance (Bedsworth, 2009; McMichael et al., 2008). Negative climate impacts on some of the most vulnerable in society– the very young and children (Sheffield and Landrigan, 2011; Watt and Chamberlain, 2011; Ebi and Paulson, 2010) the elderly (Oven, 2012; White-Newsome et al., 2011) and the severely disadvantaged (Kenny et al., 2010; Ramin and Svoboda, 2009) have been highlighted (see Chapter 11)

8.2.5. Urban Transition to Resilience and Sustainability

The question of how to promote increased resilience and enhanced sustainability in urban areas (as illustrated in Table 8-2) has become a central research topic and policy consideration. What information is needed and what steps should be taken to promote this type of transition are central to this discussion. It is well recognized that climate change risks affect this process byheightening uncertainties and altering longstanding patterns of environmental risks in cities, many of which continue to face other significant stressors such as rapid population growth, increased pollution, resource demands, and concentrated poverty (Mehrotra et al., 2011a; Wilbanks and Kates, 2010). This section discusses how climate change increasingly affects municipal decision-making frames and alters local conceptions of cities as vehicles for economic growth, for political change, for meeting livelihoods and basic needs as well as larger-scale goals of resilience and sustainability.

8.2.5.1. Uncertainty and Surprise

Climate change will contribute to more uncertain and dynamic urban conditions, making past environmental responses and baselines less valuable for predicting cities' future environments (Solecki et al., 2010). It has been suggested that "the complexities and uncertainties associated with climate change pose by far the greatest challenges that planners have ever been asked to handle" (Susskind, 2010:219). Municipal and higher-level adaptation plans will need to take into account uncertainty about future climates and extremes. These will need to consider direct and indirect economic costs, including the trade-off of inaction and locking into ill-adapted infrastructure versus investment in adaptation when climate change is less than anticipated (Hallegatte et al., 2007). Several U.S. studies have considered the cost on inaction for specific states (Wilbanks et al., 2012, Niemi et al., 2009a, 2009b, 2009c, Repetto 2011a, 2011b, 2012a, 2012b, 2012c, 2012d, Backus et al., 2012). An obvious transitional management issue is related to the many urban wastes´ repositoriesaround current city boundaries.

Several decision-making settings in urban areas are influenced by shifts in the likelihood of extreme weather events and the need to respond to climate-related surprises. Water resource managers (Fane and Turner, 2010; Dessai and Hulme, 2007), insurance companies (Crichton, 2007; Botzen et al., 2010), public health, disaster, and emergency responders (Keim, 2008; Huang et al.,2011; Hess et al.,2009) will need to grapple with heightened climate-related uncertainties and the demands of climate proofing. Infrastructure planners need to adopt various strategies to incorporate uncertainty, such as selecting no-regret strategies, favoring reversible and flexible options, buying 'safety margins' in new investments, promoting soft adaptation strategies, and/or reducing decision time horizons (Hallegatte and Dumas, 2009). Other strategies include scenario planning, sensitivity analyses, and examining risk tolerances. New challenges also will arise. For example, the need to expand the agriculture frontier, for increasing food production, will bring agricultural activities closer to the urban boundaries. This means that the fumigation effects will add a new health hazard to urban inhabitants as well as adversely affect water supply.

8.2.5.2. Extreme Event Probability

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

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

8.2.5.3. Transitions

In recent years, different models of urban environmental transition (e.g. shifts from a sanitary city to sustainable city presented by McGranahan 2007) have been introduced to illustrate how the connections between health hazards and environmental impacts as cities and neighbourhoods develop. This includes the use of global and local sinks for wastes that are outside their boundaries (ibid, Wilson, 2012). Within these models, key variables have been identified that make cities vulnerable to climate change (e.g. extensive infrastructure networks, high density population in exposed or other sensitive sites). Established sustainability approaches e.g. compact cities, eco-regions, polycentric new-town planning systems, urban agriculture, development as a strategy for moderating urbanization (Williams et al., 2012) are among the most common transition strategies. These strategies often are associated with high, often limiting, redevelopment costs.

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

Transitions in the contextof climate change emerge in two situations. The first is a systems-level perspective where urban systems could reach a tipping point in which a failure or collapse could occur. The second is a broader scale societal transition to enhanced resilience and adaptive capacity (and attention to mitigation) in the face of accelerated climate change (Solecki and Murphy, 2013; Ernstson et al., 2010; Mdluli and Vogel, 2010; Tompkins et al., 2010; Gusdorf et al., 2008; Pelling, 2011a). The latter can often occur without resulting in a broader scale transition (Pelling and Navarrete, 2011) with incremental changes also potentially precipitating regime level shifts. Although such shifts can also happen as a result of discrete regime failure (Pelling, 2011a) this is less common. Such transformational changes have been observed in a variety of urban disaster contexts. Most often they follow urban earthquake events (e.g. in Nicaragua, Guatemala, Turkey) but are also associated with flooding in Bangladesh (Pelling, 2011a). Disasters can enable regime level change at moments in history where competing approaches to development have political voice, an organizational base that articulates competing analysis of the causes of the disaster and weak systemic counter response.

8.2.5.4. Social Dynamics, Economic Tensions, and Multiple Stressors

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

Specific tensions emerging from climate change impacts have been derived from studies connecting climate impacts with disaster recovery (Solecki et al., 2011). These tensions include temporary or permanent poverty; food insecurity; lack of access to freshwater; and shifts in the informal economy. Shifts in social dynamics include the possibility and aspiration that reconstruction and recovery can improve people’s livelihoods, changing the structure of the urban economy through the disaster cycle; changes in city administration; private and public property ownership; lifestyle (Coombes and Jones, 2010) and in more dramatic cases change in the urban centre’s economic base. To help understand climate-related tensions in cities, a stronger research focus upon cities, human security, and climate change has been advocated (Simon and Leck, 2010). The links between humanitarian work and climate change are increasingly recognized, but further collaborations between climate scientists, researchers, aid workers, and international funding agencies is needed (Braman et al., 2010). Holistic strategies help to link development goals with adaptation, so that "multi-dimensional and multi-scale approaches (can) better guide the construction of adaptation responses to climate change and integrate them to development strategies" (Sánchez-Rodriguez, 2009).

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

8.2.5.5. Historical Analogues

The experience of cities in coping with environmental/resource crises in the past provides a useful analog to understand climate change impacts and shifts in urbanization process (Solecki, 2012; Ranger et al., 2011; Ford et al., 2010; McLeman and Hunter, 2010; Hallegate et al., 2007; Gibbons et al., 2006). Cities often have been able to respond to localized risks and vulnerabilities such as resource shortages and environmental quality issues by externalizing the problems either through expansion of the resource catchment or by externalising the environmental quality threats (e.g. sewerage, rubbish) to more remote and distant locations (McGranahan, 2007; Tarr, 1997). This is more complex in the case of climate change in that the source of the risk and vulnerability is external to individual cities and outside their span of control. City governments have dealt with many environmental health problems by reducing or removing the hazard, but this is beyond their capacities to accomplish with respect to climate change.

Urban development and urbanization has been dramatically impacted by past changes associated with large scale exogenous factors which have either been pervasive (e.g. globalization) and/or profound e.g. wartime devastation, civil war and natural hazards such as earthquakes, cyclones, as well as the application of new technologies (e.g., automobiles, electricity, the internet). Identity is particularly important in this context because the physical fabric can be rebuilt, but in so-doing the identity of a city may be changed. In these situations,, it is evident that well-governed cities demonstrate a capacity to adapt and to learn from crises (Solecki, 2012). As described in 8.3, there is increasing evidence of policy, practice and scientific interest in urban adaptation as a core strategy to address climate change risks.

8.3. Adapting Urban Areas

8.3.1. Introduction

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

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

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

8.3.2. Development Plans and Pathways

As AR4 emphasized, many of the forces shaping greenhouse gas emissions are those underlying development pathways – including the scale, nature and location of private and public investment in infrastructure (Wilbanks, Romero Lankao et al. 2007). These also influence the form and geography of urban development and the scale and location of climate-related risks to urban buildings, enterprises and populations. Responsibility for encouraging new investments and migration flows away from high risk sites is often shared between local, provincial and national government through a combination of climate sensitive disaster risk management and urban planning and zoning. But the priority given by national and urban governments to economic growth usually means that this is rarely implemented with vigour (Douglass 2002, Reid et al, 2013).

8.3.2.1. Adaptation and Development Planning

Urban adaptation is becoming important for some national, regional and city governments although the first steps may have come from stakeholders outside the state sector. In high-income countries, interactions between national climate policies and local level and the division of responsibilities have been examined (see, for instance, Massetti et al 2007 for Italy). There is also attention to local adaptationimplementation through subsidies and flexible schemes in different city contexts and the transfer of authority and resources to city level (for the Netherlands see Gupta et al. 2007). The design of new decision making strategies for local governments considers the complexity and dynamics of evolving social-ecological systems (Kennedy et al. 2010). Examples include adaptation plans and local responses in Sydney to cope with sea level rise and storms (Hebert and Taplin 2006) and adaptation planning in California (Bedsworth and Hanak 2010). In China, adaptation programmes are being developed and implemented at national and local level. The debate emphasizes the policy space and the division of responsibility between national and local levels (Teng and Gu. 2007).

Since AR4, there has been a growing literature on urban adaptation in low and middle-income nations. A review of the literature on climate change impacts and adaptation in cities (Hunt and Watkiss 2011) could draw on eight case studies in Asia, five in Africa and four in South America – as well as from case studies from Europe, Northern America and Australasia. Among the papers and books considering climate change adaptation in urban areas since 2007 are those on Cape Town (Mukheibir and Ziervogel 2007, Ziervogel et al 2010 and Cartwright et al 2012), Durban (Roberts 2008a, 2010, Roberts et al 2012, Cartwright et al 2013 and Roberts and O'Donoghue 2013) and other urban centres in Africa (Douglas et al., 2008, Wanget al 2009, Lwasa 2010,World Bank 2011, Kithiia and Lyth 2011, Adelekan 2012, Kiunsi 2013, Castán Broto et al 2013, Silver et al 2013), urban centres in Bangladesh (Alam and Rabbani 2007, Jabeen et al 2010, Banks et al 2011, Haque et al 2012, Roy et al 2013), India (Revi 2008,Sharma and Tomar 2010, Saroch et al 2011), Latin America (Hardoy and Pandiella 2007, Romero Lankao 2007, 2010, Hardoy and Romero Lankao 2011, Luque et al 2012, Hardoy 2013, Hardoy and Ruete 2013). Other papers or books with discussions of urban adaptation in low- and middle nations include Blanco 2007, Carolini 2007, Martine et al. 2007, McGranahan et al. 2007, de Sherbinin et al. 2007, UN-Habitat 2007, United Nations Population Fund 2007, Agrawala and van Aalst 2008, Bartlett 2008, Ayers 2009, Bicknell et al. 2009, Kovats and Akhtar 2008, Tanner et al., 2009, Hardoy and Pandiella 2009,Wong 2009, World Bank 2010b, 2010c, 2011, Manuel-Navarrete et al. 2011, UN-Habitat 2011a, Rosenzweig et al 2011a, Moench et al 2011and Bulkeley and Tuts 2013. Four relevant issues can be highlighted: the fact that these nations have most of the world's current and future urban population; the need to consider key development issues of poverty and social inequality as multidimensional problems that may be aggravated by climate change; the need to consider human agency among low-income inhabitants and their organizations as an important resource in building local responses to climate change; and the relevance of well-funtioning multilevel governance in developing adaptation strategies (Sánchez-Rodríguez 2009).

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

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

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

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

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

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

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

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

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

In growing numbers of cities in Asia (Shaw and Sharma, 2011) and Africa (Pelling and Wisner 2009), experiences with community-driven ‘slum’ or informal settlement upgrading has led to a recognition of the potential of these to reduce risk and deep rooted vulnerability to extreme weather events. This is most effective when supported by local government and civil defence/emergency response agencies (see Boonyabancha 2005 for urban centres in Thailand; also Archer and Boonyabancha 2011, Carcellar et al. 2011).

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

There are also international networks supporting innovation in disaster risk reduction and/or climate change adaptation and inter-city learning. These include la Red in Latin America that has been operating for 3 decades (IFRC 2010), the Earthquakes and Megacities project which includes multi-hazard risk assessment and the cities programme of the Asian Disaster Preparedness Centre. As donor interest has grown in supporting disaster risk management as a vehicle for climate change adaptation, a number of resilience oriented urban programmes have developed including the Asian Cities Climate Change Resilience Network (Brown et al. 2012), the UN ISDR Resilient City network (Johnson and Blackburn,2013) ICLEI's city adaptation network and UN-Habitat's Cities and Climate Change Initiative.

Despite growing international support for urban disaster risk management, it can be difficult for local governments to access the human and financial resources needed to make real change on the ground (Von Hesse et al. 2008). Local governments do not get recognition for the disasters their programmes prevented – so risk reduction investments are not seen as priorities and have to compete for scarce resources with what are judged to be more pressing needs. Effective policies are often tied to the terms in office of particular mayors or political parties (Mansilla et al. 2008, Hardoy et al. 2011). In most cases, disaster risk reduction is still not integrated into development plans and not drawing in all relevant departments and divisions of local government. Manizales in Colombia is an exception as disaster risk reduction has long been seen as part of local development and where collective interests overcome individual and party political interests (Hardoy and Velásquez Barreto 2014)

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

8.3.3. Adapting Key Sectors

8.3.3.1. Adapting the Economic Base of Urban Centres

8.2 described how climate change will bring changes to the comparative advantages of cities and regions – for instance through influencing climate sensitive resources and changes in locations of extreme weather, water availability and flooding risks. Many case studies show how extreme weather and storm surges can impede economic activities such as damaging industrial infrastructure and disrupting coastal ports and supply chains (see 8.2.3.4).Vugrin and Turnquist (2012) discuss how to design for resilience in infrastructure distribution networks such as electric power, gas, water, food production and manufacturing supply chains. Increasing the resilience of networks (and settlements) needs absorptive capacity (for instance to withstand extreme weather), adaptive capacity (for instance service provision through alternative paths) and restorative capacity (quick and cheap recovery).

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

Disasters can change perceptions of risk and discourage new investments. For instance, businesses may avoid disaster impacts in their own facilities but find that the disaster has impacted other businesses and services that they use (including utilities) or impacted their workforce and the services they use (including schools, and hospitals) (Hallegatte et al, 2011). A lack of capacity within an urban centre to reconstruct means increased vulnerability to succeeding extreme weather events and less new investment that in turn weakens the urban economic base (Benson and Clay 2004, Hallegatte et al. 2007, Hallegatte et al. 2011).

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

Climate change adaptation is generally cheaper and easier to implement in greenfield sites – for instance as low-risk sites are chosen, trunk infrastructure to appropriate standards installed and building and land-use regulations enforced. Retrofitting existing infrastructure and industries is generally more expensive (McGranahan et al.,2007).

Within and around urban centres, local governments may need to utilise several strategies to strengthen urban centres' resilience including selective relocation, land use planning to reduce exposure, shifting development from floodplains, and revised building regulations to retrofit or flood-proof structures (Hanson *et al*. 2011). There are also synergies to be encouraged in peri-urban or nearby rural areas where land-use management around a city supports rural livelihoods (and where appropriate urban agriculture and forestry) and protects ecosystem services (see 8.3.3.7). There may be opportunities for proactive adaptation outside larger cities where much of the future urban growth will occur. For instance, in Manizales, Colombia, local government has begun incorporating climate change and environmental management into its local development agenda, including the establishment of city climate monitoring systems, although this is a city that has long had innovative environmental and disaster risk reduction policies (Hardoy and Velásquez Barreto 2014). However, smaller urban centres are often institutionally weaker and lack investment capacity and critical infrastructure.

Adapting the urban economic base may require short- and long-term strategies to assist vulnerable sectors and households. The consequences of climate change for urban livelihoods may be particularly profound for low-income households who generally lack assets or insurance to help them cope with shocks (Moser and Satterthwaite 2008). For most urban centres, the informal sector is a significant part of its economy and provides employment for large sections of the population. But the effects of extreme weather on the informal economy are rarely considered as in the case of 2003 floods in Santa Fe, Argentina (Hardoy and Pandiella 2009). One example where it was considered was in Kelurahan Pabean Pekalongan in Central Java where batik production provides livelihoods for three quarters of adults and this is disrupted by floods that residents suggest are becoming increasingly frequent (UN-Habitat 2011b). Cash transfers and safety nets for vulnerable groups and those with inadequate incomes may be needed to help them cope with the short-term impacts of climate change (Sánchez and Poschen 2009) as well as climate variability. But these do not address the risks they face or support the needed collective or public investments in risk-reducing infrastructure and services (Mitlin and Satterthwaite 2013).

There is a growing discussion and literature of the importance of support for a 'green economy' combined with green infrastructure to help shift nations' economic and employment base towards lower carbon, more climate resilient patterns that also respect regional and global ecological and resource limits. For urban centres, this seeks to highlight new business opportunities as it requires existing and new businesses and employment opportunities to help limit anthropogenic climate change, resource depletion and environmental degradation. Other goals are sometimes added – for instance also supporting social inclusivity and eco-efficiency as mutually reinforcing principles (e.g. Allen and Clouth, 2012). The literature has begun to explore the changes that are needed in production systems (especially in regard to carbon intensity, waste generation and management), buildings, transport systems and electricity generation and in consumption patterns by wealthier groups (Hammer,*et al*. 2011, UNEP 2011a and b, UN-Habitat 2012 a,b,c and d, World Economic Forum 2013). But as yet, there is too little detailed discussion of how a green economy can be fostered in relation to particular cities or in regard to the incentives and regulations needed to shift private investment to this.

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

For some cities, there is documentation of the kinds of adaptation needed to protect or enhance their economic base. For instance, in Mombasa, local authorities may need to redesign and reconstruct the city's ports, protect cement industries and oil refineries and relocate some industries inland, all of which requires major capital investments (Awuor et al. 2008).There are many parts of Rio de Janeiro's diverse economy (including manufacturing, oil refineries, shipyards and tourism) that adaptation will need to protect along with the urgent need to address the vulnerability of large populations living in informal settlements (favelas) on land at risk of landslides (de Sherbinin et al. 2007). Defences needed to help safeguard coastal industries and residential areas could threaten the city's beach tourist industry and cause further erosion to other unprotected areas. It is also difficult to focus the attention of politicians and civil servants on adaptation when their planning for city development is focused on hosting the World Cup and the Olympics. As in most cities, making Rio's economic base more resilient to climate change will need to resolve such tensions and trade-offs, necessitating dialogue amongst local stakeholders (Ruth 2010).

As yet, there is little evidence that climate-change related risks or cities' adaptive capacities have an influence on the location of private sector investments. They are however, influenced by the availability of infrastructure and services that are an essential part of adaptive capacity. Many cities in Asian high growth economies are located in low-elevation coastal zones which are undergoing rapid urbanisation and economic transformation (McGranahan et al., 2007).Many of these coastal settlements are also within areas where cyclones are common. Without adaptive measures and with rising concentrations of population, infrastructure, and industries along India's coasts, there could be a non-linear increase in coastal vulnerability over the next two decades (Revi 2009). The same is true for China (McGranahan et al. 2007). In most nations, urban governments have found it difficult to prevent new developments on sites at risk of flooding, especially where these are attractive locations for housing or commerce; this is even when there is legislation and plans to that regulate land use (see Olcina Cantos et al 2010 for a study of this in Alicante in Spain)

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

8.3.3.2. Adapting Food and Biomass for Urban Populations

Large sections of the urban population in low- and middle-income countries suffer hunger while a larger number face food and nutrition insecurity (Montgomery et al. 2004, Ahmed et al. 2007, Cohen and Garrett 2010, Crush et al., 2012). This is due more to their low incomes and limited capacities to access food than to overall food shortages (Cohen and Garrett 2010, Crush et al.,2012). Among low-income urban households in such nations, food expenditures generally represent more than half of total expenditures (Cohen and Garrett 2011). This makes them particularly at risk from food price inflation.

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

Urban food-related adaptation needs to consider both supply and demand side constraints. Climate-change related constraints on agricultural production and the food supply chain can impact urban consumers through reduced supplies or higher prices. Falling agricultural production or farmer incomes also reduces their demand for the urban producer and consumer goods and services they use. Disruption to urban centres may also mean disruption to the markets, services or remittance flows on which agricultural producers rely (Tacoli 2003). Thus, food policies for climate change adaptation need to take account of complex rural-urban linkages (Revi 2009). Thus, a portfolio of responses that can bridge rural and urban boundaries, as well as action at the household, local, national, and international levels, is needed to strengthen urban food security.

Urban centres that are seriously impacted by extreme weather also face serious challenges in ensuring that the affected population have access to adequate and safe food and water supplies. Flooding, drought, or other extreme events often lead to food price shocks in cities (Bartlett 2008) as well as spoiling or destroying food supplies for many households. After the 2004 floods in Bangladesh, Dhaka's rice prices increased by 30 percent and vegetable prices more than doubled (Douglas 2009**).** Bangladesh's urban slum-dwellers and rural landless poor were the groups worst-affected by food insecurity (*ibid*.).

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

Adaptive local responses have included support for urban or peri-agriculture, green roofs, local markets and enhanced safety nets. Food price increases may be moderated by improving the efficiency of urban markets, regulations to promote farmers' markets, or investing in infrastructure and production technologies (Cohen and Garrett 2011). Food security may be enhanced by government support for urban agriculture and street food vendors (ibid., Lee-Smith 2011**).** Food security for urban dwellers with low incomes is also increased if they have access to cheaper food or to social incomes – for instance cash transfers (e.g. Brazil's Bolsa familia programme) or, for older groups pensions (Soares et al. 2010). While initially rural-focused, cash transfer programmes have been expanded in urban areas and in some nations reach a large proportion of the low-income urban population (Johanssen *et al*. 2009, Niño-Zarazúa 2010**,** Satterthwaite and Mitlin 2013).

8.3.3.3. Adapting Housing and Urban Settlements

Urban adaptation will be built on the bedrock of good quality and affordable housing that conforms to appropriate health and safety and climate-resilient building standards and has sufficient residual structural integrity over its service life to protect its occupants against extreme weather (United Nations 2009, 2011).

Section 8.2.4.4 noted how poor quality housing is often at risk from extreme weather. Its resilience can be enhanced via a range of structural interventions (for instance retrofitting existing buildings and revising standards for new-build), interventions that reduce risks (for instance expanding drainage capacity to limit or remove flood risks) and non-structural interventions (including insurance). The need for attention to all three of these are obviously greatest where housing quality is low, where settlements have developed on high-risk sites and for cities in locations where climate change impacts are greatest. However, enhancing the resilience of the buildings that house low-income groups also faces many political challenges (see Roaf et al., 2009).

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

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

Housing and extreme heat:More attention is being paid to understanding and addressing risks from extreme heat in particular cities – see for instance Chicago 2008 and 2010, Tomlinson et al 2011 for Birmingham, Matzarakis and Endler 2011 for Freiburg and Giguère 2009 for Quebec. Attention is needed to buildings that provide protection from heat waves, especially in urban heat islands and for populations that are more vulnerable to extreme heat. In locations that have large daily variations in temperature, this includes upgrading homes with limited ventilation and with low thermal mass. Interventions that reduce heat gain are also needed including passive cooling and other design measures (Roberts 2008b, Hacker and Holmes 2007) as well as modifications to buildings and open spaces in areas that are heat islands (see later discussion on green and white roofs).Chicago's 2008 Climate Action Plan discussed the need to "pursue innovative cooling," which will "seek out innovative ideas for cooling the city and encourage property owners to make green landscape and energy efficiency improvements" (Chicago 2008: 52). Air conditioning and other forms of mechanical cooling can provide relief but these are too expensive or not available for the many urban households with no electricity supplies. They are also mal-adaptive if they rely on electricity whose generation is contributing to greenhouse gas emissions. Residents' vulnerabilities may be exacerbated if electricity supplies are unreliable and "if blackouts occur on the hottest days when peak demand is at its worst" (Maller and Strengers 2011: 3). To date, the literature on adapting housing and neighbourhoods to extreme heat focuses on cities in high-income nations although many of the cities already experiencing periods of extreme heat are in low- and middle-income nations.

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

Housing and disaster-preparedness measures:If populations are displaced by disasters or need to be evacuated temporarily from their homes, provision for emergency shelters and services need to be able to respond with particular attention to vulnerable residents. For instance, housing agencies established shelters and recovery centres after Cyclone Larry in Queensland (in 2006) and New South Wales' coastal flooding (in 2007). Interviews with officials recalled the strains facing 24-hour providers in the shelters and coordination difficulties with emergency health workers, police, insurance, and other agencies (Jacobs and Williams 2011). While not addressing climate change explicitly, the study helps highlight the range of social support, structural strategies, and interagency efforts that local authorities may need to develop to adapt to climate change. For many urban centres, there is also the issue of how to move populations at risk when needed (and to get their agreement to do so) and this presents many challenges (Roaf et al., 2009).

Urban centres facing extreme heat need heat-wave plans that warn citizens of what is anticipated and what measures they can take and ensure adequate water provision, emergency healthcare, and other public services that focus on vulnerable residents. This includes special attention to infants and to the elderly in hospitals, residential facilities (Hajat et al. 2010, Brown and Walker 2008) or living alone. It should include back-up electricity although large sections of the urban population in low- and middle-income nations do not have electricity (Johansson et al., 2012) and this also means no access to devices that help with cooling. Here too, the examples of cities with responses to heat waves that focus on those most at risk (see for instance Toronto 2012) are mainly from high-income nations.

8.3.3.4. Adapting Urban Water, Storm, and Waste Systems

The challenge of this section (and this chapter), is summarizing key adaptation issues drawn from examples that come from a highly heterogeneous mix of urban areas across the globe with order of magnitude variations in the quality and extent of provision for water, sanitation and drainage. In high-income and some middle-income nations, virtually all the urban population is served by drinking quality water piped to the home 24 hours a day, by sewers or other systems of sanitation that minimize risks of faecal contamination and by storm and surface drainage. As noted in 8.2, there are many urban centres in such nations that face serious climate change-related challenges for water. But their plans do not have to address the fact that a significant proportion of their population do not have piped water or toilets in their homes, or storm drains. They also have in place billing systems that generate a substantial proportion of the funds needed for water provision and management.

At the other extreme are a very large number of urban centres in low-income and middle-income nations with very large deficits in provision for water, sanitation and drainage and with weak, under-resourced institutions (UN Habitat 2003, WHO and UNICEF 2012). There is also the billion or so people living in informal settlements where authorities or companies responsible for water and sanitation provision are often unwilling to invest or not allowed to do so. 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 in the quality and extent of provision and resources available to local water and sanitation providers. New York City can develop a ten billion dollar plan to assure it receives adequate water supplies (Solecki 2012) while many cities in sub-Saharan Africa not only have very large deficits in piped water provision, sewers and drains but also very limited investment capacities (see for instance Kiunsi 2013 for Dar es Salaam).

Some studies have sought to estimate the costs of adapting urban water and sanitation systems. Muller 2007 discusses the direct and indirect impacts of changes in rainfall patterns and stream flows on sub-Saharan African cities. He suggests that $1-2.7 billion is needed annually to adapt existing urban water infrastructure and this does not include the cost of addressing deficient infrastructure. Another $1-2.6 billion a year is needed to adapt new developments (including water storage, waste-water treatment and electricity generation). Other research also suggests significant investments needed in low- and middle-income nations to overcome current shortfalls in water and sanitation as well as to cope with climate change (Arnell et al. 2009).

8.3.3.4.1. Adapting urban water supply systems

Major et al (2011) lists 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. For cities with climate change adaptation plans, water and waste water management are usually important components (see for instance Helsinki Region Environmental Services Authority 2012). But developing such measures is not yet commonplace.

Supply-side approaches to seasonal water shortages such as increasing reservoirs are frequently advocated. An analysis of 21 draft Water Resources Management Plans in the UK found that agencies usually favoured reservoirs and other supply-side measures to adapt to climate change (Charlton and Arnell 2011). The authors suggest that additional demand-side interventions may be needed to cope with reductions in water availability. Although based upon draft plans from 2008 rather than implemented strategies, the study indicates some key trade-offs and a portfolio of responses currently under consideration. To expand its reservoir capacity, Rotterdam developed plans that combine the goals of adaptation and urban renewal (van der Brugge and de Graaf 2010). Floods in 1998 exposed the inadequacies of existing water infrastructure, particularly in the context of climate change, and municipal water authorities committed to expand retention capacity by mixing economic activities with water-based adaptive designs, including 'water retention squares' and green roofs; floating houses; and networks of channels. Seattle has utilised demand-side strategies to curtail water consumption including aggressive conservation measures, system savings and price increases linked to consumption levels (Vano et al. 2010). A simulation exercise suggested the system can withstand climate change-induced alterations in reservoir inflows, and the authors note that the "primary reason" for such robustness is the successful reductions in demand (ibid. p. 283).

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

Cape Town faces profound challenges in ensuring future supplies (Mukheibir and Ziervogel 2007). The city responded by commissioning water management studies, which identified the need to consider stresses including climate change as well as population and economic growth (*ibid*.). During the 2005 drought, the local authority substantially increased water tariffs, and such 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*).

Research in Phoenix, Arizona sought to improve water forecasting data and inform adaptation interventions (Gober et al.2010). This rapidly-expanding desert city is projected to reach 11 million people by 2050, with most growth in peripheral areas that depend on groundwater (Bolin et al.2010). Simulations explored how water usage may be reduced to achieve safe yield while accommodating future growth (ibid). Reducing current high per capita water use may be achieved through urban densification, increased water prices and water conservation measures (ibid). Gober et al 2010 agree that stringent demand and supply policies can forestall "even the worst climate conditions and accommodate future population growth, but would require dramatic changes to the Phoenix water supply system" (ibid: 370).Quito's local government has formulated a range of adaptation plans to address water shortages (Hardoy and Pandiella 2009). The city is projected to experience reduced freshwater supplies as a result of glacier retreat and other impacts of climate change. Among the municipality's responses are developing dams; encouraging a culture of rational water use; reducing water losses; and developing mechanisms to reduce water conflicts (ibid.). However, Quito has not sought to incorporate community participation in planning and implementation (ibid.). Participatory water planning has occurred elsewhere in Latin America: stakeholders in Hermosillo, Mexico, identified and prioritized specific adaptations such as rainwater harvesting and water-saving technologies (Eakin et al.2007).

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

8.3.3.4.2. Waste and storm water management

Most of theadaptations mentioned above are to help ensure sufficient water supplies. Less attention has been given to adaptations needed in sewer and drainage systems whose capacities will often need to be increased substantially and, for coastal cities, adapted to allow for the impacts of sea-level rise. We noted earlier the very large deficiencies in provision for drainage for urban centres in low- and many middle-income nations.

In St. Maarten, Netherlands Antilles, the government initiated a storm water modelling study and is developing a flood warning system (Vojinovic and Van Teeffelen 2007). Other options under consideration include institutional adaptations such as a new decision-support framework, centralised GIS to enhance all infrastructure planning measuresand public education, alongside structural measures such as improving the channel network and draining of areas with a high groundwater table (ibid).City management in Toronto, Canada has prioritised an upgrade of storm water and wastewater systems to circumvent the direct and indirect stresses from climate change (Kessler 2011). Deak and Bucht (2011) analyse past hydrological structures in the city of Lund, Sweden and use the concept of indigenous blue infrastructure to raise questions concerning current storm water management in the urban core. Cities in California have a range of flood management methods but will need to augment these with forward-looking reservoir operation planning and floodplain mapping, less restrictive rules for raising local funds, and improved public information on flood risks (Hanak and Lund 2012).

The last 20 years have seen more attention by most governments to water sector reform (UN Water 2012). Many have developed integrated water resource management (ibid) with linkages between provisions for water, sanitation and drainage and other sectors, This recognizes that water adaptation plans need to work with a range of partners, consider broader development goals, identify tensions or trade-offs and implement low-regret anticipatory solutions, For cities, this often has to include groundwater use management and water catchment management in areas that are outside their jurisdiction and thus collaboration with other local governments in integrated flood management (WMO 2009). Most examples of this are in high-income nations (for an exception see Bhat et al., 2013).

Urban water systems usually depend on reliable electricity supplies and can be energy intensive – for instance utilizing water from distant or low-quality sources that require high levels of energy for conveyance or treatment.Water adaptation planning will need to be developed in concert with energy conservation, water catchment management and green infrastructure strategies. Integrated strategies can minimize possible conflicts between water-intensive parks or gardens, support local industries, and ensure equitable access to water in cities.

8.3.3.5. Adapting Electric Power and Energy Systems

The heavy dependence of urban economies, infrastructure, services and residents on electricity and fossil fuels means far-reaching consequences if supplies are disrupted or unreliable (see 8.2.4.2). With the energy literature and urban energy policy discussions dominated by mitigation concerns, “relatively few assessments in the energy sector focus on adaptation issues” (Mdluli and Vogel 2010: 206; see also Carmin et al 2009). The UNFCCC’s estimates for investment to address climate change (UNFCCC 2007) did not estimate the costs of adapting the energy sector (Fankhauser 2010). Key issues relating to adaptation for the energy sector including electricity generation and distribution are usually national or regional and so are discussed in Chapter 10. But urban governments and urban dwellers’ responses still have importance. Research has suggested that “private autonomous measures will dominate the adaptation response as people adjust their buildings, [or] change space-cooling and -heating preferences...” (Hammer et al 2012,27) so this suggests a need for policies that encourage these measures to contribute to adaptation and mitigation and serve those with limited incomes. A few cities have adaptation initiatives underway for energy systems while some others have begun to consider the steps needed to adapt local energy systems (ibid).

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

There is also the adaptation agenda needed for industries related to the supply of fossil fuels that involve or should involve urban governments. For instance, in the State of Veracruz, Gulf of Mexico, cities such as Coatzacoalcos and Minatitlan are surrounded by oil, gas and petrochemical plants that can be affected by the impact of weather-related events REF. Even though there is a growing concern about the potential impact that climate change and extreme weather events will have in the oil industry in Canada, US and Mexico and how floods and sea level rise will disrupt oil, gas and petrochemical installations, few climate change adaptation studies on this theme have been undertaken.There are also important potential co-benefits between mitigation and reduced air pollution from thermal power stations, motorized transport and other industries.

8.3.3.6. Adapting Transport and Telecommunications Systems

Adapting urban transport and telecommunications systems to the many impacts of climate change (including rising average temperatures, more or more intense heat waves and storms and sea-level rise) poses many challenges (Mehrotra et al 2011b). Urban centres depend on road and often rail, air and waterway transport systems for daily functioning – including the movement in and out of the urban centre or core by commuters and consumers and daily deliveries. Many cities depend on underground electric rail systems which may be at considerable risk from flooding including New York and London (Eichhorst 2009).

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

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

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

Adapting roads:Climate change may increase the costs of maintaining and repairing road transport networks (see Hayhoe et al. 2010 for a discussion of this for Chicago due to rising average temperatures and more severe rainfall). In Durban, "it may be necessary to revise road construction standards and avoid routes at high risk of flooding" (Roberts 2008a: 531). Coastal road adaptation may require strengthening barriers, increasing design parameters to cope with sea-level rise, or realigning existing roads to a higher location (Regmi and Hanaoka 2011).

To adapt road networks, transport planners are beginning to reassess maintenance costs and traditional materials – for instance stiffer bituminous binding materials to help cope with rising temperatures and softer bitumen for colder regions (Regmi and Hanaoka 2011: 28). However, current cost considerations may impede their use. The Chicago Department of Transportation decided not to use more permeable, adaptive road materials instead of asphalt and concrete because of higher cost, although it recognised costs may fall with greater economies of scale as demand rises for such materials (Hayhoe *et al*. 2010: 104).Road maintenance costs vary widely, depending upon the season, local context, and future climate scenarios. In Hamilton, New Zealand, changes in rainfall were projected to increase repair costs in spring and winter, but reduced rainfall in spring and autumn partly balanced out the cost; results depend upon the scenario and further investigation was recommended (Jollands et al. 2007).

Informal settlements frequently lack all weather roads and paths within the settlement and connection to the wider road system for emergency vehicle access and rapid evacuation. For instance, informal settlements in Chittagong have extremely narrow roads so that "ambulance and fire services cannot enter most of these neighbourhoods, thus exacerbating the existing health and fire risks at household level" (Rahman et al.,2010: 572). Roads in Lagos's informal settlements are often poorly maintained and lack all-weather surfaces; a 2006 resident survey ranked roads second to drainage in terms of needed facilities (Adelekan 2010). Evacuations in low-income areas may be hampered by hazardous locations, poor quality roads, absence of public transport, prevailing insecurity, and inadequate governance. 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 to protect these and their possessions from looters (Hardoy and Pandiella 2009).

Low-income urban residents can also be profoundly affected by transport disruptions during and after extreme weather events that damage critical public transit links, prevent access to work, and heighten exposure to health risks. Interviews in Georgetown, Guyana, found that low-income households mainly rely on public transport and their limited transport access during floods made them more likely to lose time from work or school, as compared to wealthier households (Linnekamp et al. 2011). Better-off households were more likely to possess their own vehicles, while poorer households rarely owned cars, waded through floodwaters in bare feet, and were thereby exposed to waterborne pathogens (*ibid*.). Some studies suggest that urban women are more likely than men to walk or utilise public transport (World Bank 2010d), so that the gendered impacts of transport disruptions may merit greater consideration (see also UN Habitat 2011a, Levy 2013).

Adapting surface and underground railways: Underground transport systems are specific to urban areas and may have "particular vulnerabilities related to extreme events, with uniquely fashioned adaptation responses" (Hunt and Watkiss 2011: 14). Heat impacts are often significant in underground railways, as these systems may be gradually warming due to engine heat, braking systems, and increased passenger loads (Love et al., 2010). To cope with increasing frequency of hot days due to climate change, "substantial investment" in ventilation or cooling may be necessary (ibid.). Some of New York City's subways are located in coastal or river floodplains, and the system's age, fragmented ownership, and current overcapacity may augment the challenge of adaptation (Zimmerman and Faris 2010: 69-70). Pumps have been installed throughout the subway system and these helped to cope with severe floods in August 2007 during the morning commute (ibid.).

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

In flood-prone cities, more stringent construction standards, design parameters, or relocation may be needed to adapt transport systems. Much of central Mumbai is built on landfill (as the area was originally seven islands); the landfill areas are prone to flooding, but they contain the main train stations and train lines as well as large populations and a large part of the city's economy (de Sherbinin et al. 2007). Rising sea levels may cause shifts at the sub-surface level of landfill areas and structural instabilities (ibid).

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

8.3.3.7. Green Infrastructure and Ecosystem Services within Urban Adaptation

The greater attention to understanding, utilizing and protecting ecosystem services includes examples of ecosystem-based adaptation in urban and peri-urban areas. These use opportunities for the management, conservation and restoration of ecosystems to provide needed services and increase resilience to climate extremes. They can also deliver multiple development co-benefits (e.g. purifying water, absorbing runoff for flood control, cleansing air, moderating temperature, preventing coastal erosion) while helping contribute to food security and carbon sequestration (Newman 2010, Foster et al 2011, GLA 2011, Roberts et al 2012; see also Wilson et al. 2011, Oliveira, Andrade and Vaz 2011, Tallis et al 2011, City of New York 2011, Helsinki Region Environmental Services Authority 2012, Institute for Sustainable Communities, undated). An ecosystem services based approach is particularly important in low- and many middle-income countries where livelihoods for sections of the urban population and much of the peri-urban population depend on natural resources. Box 8-1 describes how ecosystem based adaptation is being developed in Durban. Another example is the contribution of catchment management to addressing flood risk that includes community-based partnerships supported by full cost accounting and payment for ecosystem services – rather than the more conventional canalisation of rivers (Kithiia and Lyth 2011, Roberts et al. 2012).

_____ START BOX 8-1 HERE _____

Box 8-1. Ecosystem-based Adaptation in Durban

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

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

1) A better understanding of the impacts of climate change on local biodiversity and how to manage Durban's open space system of 75,000 hectares. The projected warmer and wetter conditions seem to favour invasive and woody plant species.
2) A local research capacity that includes generating needed local data
3) Reducing the vulnerability of indigenous ecosystems as a short term precautionary measure
4) Enhancing protected areas already owned by local government and developing land-use management interventions and agreements with landowners to protect privately-owned land areas critical to biodiversity and ecosystem services. This needs government incentives and regulation to stop development on environmentally sensitive properties, the removal of perverse incentives and support for landowners affected by this.
5) The promotion of local initiatives that contribute jobs, promote business and life skills development and environmental education with ecosystem management and restoration programmes. Durban has initiated a large scale Community Reforestation Programme where community level 'tree-preneurs' produce indigenous seedlings and are involved in the planting and managing of the restored forest areas. This is part of a larger strategy to enhance biodiversity refuges and water quality, river flow regulation, flood

mitigation, sediment control and improved visual amenity. Local level advantages include employment creation and improved food security and educational opportunities.

Source: Roberts et al. (2012).

_____ END BOX 8-1 HERE _____

"Green infrastructure" refers to interventions that seek to preserve the functionality of existing green landscapes (including parks, forests, wetlands or green belts) as well as transforming the built environment through the use of photo-remediation and water-management techniques and by introducing productive landscapes (La Greca et al. 2011, Zhang et al 2011, Foster et al 2011). Its importance for adaptation is increasingly recognized, although much of the early innovation was in response to the need for cost effective and sustainable mechanisms to addresswater shortages or flooding and not directly linked to climate change adaptation. Case studies of green infrastructure aim to measure their effectiveness and assess the potential of urban planning and environmental conservation policies to create cityscapes that can adapt to a changing climate.

Green spaces in cities are considered beneficial for absorbing rainfall and moderating high temperatures. For instance, in the USA, the cities of Portland and Philadelphia have used green infrastructure (including encouragement of green roofs, porous pavements and disconnection of downspouts) to reduce storm waters at much lower costs than increasing storm water capacity (Foster et al 2011).Some cities have made investments in green infrastructure, linked both to regeneration and to climate change adaptation. For instance, the Green Grid for East London seeks to create "a network of interlinked, multi-purpose open spaces" to support the wider regeneration of the sub-region. It is being developed to enhance the potential of existing and new green spaces to connect people and places, absorb and store water, cool the vicinity, and provide a diverse mosaic of habitats for wildlife (GLA 2008:80). New York has a well-established programme to protect and enhance its water supply through watershed protection. This includes city ownership of land that allows crucial natural areas to remain undeveloped and work with land owners and communities to balance protecting drinking water quality with facilitating local economic development and improving waste water treatment. To this has been added an ambitious green infrastructure plan (that includes porous pavements and streets, green and blue roofs and other measures to control stormwater (New York 2010). The city government suggests that while the Program is costly, compared to the costs of constructing and operating a filtration plant, as well as the environmental impacts of the additional energy and chemicals required by filtration, it is the most cost-effective choice for New York (Foster et al 2011, New York 2010).

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

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

Dedicated green areas within urban environments compete for space with other city-based needs and developer priorities. The role of strategic urban planning in mediating among competing demands for land use is highlighted as potentially useful for the governance of adaptation as presented in planning forerunnersLondon, Toronto, and Rotterdam (Mees and Driessen 2011). The experience in Durban discussed in Box 8-1 also faces many challenges

(Roberts et al. 2012). These include an assumption that ecosystem based adaptation is an easy answer to the technological, financial, institutional and skill constraints that limit the implementation and effectiveness of "hard engineering" solutions (ibid., Kithiia and Lyth, 2011). Experience in Durban shows that implementing an ecologically functional and well-managed, diverse network of bio-infrastructure needs knowledge, new data collection, expertise and resources. It needs to have direct and immediate developmental co-benefits for local communities and ensure integration across institutional and political boundaries. Substantial knowledge gaps need to be addressed, such as the need to determine where the limits or thresholds lie; many ecosystems have been degraded to the point where their capacity to provide useful services may be drastically reduced(TEEB 2010).

Burley et al's (2011) review of the wetlands of South East Queensland, Australia indicates that adaptations focused on wetland and biodiversity conservation may impact urban form in coastal areas. A study of the change in tree species composition, diversity and distribution across old and newly established urban parks in Bangalore, India aims to find ways to increase ecological benefits from these biodiversity hotspots (Nagendra and Gopal 2011).A new methodology that seeks to evaluate the impacts on local climate of current land uses and proposed planning policies using evapotranspiration and land surface emissivity as indicators when applied in Leipzig found that green areas and water surfaces had cooling effects, as expected but some policies were found to increase local temperatures (Schwarz et al 2011).

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

Green and white roofs:Green and white roofs have been introduced in a range of cities, with the potential to create synergies between mitigation and adaptation.Rooftop vegetation helps decrease solar heat gainwhile cooling the air above the building (Gill *et al*. 2007). This improves the energy performance of buildings (Mees and Driessen, 2011, Parizotto and Lamberts 2012) and can reduce cooling demand and often the use of air conditioning with its local contribution to heat gain (Zinzi and Agnoli 2011, Jo et al. 2010) and its implications for greenhouse gas emissions if utilizing electricity from fossil fuelled power stations. Rooftop vegetation can also retain water during storms, reducing storm water run-off (see studies conducted by Palla et al 2011, Schroll et al 2011, Voyde et al. 2010) and promote local biodiversity and food production (adaptation). Studies which measure the thermal and hydrological responses of green roofs have compared the performance of living roofs across different plant cover types, levels of soil water, and climatic conditions (see e. g. Jim 2011, Simmons et al. 2008). Hodo-Abalo et al. (2012) confirmed that a dense foliage green roof has a greater cooling effect on buildings in Togolese hot-humid climate conditions. Several field experiments combined with simulated modelling of impacts in the US also confirmed the positive thermal behaviour of green roofs when compared to alternative roof coverings (for example Getter et al. (2011) compared green roofs with a traditional gravel inverted roof, Scherba et al. (2011) compared the heat flux into the urban environment of vegetated roofs, white roofs and black membrane roofs, with PV panels elevated above various roofs, Susca et al. (2010) compared black, green and white roofs, in four areas of New York City and assessed the positive effects of vegetation at both urban and building level.

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). New York's lack of space for street-level planting helped encourage the adoption of living roofs, which can provide additional area for cooling vegetation (Corburn 2009). Under its Skyrise Greenery project, Singapore has provided subsidies and handbooks for rooftop and wall greening initiatives (Newman 2010).

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

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

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

8.3.3.8. Adapting Public Services and Other Public Responses

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

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

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

The costs of adapting health care systems may be considerable – for instance, where needed modifying buildings and equipment at all levels and training staff and, setting up comprehensive surveillance and monitoring systemsand the use of modelling software that can capture the health risks of Climate Change. Risk and vulnerability assessments also need to look at the complete range of schools and day-care centres to assess their vulnerability to climate change. School buildings can be designed and built to serve as safe centres during floods or storms to which those at risk can move temporarily – although it is also important after a disaster to quickly re-establish functioning schools both for the benefits for children and for their parents (Bartlett 2008).

For cities without a robust emergency response network, adapting to Climate Change may require significant improvements in staffing, resources, and preparedness plans. This will include particular attention to providing emergency services in informal settlements lacking adequate roads or infrastructure and where needed, temporary evacuation plans that serve all those that have to move.

Many sections of 8.2 noted health impacts that can arise or be exacerbated by climate change that will increase demands on health care systems – including those linked to air pollution, extreme weather, food or water contamination and climate sensitive disease vectors. For air quality, additional research is still needed to understand the complex links between weather and pollutants in the context of climate change (Harlan and Ruddell 2011). Important synergies can be achieved through combining mitigation and adaptation strategies to improve air quality, reduce private transport and promote healthier lifestyles (*ibid.,*also Bloomberg and Aggarwala 2008).

8.4. Putting Urban Adaptation in Place: Governance, Planning, and Management

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

A share of what is needed for effective urban adaptation falls within the responsibilities of municipal governments. Many aspects of adaptation can only be implemented at the urban level through what local governments do, encourage, allow, support and control. This requires support from regional (sub-national) and national institutions and policies, suggesting that urban adaptation will necessarily be nested and policy-centric, with overlapping responsibilities and authority operating across levels of governance, relevant sectors and themes (Ostrom 2009, Dietz et al., 2003; Blanco et al., 2011; Corfee-Morlot et al. 2011; McCarney et al., 2011; Kehew et al. 2013, forthcoming). There are important precedents here in the way that new national legislation and institutions on disaster risk reduction have helped to strengthen and support local government capacity (see 8.3.2.2), though these often show that without associated budgetary support and increases in human resources, legislation has limited effect on local planning and practice (Johnson, 2011).

Approaches to adaptation include new urban policies and incentives for action as well as measures to mainstream climate considerations or auditing for climate impacts through existing policies to ensure that they reduce risk and vulnerability (Urwin and Jordan 2008, Brugmann 2012, OECD 2008, Satterthwaite et al. 2009). This can include consideration of transformation (where development is a main determinant of risk or risk mitigation), as well as difficult decisions over what can be done where there are limits to adaptation (Pelling and Navarrete, 2011). These limits might include, for example, resettlement or abandonment of previously developed land (see Section 8.3). Capacity constraints, including limited funding and technical expertise, ill-designed or inadequate institutional mechanisms, limited information on climate predictions and risk and lack of leadership will limit the ability of local authorities to work effectively on this (see Gupta et al., 2010) as well as working with others at the local, regional and national level on adaptation. Many national governments face comparable capacity constraints and still do not recognize the importance of local governments in climate change adaptation (OECD 2010a).

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

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

As stressed in 8.1, the context for adaptation decisions will inevitably vary by country and location but preconditions for sound urban decision-making and accumulated resilience can be generalised from the literature and experience to date. These relate to principles of good urban government (what government does) and governance (how they work with other institutions and actors including the private sector and civil society). These generally include science-policy deliberative practice and vulnerability assessment to support adaptation (Adger et al. 2009, NRC 2007, 2008, 2009, Renn 2008, Moser 2009, Kehew 2009, Corfee-Morlot et al. 2011). Civil society - including non-governmental and community-based organizations - has important roles in good urban governance and environmental management including community risk assessment and contribution to adaptation, incorporation of local knowledge and understanding local preferences and norms (e.g. Krishnamurthy et al. 2011, Fazey et al. 2010, Shaw et al. 2009, Tompkins et al. 2008, Van Aalst et al. 2008). It is important to recognize that human behaviour and social norms are not static and can evolve through dialogue and understanding (Moser 2006, Dietz et al.2003, Ostrom 2009), hence engagement with stakeholders over time is key to effective adaptation (Kehew et al. 2013 forthcoming). Furthermore, the capacity to act at urban levels varies with organisational form including the level of decentralisation for funding and decisions such as land use and infrastructure (Blanco et al. 2011; Corfee-Morlot et al. 2011; McCarney et al. 2011), which in turn may relate to the context for development (Bicknell et al. 2009).

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

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

A framework for urban governance emerges from the challenges climate change brings to multilevel risk governance. Figure 8-1 summarises the key interests and their relationships in the production of urban adaptation governance. In this framework, urban governments (operating at municipal and/or local levels) are provided with authority for relevant policy decisions (Blanco et al., 2011; Corfee-Morlot et al. 2011; McCarney et al., 2011; Kehew et al. 2013, forthcoming). This is combined with the mandates and capacities of quasi-governmental institutions including local water authorities or insurance regulators (in the “inner circle”). Quasi- governmental organisations may operate at a regional scale but include responsibility for urban areas within their remit. Other local stakeholders are ideally included, such as businesses, communities and expert advisors in adaptation decisions, referred to here as part of the “outer circle”. Media and other forms of civil-social infrastructure act as filters of substantive knowledge and help to join expert information with local knowledge to build understanding and engagement on climate change (Carvalho and Burgess 2005; Leiserowitz 2006). Good practice hinges in part upon the credibility, legitimacy and salience of science-policy processes, a strong local evidence base of historical and projected data on climate change, and ongoing, open processes to support dialogue between government, civil society and expert advisors (Cash 2001, Cash et al. 2006, NRC 2007, Preston et al. 2011; Kehew 2013; see also Ch.2). Communication efforts are also essential (Moser and Dilling 2006, Moser and Luers 2008, Moser 2006). Good governance depends in part on how well policy and decision processes mediate across these different actors, spheres of influence, sources of information and resources to co-produce knowledge, support learning and action over time (see Figure 8-1).

[INSERT FIGURE 8-1 HERE
Figure 8-1: Circulation of power for public decisionmaking on climate change.]

From an institutional and policy perspective, urban governments have authority in relevant domains for adaptation decisions but many of their decisions will be enabled, bounded or constrained by national, sub-national or supra-national laws and policies, land use and infrastructure planning decisions (ARUP/ C40 report; OECD 2010; Kehew et al. 2013). Large metropolitan areas raise the level of complexity of managing climate adaptation, especially when they are growing rapidly – and this requires action to be coordinated across multiple urban jurisdictions; the number of relevant jurisdictions varies by city but they are often in the dozens (e.g. Mexico City, Sao Paulo, London and Buenos Aires) and occasionally in the hundreds (e.g. Abidjan and Tokyo) (McCarney et al. 2011). Although there is some evidence of innovative responses at the sub-national levels to plan for extreme weather events and climate change, limited capacity and experience at the local government level also suggests a need for support from higher levels of government (Norman and Nakanishi 2011, Guran et al 2012). In large metropolitan areas, it will also be ineffective for a single urban jurisdiction to act in isolation of neighbouring jurisdictions; there is a need to coordinate and harmonise actions across metropolitan jurisdictions – for instance to implement flood protection of contiguous land areas or evacuation planning in response to an approaching storm or in the event of a disaster.

Adaptive capacity in cities therefore depends upon the alignment of policies and incentives such that they work coherently across multiple levels of government and on multilevel governance to define and deliver effective urban adaptation (McCarney et al. 2011; Corfee-Morlot et al. 2011, Mukheibir and Ziervogel 2007, Urwin and Jordan 2008, Cash et al. 2006, Young 2002, Bulkeley and Kern 2006, Kern and Gotelind 2009). Institutions operating at different levels and with different scopes of authority may be responsible for key decisions in relevant urban adaptation sectors (e.g. coastal zone management and buildings). Water authorities may operate at waterbasin level and as such represent both national and local interests while also operating independently of urban authorities. This points to a need to audit and align (pre)existing policies and screen new policies across levels of government to ensure the consistent integration of urban climate change risk management. Failing to do so can lock-in outcomes that raise the vulnerability of urban populations, infrastructure and natural systems to climate change (mal-adaptation) even where pro-active adaptation policies exist (Benzie et al. 2011; OECD 2009, Urwin, Jordan 2008). Raising urban adaptive capacity requires local government capacity as well as the institutions that facilitate coordination across multiple, nested and poly-centric authorities in making decisions to address urban vulnerability and risk, and which have potential to mainstream adaptation measures.

Opportunities for accelerating learning and action may stem from horizontal coordination and networking across actors, professions and institutions in different municipalities and metropolitan areas, many of whom are facing similar challenges (Lowe et al., 2009, Aall et al., 2007, Schroeder and Bulkeley 2008). Local contexts and implementation agendas also underscore the need for tailoring of national goals and policies to local circumstances and preferences. Consultation and awareness raising are essential to avoid the kind of public backlash that occurred in response to the French government's attempt to ban urban development and require strategic retreat in areas of current and increasing risk to coastal flooding following the storm Xynthia in 2010 (Laurent 2010; Pryzyluski and Hallegatte, 2012). Urban adaptation planning has also to recognise the influence of vested interests and trade-offs, where near-term development may appear to conflict with longer-term adaptation and resilience goals. Public engagement, openness and transparency about climate change information and its risks can help to ensure democratic debate to balance public interests and longer-term sustainability goals against the short-term benefits of unconstrained development.

Urban governments are uniquely situated to understand local contexts, raise local awareness, respond to citizens and civil society pressures, strengthen planning and build capacity to take actions in some areas. They can work closely with local stakeholders through an analytic-deliberative process to build a policy space (Brunner 1996, Brunner et al. 2005, Cash and Moser 2000, Grindle and Thomas 1991, Healy 1997). Within this, it is possible to generate a good understanding of local contextual factors that will matter to decisions about how to manage climate change adaptation (Healy 1997, Ostrom 2009). Urban governments can also promote understanding of climate change risk and drivers of vulnerability for adaptation and help to create a common vision for the future (Corfee-Morlot et al. 2011, Moser 2006, Moser and Dilling 2006, Ostrom 2009). The fact that preferences of different actors tend to be more homogenous across smaller than larger units (Ostrom 2009) provides opportunities for leadership and flexibility to innovate that may not exist at higher levels of governance. Thus, some evidence suggests that urban governments may be unique in their ability to provide accountableleadership, to innovate and to promote learning-by-doing (OECD 2010).

Beyond setting out a vision for the future, urban governments are central to the interface between climate change and development, including provision for essential services (water, sanitation, drainage, solid waste management, shelter, mobility services as well as education and health services) (Bulkeley 2010; Bulkeley and Kern 2006). Urban governments often have responsibilities for a substantial share of urban infrastructure to provide these services (ARUP/C40 2012). An essential step is to integrate and mainstream adaptation plans and risk management into urban and development planning from local to national levels with a clear time frame, mandate and resources for implementation (Brugmann 2012, OECD 2008, Satterthwaite et al. 2009). This includes influencing territorial development planning and infrastructure planning even if functional authority is at the national or sub-national regional levels (Vigue and Hallegatte 2012, Hall et al. 2012).

Despite the unique opportunities to support adaptation, local government decisions are often driven by short-term priorities of economic growth and competitiveness (Carmin and Dodman 2012, Moser and Luers 2008). Addressing climate change requires shifting ways of thinking about the future to take a longer-term perspective and reconcile this with near-term priorities (Leichencko 2011, Pelling 2011a, Romero-Lankao and Quin 2011). Tension also exists between focusing on economic growth and the large and often growing numbers of the urban poor that are ill-served or unserved by infrastructure and services; for much of the urban population, resilience to climate change will depend on this being addressed (Bicknell et al. 2009). The challenges of advancing adaptation through urban governance processes in low- and middle-income countries are exacerbated by inattention from international donors to urban policy and development concerns, as they work almost uniquely with national governments. Donors may also have preferences for physical infrastructure projects with visible results over local institution and capacity building investments. Similarly, national governments in high-income countries have yet to fully embrace and find ways to support local adaptation initiatives (McCarney et al. 2011).

While there is evidence of growing awareness and analytical capacity (i.e. in the form of adaptation planning) within many urban governments and governance processes, there is much less evidence of action in the form of adaptation implementation and influence on key sectors (Roberts 2010). This may be because adaptation planning is often done separately from urban and territorial development planning making it difficult to gauge progress in efforts to mainstream adaptation into urban planning.

8.4.1.2. Mainstreaming Adaptation into Municipal Planning

Whether and how urban governments mainstream climate change into municipal planning and land-use management and legal and regulatory frameworks for development is key to successful adaptation in all countries (Lowe *et al,* 2009: 6; Kehew et al. forthcoming). Mainstreaming has particular importance in countries where much of the vulnerability and risk from climate change comes from inadequate provision of infrastructure and services (Kithiia 2010, Roberts 2008a). Integrating climate change adaptation in urban development could help planners rethink traditional approaches to land use and infrastructure design based on past trends and move towards a new approach of forward looking risk-based design for a range of future climate conditions (Kithiia 2010; Solecki, Leichenko and O'Brien 2011). Important opportunities also exist in high-income countries to use ongoing planning processes to climate-proof infrastructure, spatial form and land use decisions in cities and to build resilience through existing policy channels (Benzie et al. 2011; Blanco et al. 2011; Urwin and Jordan 2008).

Some have argued that adaptation planning should be an integrated, cross-sectoral process (Parry et al. 2007; Sanchez-Rodiguez 2011) yet initiating mainstreaming may best be achieved through encouraging pilot projects and supporting key sectors to take initiatives. Assigning responsibilities and actions to specific departments can make the climate message easier to understand and more transparent (Roberts 2010, UN-Habitat 2011a). Pilot projects ground the imperative of adaptation in practical reality (Roberts 2010, Tyler et al. 2010; Brown et al. 2012). Sectoral approaches and pilot projects can be a pragmatic way to build more comprehensive and cross-sectoral and approaches. Urban authorities in India can see climate change adaptation as a priority if they see co-benefits between adaptation and measures to address development and environmental health concerns (Sharma and Tomar 2010) (see also section 8.4.3). Local governments may be able to address both adaptation and mitigation using the same policy levers such as building standards, transport infrastructure, and other urban planning tools (Hallegate et al., 2011). Addressing adaptation and mitigation together can also avoid tradeoffs when designing policies and build response capacity by developing institutional links (Swart and Raes, 2007). A further challenge is to develop methods to evaluate emerging adaptation measures in a timely manner (Hedger et al.2008, Preston et al. 2011).

Despite the potential for change, evidence from the literature suggests that opportunities to mainstream climate change into urban planning and development are so far largely missed (Sanchez-Rodriguez, 2009). Challenges include lack of leadership, inadequate information, institutional compartmentalization and fragmentation, and resource constraints (Sanchez-Rodriguez, 2009; Wilson, et al, 2011). It is difficult to introduce an additional layer of climate change planning to already complex (and often fragmented) planning systems (Kithiia 2010, Roberts 2008a). The planning agenda can be already full, which in turn makes it difficult to find institutional space for climate change adaptation (Measham et al. 2010). Climate change policies may also be seen merely as "add-ons to the overall strategies driven by economic and spatial concerns" (Kithiia and Dowling 2010: 474). In all instances, where progress on adaptation planning is observed, local leadership is a central factor (Carmin and Anguelovski 2009, Measham et al. 2010).

8.4.1.3. Delivering Co-Benefits

Co-benefits of adaptation and development for urban contexts include delivering safer, more comfortable and healthier urban environments and reducing the vulnerability of low-income groups to wider concerns of environmental and public health and local development capacity – livelihoods, skills training, leadership capacity (Burch 2010, Clapp et al., 2010, Hallegatte et al., 2011, Kousky and Schneider 2003, Carmin and Anguelovski 2009, Roberts 2010). Co-benefits also extend beyond the urban core where hazard is driven in part by local environmental conditions such as land-use on hill-slopes or in wetlands – and also influenced by what is done in water-basin management and coastal defence regimes.

Co-benefits may be particularly important to highlight and plan around in low and middle income countries, where lack of policy buy-in is associated with limited local capacity to make changes to policy agendas capacity (UN-Habitat 2011a) and where current climate change challenges appear marginal when compared with the deficits in infrastructure and service provision outlined earlier and other socio-economic problems faced by authorities responsible for urban development and security (Kithiia and Dowling 2010, Roberts 2008a).

Development and climate change adaptation are often seen as separate challenges in a sub-national, regional planning context. A review in OECD countries revealed that only Japan and South Korea are championing climate action as an integral part of sub-national development planning, however Finland and Sweden also have innovative sub-national climate policies and action programmes that are incentivised and funded by the central government (OECD 2010, Ch. 8). For most OECD countries, however, the two issues of urban development and adaptation are tackled separately. Policy research argues that successful adaptation has to be rooted within development context of the city or country and harmonised with its development priorities, such as poverty reduction, food security and disaster management (Moser and Luers 2008, Satterthwaite et al. 2009, Lwasa, 2010, Measham et al. 2011).

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

Principles of good practice in public decision-making and urban climate risk governance include an important component of science. This includes policy exchange and deliberation where good adaptation decisions will necessarily be based on credible scientific and expert information to consider future predictions and uncertainty around these (Bourque et al 2009, NRC 2009, Rosenzweig and Solecki 2010; Government of South Africa,2010). Climate science shows that future changes will need to vary in some cases significantly from past trends, so the past is no longer a sufficient basis for future planning. Understanding climate risks and vulnerabilities at the urban scale demands a continuous re-assessment of the scientific knowledge about local climate conditions and translating this into useable local knowledge. This will depend upon local capacity to access and use climate change information as it becomes available and processes for local stakeholder engagement in science-policy exercises to understand and assess climate change risk and uncertainties in national, regional and local contexts (Hallegatte et al. 2011; Carmin, Dodman and Chu 2013 forthcoming).

Urban climate science refers to the ability to understand past climate conditions, monitor and attribute historical and present climate change to anthropogenic forcings, and project future changes in temperature, sea level and precipitation sufficiently well that urbanites and urban governments can plan for and adapt to these changes (McCarthy et al. 2010). The paths by which climate change alters local climatic conditions and who is exposed to risk and impacted, will vary with local contextual factors such as local physical and socio-economic conditions (e.g. the size of the local population and its distribution across the land; age structure, the quality, thermal characteristics and location of the built environment; and altitude, soil and vegetation conditions, proximity to the sea or river basins of the area). Urban climate science requires the integration of different kinds of detailed information and projections from physical science and socio-economic domains (Hallegatte et al. 2011, McCarthy et al. 2010). Attention to credibility, legitimacy and salience increase the usability of science and other expert knowledge in policy assessments (from local to global) (e.g. NRC 2007, Preston et al. 2011).

On science-policy issues, such as climate adaptation, research demonstrates the key role of boundary organisations to interpret and shape scientific inputs such that they become more useable in a political context (Cash 2001, Jasanoff 1990, Gieryn 1999, Guston 2001, Driessen et al 2010). In urban adaptation planning, local or regional boundary organisations have also been shown to have influence and support policy decisions (Bourque et al 2009, Corfee-Morlot et al. 2011, Horton et al. 2011). Boundary activities designed to support urban decision-making can take a variety of institutional forms (NRC 2009) and receive funding and support from different sources (e.g. national or sub-national public sources, and in some cases private funding) (Corfee-Morlot et al. 2011). In many instances, key boundary functions are carried out by nearby academic or research communities; local scholars in these institutions can also be a source of leadership for urban adaptation efforts (Molnar et al., 2012; Sanchez-Rodriguez 2009; Government of South Africa 2010).

Even where detailed quantitative and technical urban climate vulnerability or risk assessments exist, the influence of these may be limited if the timing is mis-matched with major policy decisions or if decision-makers do not access and use this information. For example, urban master plans or strategic plans with a time horizon of ten or more years into the future have the potential to incorporate climate risks and vulnerabilities, but timely assessments need to be made available to influence such plans. Beyond timeliness, Moser and Tribbia (2006) explore how decision makers access or use scientific information and the sources they rely upon. Resource managers are more likely to rely upon informal sources, such as maps or in-house experts, media and internet, thanon scientific journals. This emphasises the need to work closely with decision makers in the production and communication of scientific information (ibid, Moser 2006, Cash et al. 2003 and 2006). This demonstrates a need for two-way communication between producers and consumers of scientific and expert information early in any urban climate change assessment and adaptation planning process (Carmin et al. 2012, Horton et al. 2011, McCarthy et al. 2010).

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

Assessments of risk and vulnerability to climate change's direct and indirect impacts are often the first step in getting the attention of governments, especially where these are assessed in the context of general development policy objectives (Hallegatte et al. 2011; see also 8.2). Including risk management information in infrastructure design at the planning or early design phase including that associated with climate change, can avoid higher costs of retrofit at a later date (Baker, 2012, Dickson et al. 2012). This can be assisted through a variety of planning and assessment tools including environmental impact assessment, vulnerability mapping and urban integrated assessment as part of public investment planning and as used by community organisations (UN-Habitat 2007). Governments can ensure that up to date climate information is available to the private sector to support adaptation (Agrawala et al. 2011; see also section below).

A wide range of tools have been developed and used to assess the environmental performance of urban areas including environmental impact assessment tools, environmental audits, strategic environmental assessments and local agenda 21s (Haughton 1999) as well as disaster risk assessment and management tools (Baker 2012). These have potential to support adaptation planning, as they provide useful entry points for adaptation and a means for participatory engagement; however in practice they often give little or no consideration to adaptation (Gurran et al 2012). More reliable, specific and downscaled projections of climate change and tools for risk screening and management can help engage not only relevant public sector actors but also the interest of businesses and consumers (AGF 2010a, UNEP-FI 2011).

Local climate change risk assessments, vulnerability and risk mapping can identify vulnerablepopulations and locations at risk and provide a tool for urban adaptation decision makers (Ranger et al 2009, Hallegatte et al. 2010, Livengood and Kunte 2012). One example is the LOCATE methodology (Local Options for Communities to Adapt and Technologies to Enhance Capacity) that is being tested in eight African countries; in each, a non-governmental organisation is working with one or more communities on project design and implementation, as well as monitoring, evaluation and learning phases. It integrates hazard and vulnerability mapping to inform choices about which populations, infrastructure and areas to prioritise for action (Annecke 2010). Elsewhere, Halsnaes and Traerup (2009) recommend the use of a limited set of indicators, engagement with representatives of local development policy objectives, and a stepwise approach to address climate change impacts, development linkages, and the economic, social and environmental dimensions. There is also a need for assessment tools that go beyond spatial and multi-criteria assessment in order to consider the urban environment as a system; this will allow better understanding of the inter-connections between root causes and risk production, cascading impacts and vulnerabilities (da Silva et al, 2012, UN-ISDR, 2011).

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

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

Despite growing attention, useful information and assessment of climate change at urban spatial scales is generally still lacking (Hunt and Watkiss 2011; Kehew 2009). Only a small number of cities, largely in high-income countries, have quantified risks in local contexts and even fewer have quantified possible costs of climate change risks under different climate, adaptation and/or socio-economic scenarios. Some exceptions exist – as in the case of Durban and the development of a benefit-cost model for climate change adaptation options (Cartwright et al 2013). Other exceptions include urban climate risk assessments carried out in low- or middle-income countries as part of targeted development cooperation programmes and thus supported by external partners (World Bank 2011). Sea level rise and coastal flood risk, health and water resources are among the most studied sectors, while energy, transport and built infrastructure receive far less attention (ibid, Hunt and Watkiss 2011, Roy et al. 2012). While science and climate change information is increasingly available, socio-economic drivers of vulnerability and impacts, as well as opportunities and barriers to adaptation, are less well studied or understood (Romero-Lankao and Qin 2011; Measham et al. 2011).

8.4.2. Engaging Citizens, Civil Society, the Private Sector, and Other Actors and Partners

8.4.2.1. Engaging Stakeholders in Urban Planning and Building Decision Processes for Learning

If the goal is a resilient, safe and healthy city, having a common understanding or vision of what such a future might comprise at urban scale is a first step to achieving it (Corfee-Morlot et al. 2011, Moser 2006, Moser and Dilling 2006, UN-Habitat 2011a). Participatory processes figure prominently across cities that have demonstrated leadership on urban adaptation (Carmin et al. 2012, Brown et al. 2012, Rosenzweig and Solecki 2010; see also below). This experience is consistent with the conceptual literature that suggests that participatory decision-making is essential where uncertainty and complexity characterise scientific understanding of the policy problem (Funtowicz and Ravetz 1993, Liberatore and Funtowicz 2003). Further, many have argued that, the institutional features of the risk management decision-making process -- notably participatory inclusiveness, equity, awareness raising, deliberation, argument, and persuasion -- will determine the legitimacy and effectiveness of action (Dietz 2003, Corfee-Morlot et al. 2011,Lim et al. 2005, Mukheibir and Ziervogel 2007). Yet a recent review of 45 vulnerability mapping exercises found that only 40 percent included stakeholder participation; this raises questions about procedural justice, legitimacy and salience of contemporary approaches to support adaptation investments and other adaptation decisions (Preston et al. 2011). It also highlights the challenge that local governments face to garner resources, including technical expertise and institutional capacity, to organise and effectively use participatory processes to strengthen rather than delay adaptation decision-making (Carmin, Dodman and Chu, 2013).

In many urban settings, civil society and the private sector already have significant and positive roles in support of adaptation planning and decisions. For example, some studies show that despite limited information, some action is moving ahead on adaptation at urban scale particularly through initial planning and awareness raising (Hunt, Watkiss 2011, Anguelovski, Carmin 2011, Lowe et al 2009, Carmin, Anguelovski 2009). Experience in a handful of cities – e.g. Cape Town, Durban, London, New York -- demonstrate that engaging a wide number and variety of stakeholders at early stages in the risk assessment helps to create political support and momentum for follow-on research and ultimately adaptation planning (Hunt and Watkiss 2011, Anguelovski and Carmin 2011; Rosenzweig and Solecki 2010). In informal settlements where there is little or no formal infrastructure and services, stakeholder engagement provides a means for participatory community risk assessment, where local capacity to adapt is built in part through accessing local knowledge (Livengood and Kunte 2012, Kiunsi 2013). Overtime, it is possible to establish institutional mechanisms that support innovation, collaboration and learning within and across sectors to advance urban adaptation action but this takes time and resources (Mukheibir, Ziervogel 2007, Burch 2010, Anguelovski and Carmin 2011, Roberts 2010).

8.4.2.2. Supporting Household and Community-Based Adaptation

In well governed cities, community groups and municipal governments are mutually supportive providing information, capacity and resources in maintaining local environmental and public safety. Where local government has not yet formulated adaptation strategy, community groups can be important in raising political visibility for climate risks and in providing front-line coping (Wilson, 2006; Granberg and Elander, 2007) including highlighting gender disparities in urban risks (Björnberg and Hansson, 2013). Where cities are less well managed and governed, community organizations may be discouraged and seen as a threat to formal urban planning. They may have to lobby an under-resourced municipality in the hope of getting some provision for infrastructure. Or they may have to address the deficit in roads, drains, good quality buildings and other infrastructure and services themselves (and thus it also falls to them to build local resilience to climate change impacts). This has been observed in rapidly urbanizing middle-income (Redclift, et al 2011) and low-income countries (Pelling, 2011a). But it is generally only in middle and upper income residential developments that the full range of infrastructure and services needed for resilience can be afforded.

However, in many cities, community organizations formed by lower-income groups offer a rich resource of flexible capacity that can adapt to take on local priorities for development under climate change (Mitlin and Satterthwaite 2013). They are active in coping that better uses current resources to live with risk and at adaptation that seeks to realign resource options to prepare for future risks. But shifting the burden of adaptation to the community level is unlikely to bring success. Work from the Caribbean and Latin America has indicated the necessity of supportive linkages to wide community networks and/or local government for community level adaptation to be sustainable (Pelling 2011b)

Individuals and households in informal settlements are well used to coping with environmental hazards and the human vulnerabilities that generate risk; they have been shown to take multiple measures to mitigate the impact of extreme weather, especially where there is a history of floods, heat waves or high winds (Wamsler 2007, Adelekan 2010, Jabeen et al. 2010, Livengood and Kunte 2012, Kiunsi 2013). Some seek to modify the hazard itself e.g. ventilation and roof covering to reduce high temperatures during heat waves or barriers built to prevent floodwater entering homes) or reduce their exposure e.g. by sleeping and keeping food stores on top of high furniture and moving temporarily to safer locations. Exposure reduction measures are the most common *(*Douglas et al 2008).

There is an important distinction to be made between coping and adapting. SREX (IPCC 2012) distinguishes between coping as acts that bring together existing resources and entitlements to protect against a current threat, and adaptation, which seeks to adjust entitlements and future resource portfolios in the expectation of future risk. Many studies show the importance of coping mechanisms for low-income households because they lack the resources or capacities for adaption. A study in Korail, one of the largest informal settlements in Dhaka, showed that diverse household responses to flood risk (see Figure 8-2 for one example of this). Measures include barriers across door fronts, increasing the height of furniture, making floors or shelves to store goods above the flood line. Provision for ventilation, creepers or other material on roofs and false ceilings helped to keep down temperatures. Households also used portable cookers that can be used on shelves or furniture (Jabeen et al. 2010). These are important coping responses (and comparable responses are found in many informal settlements – see for instance Adelekan 2010 and Kiunsi 2013) but they do not articulate capacity to adapt – to influence future coping.

[INSERT FIGURE 8-2 HERE
Figure 8-2: Household adaptation - a cross section of a shelter in an informal settlement in Dhaka (Korail) showing measures adapting the dwelling to better cope with flooding and high temperatures.]

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

Community-based adaptation arises when a group of residents in a particular settlement agree to work together to address a perceived risk they face that the city government is not addressing (Boyd et al. 2009, Dodman and Mitlin 2011). These responses to climate change can be autonomous of, or engage with, local governments, sometimes via networks of community organization or with brokerage from NGOs (Mitlin, 2012). There is typically far less need for comprehensive community action in well governed cities, as shown in Table 8-2. In low and most middle-income nations where capacity and resources are most stretched as well as cities in high-income countries with inadequate governance and resource base, enabling community based adaptation and building resilience is more relevant. This is because of the limited capacity of governments to provide much needed risk-reducing infrastructure and services or their unwillingness to work in informal settlements. A range of studies documents how local populations have a depth of knowledge and capacities to mitigate their vulnerabilities (Dodman and Mitlin 2011, Anguelovski and Carmin 2011, Livengood and Kunte 2012). Close to a billion people live in informal settlements in urban areas across the world and for a high proportion of these, community-based adaptation is their only means of response.

Community-based responses are often reactive – also more coping than adaptation facing - as residents within a particular settlement work together to install or repair infrastructure or provide services or action to engage local government and if possible work with it. There are many precedents for this engagement with local governments, including many upgrading programmes in informal settlements that have improved housing quality and infrastructure provision. Most upgrading programmes also mean that those living in these settlements became incorporated into 'the formal' city and this often means other measures by the state to reduce their risks – for instance though access to schools, health care and safety nets (Almansi 2009, Boonyabancha 2005, Fernandes 2007, Ferguson and Navarrete 2003, Imparato and Ruster 2003, Some et al , 2009, UN Millennium Project 2005). In many informal settlements, the issue of land tenure is difficult to resolve and this impedes upgrading programmes and local level adaptation action (Boonyabancha 2005, 2009, Almansi 2009). Where upgrading is able to deliver basic needs and services including security of tenure this can act as a foundation for coping and potentially adaptive capacity. Where adapting to or coping with climate change dovetails with the meeting of existing priorities and reducing existing risks, considerable local scope can exist. But where climate change or disaster risk are seen as distant or low probability then the immediate pressures of poverty tend to dominate local agendas (Banks et al. 2011). The studies noted above highlight how the willingness of individuals to invest in collective action is influenced by their tenure status. Tenants and those with the least secure tenure are often amongst the most vulnerable and exposed to hazards but also are usually unwilling to invest in improving the housing they live in and less willing to invest in community initiatives. But the contribution of community-level organization, DRR and climate change adaptation can be greatly enhanced where local governments and other agencies like civil defence organizations recognize the potential role of community organization and action and support them.

It has become more common for local governments to work with community-based organizations not only in upgrading but also in disaster risk reduction (Pelling 2011b, United Nations 2009, 2011, IFRC 2010). Community-based adaptation will probably be preceded by community-based actions to reduce risks and vulnerabilities to flooding, storms and heat waves in the past (Archer and Boonyabancha 2011, Carcellar et al 2011). But there are limits to what community action can do in urban areas. For instance it may be able to build and maintain community water sources, toilets and washing facilities or construct or improve drainage (see for instance the large community-driven sewers and drains programmes in cities in Pakistan Hasan 2006) but it cannot provide the network infrastructure on which these depend (e.g. the water, sewer and drainage mains and water treatment) or city-region management (Satterthwaite et al. 2009). Most informal settlements are embedded in a larger built up area so there is no space in their periphery to which to channel flood waters or dispose of household wastes. But here, supportive local governments or utilities can help – for instance in Karachi, the water and sanitation utility supported the community-driven provision mentioned above by providing the trunk infrastructure into which it could integrate. There are also many examples of where community organizations in informal settlements negotiated inclusion into formal water and sanitation systems (Boonyabancha 2005), such as in in Penjaringan, a low-income informal settlement in North Jakarta, where community groups organized to gain connection to the city piped water network (Prabaharyaka and Pooroe 2010).

Urban resilience to climate change impacts requires actions, investments and governance frameworks that only local governments can provide, even though private sector and community-based action may support this. A focus on community-action may mean a lack of attention to the structural and institutional inequalities or failures that underpin local vulnerabilities and the failure of local governments and agencies to address these (Dodman and Mitlin 2011). Table 8-3 illustrates the contemporary limits of community based action across key sites of coping and adaptation – highlighting where strategic partnerships, especially with a supportive municipal government have key advantages.

[INSERT TABLE 8-3 HERE
Table 8-3: The possibilities and limitations of focused activity for community groups on climate change.]

The IFRC (2011) identify three broad requirements for successful urban community based disaster risk reduction, work that can be extended to assess coping and adaptive capacity. These requirements are: (1) the motivation and partnerships of stakeholders; (2) the levels of community ownership, wider integration and flexibility in project design, and (3) having sufficient time, funding and management capacity.]

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

The effectiveness of community-based adaptation in urban areas depends on the extent to which community organization (and the larger networks or federations they form) can generate pressure for larger changes within government and for relations between community organizations and government (Boonyabancha and Mitlin 2012). Community-based adaptation can engage with key development agendas that reduce poverty and vulnerability (Sabates-Wheeler et al. 2008) and potentially be effective in light of local inequalities and adverse power relations at district, city, national and transnational levels (Mohan and Stokke 2000). But urban governance regimes are often resistant to challenge and civil society organizations can be marginalized or co-opted reducing scope for adaptive action at the level of governance (Pelling and Manuel-Navarrete, 2011)..

There are new methods of documenting and mapping risks and vulnerabilities in informal settlements that serve and support community based adaptation. Even though it is common for a third or more of the inhabitants of cities in low- and middle-income nations to live in informal settlements, these are often not included in official government records and maps. In a growing number of cities, the mapping and enumeration of informal settlements has been undertaken by residents organizations supported by grassroots leaders and local NGOs – with city governments coming to support these and recognizing the validity of the data and maps produced (Patel and Baptist 2012). These provide the household and settlement data and maps needed to plan the installation or upgrading of infrastructure and services that reduce risks from extreme weather. Some of these community-driven enumerations also collect data for each informal settlement on risks and vulnerabilities to extreme weather and other hazards (Pelling 2011b, Carcellar et al. 2011, Livengood and Kunte 2012, UNHABITAT 2007). For instance, community surveys in the Philippines identified at risk communities under bridges, near cliffs and other landslide-prone areas, on coastal shorelines and river banks, in public cemeteries near open dumpsites, and on those in flood-prone locations (Carcellar et al. 2011). This mapping also helps raise awareness among the inhabitants of informal settlements of the risks they face, as well as getting their engagement in planning risk reduction and making early warning systems and when needed emergency evacuation effective (Pelling 2011b).

8.4.2.3. Private Sector Engagement and the Insurance Sector

Cities represent a particular interest for companies because much business activity, private investment and demand is concentrated there and because of their dependence on the functioning of infrastructure and usually a wide range of services. Brugmann (2012) notes how cities concentrate a high proportion of global investment and value added in global supply chains of production, and therefore a high proportion of what requires adaptation (and the funding needed to realize it). He argues that the costs of effective adaptation reaches far beyond what governments or international agencies can provide and depends on catalysing market-based investments in adaptation and financial instruments that reward investors who contribute to resilience. There is also a large number of private service providers and professional associations -- including architects, engineers and urban planners – positioned to influence the pace and quality of adaptation efforts (McBain et al. 2010).

Others argue that most of the investment required for sound adaptation will come from a multitude of private decisions spanning individuals, households and firms (Bowen, Fankhauser et al. 2008, OECD 2008). In contrast, international discussions often assume that the public goods nature of adaptation will require a major public investment to cover the principal adaptation needs in low- and middle-income countries (AGF 2010b and c). Even when considering this more political set of questions around how to support adaptation efforts internationally, it is clear that the need for adaptation investments will far exceed available funds from public budgets (Hedger 2011, OECD 2008, World Bank 2010e). This underscores the need for both public and private engagement to address adaptation.

For markets to work in favour of urban adaptation, the private sector will need to see financial value in getting involved. In a survey of the most serious risks that companies face (Aon 2011), the top ranked risks were economic slowdown, regulatory/legislative change, increasing competition and damage to reputation. Weather and natural disasters came16th and climate change 44th – even if some risks that were ranked higher may be associated with climate change impacts (business interruption was 5th, commodity price risk 8th and distribution or supply chain failure 12th). It is not clear that private sector actors are well positioned to consider the big questions of urban development that climate change adaptation requires (Redclift et al. 2011). For example, in Cancun, Mexico close relationships between government and the corporate private sector, and the push for lucrative urban development, have led to a failure to reflect on the urban development model and generates climate change risk through hazard exposure of capital intensive and large-scale coastal development. Private sector investments in adaptation in this context are limited to superficial changes, for example in building design to withstand hurricanes; most investment in risk management comes from the state sector through for example beach replenishment and a focus on policies for rapid disaster recovery (Manuel-Navarrete et al. 2011).

The Private Sector Initiative of the UNFCCC Nairobi Work Programme offers support for businesses to integrate climate change science into their business planning, including urban infrastructure and high technology developments (see http://unfccc.int/adaptation/nairobi_work_programme/private_sector_initiative/items/6547.php). This experience has shown that both public and private (including civil society) actors can have a role in providing regional and local climate predictions and hazard mapping e.g. data and projections on socio-economic trends, climate change, urban water supply and management practices and land use and building trends (UNEP-FI, 2011). A recent review of private sector engagement in adaptation shows anecdotal evidence of some large businesses beginning to invest in vulnerability assessments, yet few have begun to invest in adaptation; these include business with assets at risk to climate change, or with dependence on natural resources that are particularly exposed to climate change e.g. freshwater resources (Agrawala et al. 2011). While some private sector actors may be pro-active in taking action against climate change risks, many more will postpone upfront investments for longer-term benefits against uncertain risks. Eakin et al. (2010) and Chu and Schroeder (2010) suggest that the private sector may become more prominent when local governments and civil society action is limited but this raises the issue of what incentives private sector enterprises require to do so and whether they will do so for the public good.

Insurance markets can play a unique role in urban adaptation by sharing and spreading financial risk from climate change, for example, to help limit damages and manage risks of climate change in urban flood prone areas (Rosenzweig and Solecki 2010). Risk-differentiated property insurance premiums can incentivise individuals and businesses to invest in adaption or to avoid being or building in high-risk areas (e.g. flood prone or fire hazard areas) and retro-fit property to reduce risk (Fankhauser et al. 2008, Mills 2007). Relevant insurance instruments include provision of health and life insurance to individuals; property and possessions insurance for home and commercial property owners, and micro insurance or micro finance mechanisms to support those in low-income urban communities that are not covered by commercial insurance (see Box 8-2) Catastrophe bonds may also be developed to cover some urban climate risks, however experience to date suggests that they are written quite narrowly - for specific events in specific locations - and thus may not provide the broad protection necessary to limit catastrophic risk as warranted in a changing climate and urban context (Brugmann 2012, Keogh et al. 2010).

Where risk levels exceed certain thresholds, insurers will abandon coverage or set premiums that cannot be afforded by most of those at risk. Private investment or standard insurance markets will not protect low-income urban dwellers, many of whom live in informal settlements where risk levels are high, where insurance is often inappropriate (few assets are legally owned), inaccessible (they are unable to get bank accounts that are required), or unaffordable (premiums set too high so that the up-front costs of insurance prevent its take up) (Ranger et al., 2009, Hallegatte et al. 2010). For example, around half of Mumbai's population currently live in informal settlements, most of which have inadequate provision of basic infrastructure and are at risk to floods today (Hallegatte et al.

2010, Ranger et al. 2011, McFarlane 2008). The risk profile for this informal settlement population is set to increase under most scenarios of climate change. This population will not be served by insurance mechanisms unless the risks they face are greatly reduced (and thus insurance costs lowered). They will rely instead upon government assistance and local solidarity, such as family and community support, to respond when disaster hits (Hallegatte et al. 2010). So insurance while reducing net risk and loss potential in urban areas can increase inequality in security across the city and within neighbourhoods or across regions (da Silva 2010).

In many informal settlements, informal savings groups are active and provide members with quick access to funds. Most savers and most savings managers are women and these groups have particular importance for providing their members with rapid access to emergency loans (Mitlin 2008). Where access to formal banking is limited by poverty, but where social capital is high, slum dwellers have pooled their savings and used these for collective investments that reduce risk within their existing settlement or reduce risk by allowing them to negotiate land and support where they can build new homes (d'Cruz et al 2013, Manda 2007, Mitlin and Muller 2004).

_____ START BOX 8-2 HERE _____

Box 8-2. Microfinance for Urban Adaptation

Microfinance schemes may contribute to pro-poor, urban adaptation through a variety of different instruments including micro-credit, micro-insurance and micro-savings to help households and small entreprenuers that do not have access to formal insurance or commercial credit markets. To date, these have been applied mostly in rural areas generally benefitting those with some property status (and thus not the poorest of rural populations). 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 micro insurance – products and sharing of knowledge and information to influence behaviours*." Although typically more costly than commercial bank loans, micro-finance can support entrepreneurial undertakings by those unable to get bank loans, help diversify local economies and empower women in particular, which can in turn contribute to adaptive capacity in a local context (World Bank 2010c, Agrawala and Carraro 2010). But micro-finance may focus on short-term gains by encouraging growth in risk-prone areas and sustaining livelihoods with little resilience to climate change (Agrawala and Carraro 2010). This suggests a need for "climate-proofing" microfinance practices and targeting its use to priority tasks that will deliver adaptation and development benefits in the nearer term including disaster risk reduction and community based technical training and education (ibid.). Microfinance also provides a means for donors to deliver support to low-income groups without creating an ongoing dependence on aid (ibid., Hammill et al. 2008). But one limitation of micro-finance for adaptation is that it typically provides credit to individuals for their use only, so it is not easily used to help finance collective investments - for instance to improve drainage - and can be a route into indebtedness especially during disaster recovery. There has been some experience of pooling savings, e.g. in low-income communities to set up City Development Funds in Asia, from which they can draw loans for disaster rehabilitation among other things (Archer 2012).

_____ END BOX 8-2 HERE _____

For the private sector to fulfil its potential to facilitate adaptation, public policy needs to establish enabling conditions in markets (see 8.3). For example, urban policies can target payment for provision of ecosystem services that will otherwise fall outside of the market system to provide adaptation benefits; such services include storm buffering and flood protection through payments for mangrove protection in coastal zones or payment for protection of urban green space along river-ways (Fankhauser et al., 2008, Roberts et al. 2012). In the buildings sector, well-documented examples of market failure exist where optimal investment in weather proofing new construction and retrofitting existing stock will not occur without regulatory intervention; this is also an area where municipal governments often have authority to act. Public policy and funding is also needed to protect the poorest and most vulnerable populations, who are least able to protect themselves through private action. More generally, where information is highly uncertain or not consistent with past experience, as is the case for the prediction of extreme weather events and potential losses, public policy has a role to help provide information about risks and to ensure action e.g. to fill gaps in insurance markets where insurers are unable or unwilling to act (Fankhauser et al., 2008, Mills 2007, SREX 2012, UN-Habitat 2011). For example, regulations can require pro-active engagement of the private sector, as in the UK, where vulnerability assessment is required for infrastructure investments with implications for urban planning and investments (Agrawala et al., 2011). Other examples exist where urban governments lead by example by requiring the integration of adaptation considerations into public operations and infrastructure investments through procurement requirements, which in turn affects private sector providers of services and products in the supply chain of these operations. Thus even where markets exist and are well-functioning, public intervention – spanning local to national level action - is warranted as a means to engage the private sector in adaptation. There will also be a role for public-private initiatives to provide educational and skill development resources to ensure that professional networks of private service providers (i.e. architects, engineers and urban planners) are trained in the latest decision tools, assessment methods and practices (McBain et al., 2010, da Silva, 2012)

8.4.2.4. Civil Society Partnerships and Philanthropic Engagement

Philanthropic and other civil society support for urban adaptation is gaining rapid momentum at all levels of operation. The most diverse are local actions undertaken by community based organisations, and these often build on long experience of working with the urban poor on livelihoods, governance and basic needs fulfilment. The greatest learning process has taken place amongst international philanthropic and civil society humanitarian organisations that now take urban adaptation seriously and build from experiences in urban climate change mitigation and rural adaptation respectively. These are sectors where lessons are not easily transferred so that new experimentation and practice development is underway.

An expression of international civil society as an enabling framework is the role played by philanthropic organizations.

One example of this is the Rockefeller Foundation’s support for the Asian Cities Climate Change Resilience Network (ACCCRN). This is supporting partner institutions in ten cities in India, Indonesia, Thailand and Vietnam to build local knowledge, capacity and strategies to institutionalise climate change adaptation and resilience in local planning and development. This includes prioritising support for interventions to guide future investments to build resilience into the measures to meet the diverse needs of residents, businesses and the urban economy (Moench et al. 2011, Brown et al 2012). Others, such as the Bill and Melinda Gates Foundation approach urban adaptation indirectly through interests in poverty and disaster response and emphasise capacity building through education including programme support for universities in disaster-prone regions in Africa and Asia to establish a network of education and development programs in disaster resilience and leadership organized from Tulane University, New Orleans. The growth in philanthropic foundation spending has as yet largely unresearched implications for the direction of knowledge and capacity building on urban adaptation (Buchner et al. 2011).

Many civil society initiatives have developed models of infrastructure delivery; these are not centered on adaptation but they do have relevance for it. For instance, the installation of community-managed sewers and drains supported by the Orangi Pilot Project Research and Training Institute in urban areas in Pakistan shows capacity at community level but also how the scale and scope of what could be achieved was much increased by supportive investments by government (Hasan 2006). Elsewhere ad-hoc coalitions of civil society actors, or uncoordinated activity in many other cities provide a de facto delivery mechanism for accessing basic infrastructure and rights as part of development and disaster response (Pelling 2003). Here, while individual community groups may be foresightful and adaptive, the lack of coordination across communities limits the scale and scope of adaptive capacity. Adding to the argument for enhanced civil society coordination is the recognition that many disaster events are small, local but have a widespread and cumulative impact on the development prospects of low-income households and communities (United Nations 2009). The scale and range of recent disaster events in Asian cities suggest a growing need for new support mechanisms to facilitate action among local stakeholders – one that should include local government as well as local civil society organisations (Shaw and Izumi 2011). One experiment in this regard, though not exclusively focused on urban contexts, is the Global Network of Civil Society Organizations for disaster risk reduction. This has organised community groups at national and then (supra-national) regional and global levels in a structured assessment of the local delivery for disaster risk reduction goals, as set out in the Hyogo Framework, as a means of verifying claims made by national government submissions to the ISDR.

Where urban-based civil society is well coordinated and has high degrees of legitimacy, it can reach beyond this to offer alternative models for urban governance and for adapting to climate change as part of the development struggle (Mitlin 2012). These are alternatives that need not be in confrontation with local government. Evidence from Santo Domingo, the Dominican Republic has shown the importance of partnerships between local urban government and local civil society actors in achieving longevity, in options for upscaling local disaster risk reduction initiatives and for building on trust generated by such projects to deliver other gains, in this case improved policing and reduction in gang related violence (Pelling 2011b). In the Philippines, many local governments now work with the Philippines Homeless People's Federation in identifying those most at risk to natural disasters and acting to address this (Carcellar et al., 2011)

The coming together of grassroots civil society organisations to form international collaborations strengthens the framing role of civil society while retaining its local accountability and focus. The local situatedness of adaptation and the need to both address local conditions and structural root causes of vulnerability makes such organisations well placed. Amongst the most active with a dedicated urban focus is Shack/Slum Dwellers International (SDI), a network of community-based organizations and federations of the urban poor in 33 countries in Africa, Asia, and Latin America and their local support NGOs. Its member federations share experiences, lobby and undertake practical upgrading and risk reduction initiatives as well as seeking to influence the policies of development assistance agencies. Regional networks of organisations also contribute to the emerging international architecture of civil society movements working on risk reduction - for example, the Asian Coalition for Community Action Program managed by the Asian Coalition for Housing Rights is supporting community-driven upgrading initiatives in 150 cities in 18 different nations and supporting improved relations between community organizations and local governments (REF). Other civil society networks have broader interests but include urban risk reduction, for example the Asian Disaster Reduction and Response Network (ADRRN), which aims to strengthen local civil society groups in the region.

8.4.2.5. University Partnerships and Research Initiatives

Since AR4, interest in urban aspects of adaptation has grown amongst researchers and universities and some associated national research funding agencies. This is also evident in the number of conferences on this topic and in the number of professional societies (including architects, urban planners and engineers) that are considering their roles and responsibilities. Parallel agendas from social and behavioural sciences and policy on one hand and engineering and city planning sciences on the other are beginning to integrate. Examples of this include the Urban Climate Change Research Network (UCCRN), which brings together researchers and city planners to exchange knowledge and build a coalition of awareness and policy – particularly important when national level policymaking on adaptation is slow (Rosenzweig et al, 2010).

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

Individual academic institutes have also begun to champion and support urban adaptation efforts. For example the Urban Observatory in Manila has become a regional hub for climate change science and urban adaptation, though interests in mitigation and rural adaptation are much more developed. In Malaysia the Universiti Kebangsaan Malaysia hosts a Malaysian Network for Research on Climate, Environment and Development (MyCLIMATE) and has focused on building awareness and capacity amongst industry and civil society (Izumi and Shaw, 2011). The

Climate and Disaster Resilience Initiative (Kyoto University, CITYNET and UNISDR) has focused on working with city managers and practitioners (Shaw and IEDM Team 2009). Centres for capacity building are also emerging such as the International Centre for Climate Change and Development (ICCCAD) in Dhaka which offers short course on urban adaptation planning (Mehrotra et al. 2009, Anguelovski and Carmin 2011, Molnar et al. 2010). In Latin America networks such as FLACSO provide leadership across the region in disaster risk reduction, management and climate change adaptation. Such networks can bring knowledge across urban centres and connect to international knowledge. Individual centres have also become more engaged in urban adaptation from established expertise in urban climate change mitigation (eg UNAM in Mexico).

8.4.2.6. City Networks and Urban Adaptation Learning Partnerships

The growing interest in urban adaptation among researchers and urban governments is also seen in the growth of transnational networks where urban actors work across organisational boundaries to influence outcomes (Bulkeley and Betsill 2005, Bulkeley and Moser 2007, Rosenzweig et al 2010). Some of these have been created through formalised information networks and coalitions acting both nationally and internationally, including ICLEI's Cities for Climate Protection, the Climate Alliance, the C-40 Large Cities Climate Leadership Group, and the Urban Leaders Adaptation Initiative in the US. The United Cities and Local Governmentsthat represents local governments within the United Nations have a growing interest in climate change adaptation. The Asian Cities Climate Change Resilience Network (ACCCRN) mentioned above also encourages inter-city learning for officials and local researchers (Brown et al. 2012). The Making Cities Resilient network supported by the UN International Strategy for Disaster Risk Reduction seeks to catalyse city governments to take action based on a ten-point priority agenda that includes a call to adapt to climate change by building on good risk reduction practices (UNISDR 2008; see also Johnson and Blackburn 2013).

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

8.4.3. Resources for Urban Adaptation and their Management

Resources for urban adaptation action can come from domestic and international public and private sectors. Table 8-4 summarizes the main financial instruments that can help fund adaptation in cities. For high-income countries, estimates show that local governments are responsible for about 70 percent of public spending and roughly 50 percent of the public spending on environment infrastructure – although often operating in partnership with other levels of government (OECD 2010). The scale and source of funds that might contribute to adaptation varies widely by city and location. The local revenue sources available to an urban government depends upon the national institutional and legislative framework that devolves some authority to tax or imposes other fiscal policies on local residents, property owners and businesses. Some of the environmental innovation shown in cities in Latin America over the last 20 years is associated with decentralization that has strengthened fiscal bases for cities, as well as elected mayors and more accountable city governments (Campbell 2003, Cabannes 2004). Much less is known about urban fiscal policies in Africa and Asia except that a high proportion of urban governments have very limited investment capacities as most of their revenues go on salaries and other recurrent expenditures (UCLG 2011).

[INSERT TABLE 8-4 HERE
Table 8-4: Main sources of funding and financial instruments for urban adaptation.]

Table 8-4 highlights how large cities with strong economies and administrative capability are most able to attract external funding (including transfers from higher levels of government) and raise internal funding for adaptation. There are far fewer possibilities for less prosperous and smaller urban centres and for cities with fragmented governance structures or where administration is manifestly lacking in capability. One key issue here is 'unfunded mandates.' In many nations, local governments have been assigned responsibilities without the needed increase in funding and capacity (UCLG 2011) – and this may now also happen in relation to new responsibilities for adapting to (or mitigating) climate change (Kehew et al. 2012). The implication is that the funding regime and supportive legal frameworks need to integrate climate change risk management and adaptation into development.

8.4.3.1. Domestic Financing: Tapping into National or Sub-national Regional Sources of Funding and Support

Domestic public funding is one of the most significant and sustainable source of funding for adaptation in many countries. In recent years, initiatives to green local fiscal policies have spread. These include congestion charges on automobiles and value-capture land taxes that make visible the cost of environmental externalities and/or the benefits of infrastructure and services provided to property owners (e.g. transport, water and wastewater services). Such measures can promote private investment in risk management while mobilising local revenue sources (where a portion could be targeted to support urban adaptation). Local fiscal incentives for mal-adaptation may also exist, e.g. in China and parts of Québec, urban government budgets and actions are financed by land sales, which in turn promote urban sprawl or development in areas at risk (Merk, 2012; Drejza et al. 2012). Greening local fiscal policies will need to identify and address pre-existing policies that incentivise mal-adaptation.

Another important source of funding for local adaptation is grants, loans or other forms of revenue transfers from national or regional (sub-national) governments (OECD 2010: Ch 9, Hedger and Bird 2011). OECD (2010:239) states: "*In cases where environmental policies with large spillovers are assigned to local governments, intergovernmental grants could make sense in order to compensate local governments for the external benefits of its expenditures*." One example of this is municipal funding in Brazil that is influenced by ecosystem management quality; in this case the allocation of tax revenues is performance based (see Box 8-3).

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Box 8-3. Environmental Indicators in Allocating Tax Shares to Local Governments in Brazil

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

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

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

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A number of other innovative financial mechanisms may be used to support urban adaptation. These include revolving funds and the energy services company (or the "ESCO") model (OECD 2010:Ch. 8 and Ch 9). Revolving funds can be developed from a variety of different revenue streams, say from a Clean Development Mechanism project (Puppim de Oliveira 2009) or financial savings from energy efficiency investments in municipal buildings, to feed a public fund that can support public investments that yield adaptation benefits. Local governments in high and some middle income countries may also have direct access to debt instruments such as bond markets or loans from national (or regional) development banks or financial institutions (OECD 2010, EIB 2011). Local access to capital markets to fund adaptation investments can also be facilitated through risk-sharing mechanisms or financial guarantees provided by external or domestic development banks e.g. Kfw provides low-interest loans to local banks which in turn finance energy efficiency renovations in residential and commercial building (OECD 2010, Kfw 2011). Funding for climate change adaptation in cities is usually oriented towards technological investment and capital projects, rather than to integrating economic and social approaches. A key challenge is to determine how far adaptation funding should be recalibrated to better take advantage of inputs from social, economic and behavioural sciences and target associated policy realms. For example, the very high costs brought by extreme weather events in urban areas, described in earlier sections, and the fact that climate change increases these risk indicates the need for increased funding and attention from national budgets for disaster risk reduction, early warning and evacuation procedures within urban areas, alongside other adaptation measures (World Bank 2010a, 2010f, Hallegatte and Corfee-Morlot 2011). The urban funding gap may be particularly wide for "soft" rather than "hard" infrastructure investments yet they can be a motor for resilience.

8.4.3.2. Multilateral Humanitarian and Disaster Management Assistance

The international humanitarian community is increasingly active in urban contexts. The scale and scope of action is often impressive, particularly when large disasters unfold in major urban areas. There is opportunity for humanitarians to learn from non-climate related disasters (earthquakes, tsunamis and technological or military events), and the sector is beginning to review experience and develop appropriate tools and guidelines for urban contexts (eg ALNAP, 2012). In 2009 the Inter-agency Standing Committee, an umbrella group of humanitarian groups that sets policy for the aid community, formed a reference group on meeting humanitarian challenges in urban areas, setting a two-year action plan in 2010. It has developed a database of urban specific aid tools, the Urban Humanitarian Response Portal (http://www.urban-response.org/). The complexity faced by humanitarians working in urban areas makes it difficult to target aid to risk reduction or response. One report concludes that the humanitarian sector needs to make better use of social sciences and urban planning in humanitarian teams to better understand urban settings (Grűnewald et al, 2011). Amongst the biggest challenges facing the sector working in urban contexts is to develop policies sensitive to the needs of internally displaced urban populations, and how this can be managed in contexts where the resident population is chronically poor (Zetter and Deikun, 2010); also how international agencies can respond appropriately to the prospect of a significant increase in urban food insecurity (see IRIN, 2013).

The systematic programming of climate change adaptation into multilateral humanitarian, disaster response and management funding is in its infancy and urban dimensions are largely under-developed although this is changing (see United Nations 2009, 2011, IFRC 2010). The World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) explicitly includes adaptation to climate change and its Country Programmes for Disaster Risk Management and Climate Change Adaptation 2009-2011 also seek to deepen engagement in selected priority countries (GFDRR 2009). The GFDRR has also worked with UNISDR to advocate for more joined up policy and advisory services at the technical level (see Mitchell et al. 2010). A survey of 2009-2011 reports from 82 governments on how they were advancing disaster risk reduction and the treatment of urban and climate change issues within this, found that some progress has been made in both areas, across different types of countries (i.e. from low to high income) (Figure 8-3, United Nations 2011).

[INSERT FIGURE 8-3 HERE
Figure 8-3: Progress reported by 82 governments in addressing some key aspects of disaster risk reduction by countries' per capita income.]

Despite such progress, many urban governments lack the capacity to address disaster risk reduction and management. Almost 60 percent of the countries surveyed by the UN and almost 80 percent of lower-middle income countries reported that local governments have legal responsibility for disaster risk management, but only about a third confirmed dedicated budget allocations and these were mostly in upper middle and high income countries (United Nations 2011). Figure 8-3 highlights a relative lack of attention to urban and land-use planning and greater attention to investments in drainage infrastructure. As a whole, attention to these linkages is lower in low and lower-middle income nations, yet in more than half the high to lower middle-income nations, governments reported progress to integrate climate change policies into disaster risk reduction.

8.4.3.3. International Financing and Donor Assistance for Urban Adaptation

To date international adaptation financing has largely overlooked urban areas (UN HABITAT 2011) and most of the most vulnerable cities and municipalities are not well positioned to access available funding (ICLEI, 2010, Paulais and Pigey 2010). This generates a double funding gap – low availability of fundsfor adaptation and often very large deficits in risk-reducing infrastructure and services.

While more international funding for adaptation and mitigation is being committed (see for instance the Cancun Agreements) and there are some indications that governments are broadly on track to deliver on these (Clapp et al. 2012 , Buchner et al. 2011), there is less in evidence is the institutional arrangements by which such support is available to urban governments for adaptation – and thus to support work that can build adaptive systems for urban management, systems that evolve with changing social and environmental dynamics as indicated in the IPCC SREX report (IPCC, 2012). The failure to explicitly recognise urban adaptation needs is also the case for new dedicated climate change funds. In addition, international public funding for adaptation may be difficult to discern from development finance (Tirpak et al. 2010, Buchner et al. 2011).

Recent data suggest that a notable yet still minor share of development finance targets climate adaptation (UNEP 2010, OECD 2012). The extent to which urban adaptation is explicitly or even indirectly covered in donor portfolios is largely unknown, although many bilateral agencies choose to have a very limited engagement with urban initiatives (Satterthwaite and Mitlin, 2013). OECD estimates that between 23-38% of reported ODA commitments from bilateral donors for climate change target adaptation (OECD 2012). In an in-depth assessment of five major donors, with coverage of concessional (ODA) and non-concessional finance, adaptation was estimated to be 30% of the climate change portfolio, most of it targeted to water and sanitation (about 75%) while the remainder targeted urban relevant sectors (i.e. transport, policy loans, disaster risk reduction) with energy and health seemingly largely overlooked (UNEP 2010, see also Atteridge et al. 2007). Conventional multilateral and bilateral channels for development finance appear to have the biggest role in adaptation financing, though several new vertical funds are also emerging. The proliferation of multiple, single purpose funding mechanisms runs contrary to long-standing principles of sound development cooperation notably harmonisation and alignment (McKenzie Hedger 2011). This also creates a more complex funding architecture, making it difficult for smaller actors, such as local authorities, to access available sources for timely adaptation investments.

Reconciling external resources with bottom-up, locally based planning and project preparation could provide a means to better target development assistance (i.e. to urban planning processes that take climate risks into account), while also ensuring that limited funding is directed to programmes that aim to be mainstreamed into urban development over time (Brugmann 2012). Yet research shows that partner countries typically lack defined priorities for the use of funds; when combined with a donor tendency to “control” funds to ensure short-term results, and a large variety of different funding instruments, the result is highly fragmented delivery systems that lead to unclear outcomes (Peskett and Brown 2011). Even where national leadership and climate strategies exist to guide action – as in the case of Bangladesh, an “early mover” on adaptation planning – the plan is not yet costed nor is it sequenced. This makes it difficult to use as a framework for delivery of international climate finance (McKenzie Hedger 2011). A key to improving effectiveness of international public finance will be building the capacity for country-led planning processes that identify priority projects and programmes for the targeting of adaptation funds that include urban adaptation.

National Adaptation Plans of Action (NAPAs) have become a principal way of organising an integrated, climate change aware approach to development but the majority of plans do not explicitly include urban adaptation projects.UN-Habitat's review of a quarter of submitted NAPAs in 2011 found that only 14 per cent of the resources called for by those NAPAs were for projects that were largely or exclusively urban (UN HABITAT 2011c). NAPAs remain essentially top down, led by the national government. Urban governments typically only have access to international public finance through their national governments. One possible approach is for national governments to set up funds that are supported by international finance and on which urban governments can draw (Paulais and Pigey 2010).

A growing consensus among authors concludes that international development finance is failing to tackle urban adaptation financing needs (Parry et al 2009,Paulais and Pigey 2010, UN-Habitat 2011c, ICLEI 2011a). In some middle income countries, such as Indonesia, rather than focusing on large amounts of new external funding to support climate action, a more effective and sustainable strategy may be national fiscal policy reforms and incentives to steer investment to priority needs (Peskett and Brown, 2011). Beyond better delivery and use of development finance, there is also a need to mobilise domestic public and private investment to ensure delivery of adaptation at national and urban levels (Hedger 2011a & b, Hedger and Bird 2011, OECD 2012). Accessing international development finance for urban adaptation will require building routine institutional mechanisms for supporting multilevel planning and risk governance (Corfee-Morlot et al. 2011, Carmin et al, 2013).

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

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

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

[INSERT FIGURE 8-4 HERE
Figure 8-4: The basic challenge of effective climate change communication to change behavior and norms.]

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

8.4.3.5. Monitoring and Evaluation to Assess Progress

Tools for monitoring and evaluation of urban adaptation actions are needed to assist adaptation leaders and funding institutions to justify investments. Monitoring urban adaptation activities and their effectiveness requires indicators that show if adaptation is taking place, at what pace, and in what locations. Among the relevant evaluation criteria to track are: cost, feasibility, efficacy, co-benefits (direct and indirect), and institutional considerations (Jacob et al. 2010). Assessment methods can capture outcomes of adaptation decisions, or the decision-making processes themselves, and ideally both. Monitoring is particularly challenging for urban adaptation given that there are no standard metrics to assess progress (Lamhauge et al. 2011, GIZ et al. 2012).

City authorities, NGOs and researchers have begun to design adaptation monitoring and evaluation frameworks. Coordinated development of tools offers scope for international benchmarking and comparison and coordination across scales of assessment, for example by associating local indicators of resilience with international ones attributed to the Hyogo Framework for Action and post-2015 agenda (IFRC, 2011). Box 8-4 presents the experience of monitoring from New York City.

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Box 8-4. Adaptation Monitoring: Experience from New York City

Jacob et al. (2010) describe an adaptation monitoring approach developed for New York City. This has four indicator elements: (1) physical climate change variables; (2) risk exposure, vulnerability and impacts; (3) adaptation measures; and (4) new research within each of these categories. Examples of climate change adaptation indicators arising from these four categories include: the percentage of building permits issued in any given year in current FEMA coastal flood zones, and in projected 2080 coastal flood zones; an exact tally of building permits that have measures to reduce precipitation runoff; an index based on insurance data that measures the insurer's perception of New York City's infrastructure-coping capacity; an index that measures the rating of bonds issued by the City or infrastructure operators for capital projects with climate change risk exposure; the detailed trend of weather-related emergency/disaster losses (whether insured or uninsured, relative to the total asset volume); and the number of days with major telecommunication outages (wireless versus wired), correlated with weather-related power outages.

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The New York experience has demonstrated that once monitoring is in place new demands for data can refine existing data collection systems including a preference for long-term data sets that span a range of disciplines. This has additional benefits for adaptive planning. In the New York case this need was resolved through data criteria decided through a scientist-stakeholder consensus with designated groups used to evaluate prospective indicators and their values. With its focus on data and processes required to monitor progress on urban adaptation, this case study shows the need for interdisciplinary and longitudinal data collection and analysis systems along with an inclusive and transparent process for stakeholder engagement to interpret the data as part of new monitoring programmes.

A more established aspect of monitoring and evaluation focuses on the effectiveness of donor aid on climate adaptation (Chaum et al. 2011). Recent work shows that consistent and internationally harmonised data collection is urgently needed to support monitoring, this is a concern for adaptation and wider disaster risk reduction spending suggesting a systemic challenge to the architecture of international finance (Kellett and Sparks, 2012). Steps are being made in this direction through multi-site assessment programmes and in some instances this includes treatment of urban issues. For example, the World Bank has recently included an adaptive capacity index as part of an analysis of risk and adaptation options for five cities in Latin America and the Caribbean; the methodology was applied before this to Guyana where it demonstrated a gap between national and city level adaptive capacity (Pelling and Zaidi, 2013).

Monitoring also needs to consider the delivery and use in cities of available international climate finance to ensure that funds are being directed in an effective manner (Hedger 2011, Buchner et al. 2011). This is especially important for cities at an early stage of planning, implementing and monitoring of adaptation, as they can learn from one another's experiences. There is some evidence of an increasing burden of reporting falling on partner organizations and countries, in some cases city authorities, who receive international support, where partners have to devote significant time and human capacity to reporting on progress; reporting may carry high transaction costs, which in turn can detract from further programme design and implementation.

Thus, in reviewing the development of urban adaptation interventions and strategies, do or will they:

- Have potential co-benefits with sound development, disaster risk reduction and ecosystem-based adaptation?
- Reduce mortality and help reduce illness and injury and/or their impacts especially on low-income and vulnerable groups?
- Make livelihoods more resilient and improve choices on employment and livelihoods?
- Meduce negative impacts on economic output and urban centres' capital stock?
- Increase the resilience of lifeline physical and social infrastructure and services?
- Increase the resilience of housing, especially for people with limited incomes and assets?
- Mitigate impact and improve the productivity and resilience of ecosystem services?
- Have potential co-benefits with poverty reduction and mitigation interventions and prepare the base for transformatory adaptation and the reduction of intergenerational risk transfer

8.5. Conclusions

8.5.1. Introduction

Urban areas are and increasingly need to be at the forefront of climate change adaptation and mitigation agendas. They house more than half the world's population and concentrate most of its assets and economic activities. Urban-based activities generate a high proportion of global greenhouse gas emissions so urban policies are key to addressing mitigation. Urban centres also concentrate a high proportion of the populationand economic activities most at risk from climate change and most in need of adaptation. Most of the increase in the world's population and much of the increment in capital formation, economic activity, infrastructure development, ecosystem degradation and emissions is projected to take place in urban areas in low- and middle income countries.Urban centres are thus places where the present and future well-being and safety of humanity must be secured in the face of the increasing uncertainty generated by climate change and other socio-ecological challenges (da Silva et al 2012).

The key role of urban governments in climate change adaptation has become more widely recognized. One example of this is the signing of the Durban Adaptation Charter in December 2011 by 107 mayors representing over 950 local governments at COP17. This signalled their intention to begin addressing climate change adaptation in a more concerted and structured way and is indicative of the climate change leadership being shown by local governments around the world (Rosenzweig et al 2010). But as this chapter has described, the way forward is not simple, with both climate change and climate change adaptation being acknowledged as highly complex and difficult to resolvein most urban contexts (Martins and Ferreira 2011, Fünfgeld and McEvoy 2011). As yet, only a small proportion of urban governments have begun to act on adaptation, often with variable levels of national support.

Because of the complexities and uncertainties involved, action has been limited and focused mostly 'no-risk' and 'low cost' interventions that have adaptation as a co-benefit of existing work streams, rather than a new, stand alone work area (Roberts 2008a, Toronto Environment Office 2008, Runhaar et al 2012). This 'business-as-usual with climate benefits' approach has resulted in a focus on interventionist and reactive infrastructure or asset-oriented adaptation (e.g. LCCP 2006, Awuor, et al., 2008, Mehrotra et al. 2011a, Mees and Driessen 2011) rather than on the 'soft' or process (i.e. human, institutional and ecological) elements of adaptation, such as resilient development, good governance, poverty reduction, livelihood security, social cohesion and ecosystem based adaptation (Lwasa 2010, Jones et al. 2010). A focus on adaptation measures rather than on building adaptive capacity or resilience is especially problematic in urban areas of the global South where it is "limited by resources, weak institutions, poor/inadequate infrastructure and poor governance" (Kithiia 2009:19). This suggests a need to shift from looking at "what a system *has* that enables it to adapt, to recognising what a system *does* to enable it to adapt" (Jones, et al2010:1). This in turn implies a need for more open-ended and flexible concepts such as adapting well, climate smart, sustainable adaptation and resilience (Eriksen and Brown 2011, Wilson and Termeer 2011, Brown et al. 2012).

This socio-institutionalemphasis also encourages a more transformative view of adaptation. It shifts from being a tool of last resort, or an 'end-of-the-pipe' and incremental intervention (Roberts, et al. 2012:2; Foster et al. 2011) that supports the prioritisation of existing coping strategies (Heindrichs et al, 2011:216) to one that underscores the need for "bouncing forward" (Shaw and Theobald, 2011; Manyena et al 2012) and a departure from the norm. This is characterised in Table 8-2 as a shift from adaptation to resilience and then transformation (Pelling 2011a). This 'business-unusual' approach is especially important in a world where transgressions of key planetary boundaries such as climate change and biodiversity will take humanity out of the globe's "safe operating" space (Rockström et al. 2009: 1) into an unsafe and unpredictable future. If effective adaptation in urban centres is good development conceived and implemented with adaptation in mind, transformation is adaptation that helps achieve the needed global reductions in greenhouse gas emissions and other drivers of anthropogenic climate change. This requires changes to the "fundamental attributes" of existing technological, governance, planning, economic, cultural and value systems(IPCC 2011; Costanza et al 2012, O'Brien, 2011, Pelling 2011a).

8.5.2. What Hinders Adaptation Progress in Urban Areas?

Lack of mandate: There is a need to clarify which sphere (national, provincial, metropolitan and urban) of government has a legal mandate to act on climate change through the promulgation and assignment of appropriate constitutional and legal powers. Without these formal mandates, adaptation becomes an optional and discretionary extra, dependent on local level interest and resources and particularly vulnerable to leadership change. Although much of the innovation in adaptation and mitigation has come from particular local governments, for these to become effective at a national scale and to ensure coherence and widespread implementation, support from higher levels of government is required (Kazmierczak and Carter 2010, also Carter 2011, Brown 2011, Martins and Ferreira 2011). Where mandates exist, they have been important in driving local level action (Kazmierczak and Carter 2010) but they need increased co-ordination and co-operation if they are shared between the different spheres of government (Martins and Ferreira 2011, Carter 2011) or cross jurisdictional boundaries. New mandates (formal or informal) may also require institutional changes(Lowe *et al*. 2009, Roberts 2008a, Kazmierczak and Carter 2010).

Political obstacles: Decisions in urban centres including those related to climate change adaptation, are affected by political interests and competition for support (Mees and Driessen, 2011, Brown et al, 2012). Those who are most at risk from climate change are often those with the least voice and influence on these decisions. Addressing constraints such as information and resources alone will not ensure transformation if there is political resistance, particularly as politicians control local level resources (Roberts 2008a). A further complication is the disjuncture between political and climate time lines (Mees and Driessen, 2011). This sets short-term (often personal advancement) priorities against the inter-generational and public good impacts of climate change adaptation, making communicating and negotiating climate change related objectives in the political space often very difficult to achieve (UN-Habitat 2010).

The weakness of climate change focal points within local government: These are often housed in or championed by environmental line department which usually leads to marginalisation (Roberts 2010, Hardoy and Romero Lankao 2011) and limited institutional influence and access to resources given the low priority usually assigned to environmental departments. There is also a concern that in the current recession, that local authorities(with already limited resources) will prioritise conventional economic and development goals over 'environmental' issues including climate change adaptation(Shaw and Theobald 2011, Solecki 2012).

Undervaluing community resources and social capital: Although 8.4 gives examples of the effectiveness of household and community based adaptation in urban contexts, there is still limited work and limited understanding of the potentials and limitations (Jones et al. 2010). This is a critical gap given that social capital and community based adaptation may provide opportunities to achieve the "bouncing forward" required by adaptation, as community collaboration, relationships and trust can provide a platform to generate material interventions directed at reducing vulnerability (Kithiia 2009). The issue of social capacity has been identified as important to urban resilience in a number of urban areas (TARU 2011, Roberts 2010) but there is also a need to determine the limits of community based intervention; for example, communities cannot install, maintain and fund trunk infrastructure and the scale and scope of needed service provision at city and city-region scales.

The complexities of developing locally relevant adaptation plans: Mitigation-focused interventions provided the first experiential training for most local governments engaging with climate change. These were often based on step-wise guidebooks or programmes (e.g. ICLEI's Cities for Climate Protection Programme, UN-Habitat's Planning for climate change manual) (Anguelovski and Carmin 2011, Martins and Ferreira 2011). Experience with adaptation programmes show they are less open to a standard set of requirements, given that actions are oftencross-sectoral, cross-institutional, complex, operating across a range of scales and timelines,rooted in local contexts,involve more stakeholders and include high levels of uncertainty (Roberts et. al. 2012, Roberts and O'Donoghue 2013). More than standardised guidelines, urban adaptation practitioners need clarity, creativity, and courage (ICLEI Oceania 2008).

Dealing with uncertainty: Adaptation costs areimmediate, a fact which contrasts with the uncertainty associated with climate change projections (see 8.2.5.1.) and the possible delay in the benefits (OECD 2010). A pragmatic approach is therefore to focus on existing vulnerabilitiesand to use those to identify 'no-regrets' options with near and long-term co-benefitssuch as enhanced competitiveness, improved service delivery, economic resilience (and success), job creation and risk management as these help get the attention of politicians and decision makers (e.g. Durban, London, New York and Copenhagen) (Foster et al. 2011, Roberts 2010, GLA 2011, City of New York 2011, City of Copenhagen 2011, Runhaar et al , 2011).The use of scenario planning as a possible alternative to scaled down projections, the undertaking of further studies to develop better local data and understand the costs of inaction, avoiding maladaptation and increasing awareness also contribute to increased adaptive capacity (Tyler et al. 2010, OECD 2010, TARU 2010, Neimi 2009). Facilitating networking and learning between adaptation practitioners also assists in improving the capacity to deal with uncertainty (Mees and Driessen, 2011).

The issue of thresholds and conflicting agendas: Most local governments acknowledge the value of mitigation and adaptation, but to lead with one or the other depending on circumstances, priorities, resources and institutional affiliations (Roberts 2010, Carmin et al. 2012, Hamin 2011, Moser 2012). The result is that little progress has been made in ensuring that adaptation and mitigation policy goals are not in conflict (Hamin and Gurran 2009, Moser 2012). Section 8.3.3.7 discussed what Hamin and Gurran, 2009 described as the "density conundrum" where the densities that serve mitigation can prevent or limit the possibilities of ecosystem based adaptation and may also exacerbate the urban heat island and limit the possibility of utilizing solar energy. There is therefore an urgent need for research to determine the thresholds for unacceptable biodiversity change and to derive from these locally specific limits to urban densificationand ensure that climate actions do not undermine other global environmental change agendas such as biodiversity protection (Moser 2012). The issue of thresholds is also relevant beyond biodiversity concerns, for example, determining when and where adaptation is no longer possible in urban areas, due to technical difficulties or cost (or both) resulting in residual damage (UN-Habitat 2011c, Parry et al. 2009). This knowledge about limits within existing systems will be vital in developing appropriate planning responses to future climate challenges, especially as there is increasing concern that the current state of global inaction and lack of ambition on mitigation could result in 4 degrees or more of global warming, necessitating a "more substantial, continuous and transformative process" of adaptation (Smith et. al. 2011:196). This also raises the possibility of abrupt, non-linear and unpredictable global environmental change (Rockström et al. 2009) that will stretch the adaptive capacity not only of existing urban systems, but of the whole global system.

8.5.3. What Contributes to the Development of Effective Transformative Adaptation Plans?

Building on future urbanization opportunities: United Nations projections suggest that in the next 40 years, the world's urban population will nearly double (United Nations 2012) requiring the same scale of urban infrastructure be built in 40 years as in the past 4000 years (ICLEI, 2011b). This provides a transformative opportunity at a global level, especially in the global South with its large infrastructural deficits, to break away from unsustainable lifestyles and patterns of development and ensure that urban areas develop in ways that acknowledge that “natural capital and ecosystem services are not infinitely substitutable, and real limits exist” (Costanza et al 2013). This represents a significant opportunity to urbanise the adaptation agenda, and converge climate mitigation and adaptation actions within an understanding of a “full-world” context (Costanza et al 2013).

Prioritising poverty reduction within climate change responses: While cities like Boston and London consider low-income groups among the vulnerable groups in their planning (Boston 2011, GLA 2011) for most cities and smaller urban centres in low and middle-income nations, poverty reduction needs more attention because of its greater scale and depth and because of the strong association between poverty and poor environmental health (Hardoy et al. 2001), disaster risk (United Nations 2009) and climate change risks (Hardoy and Pandiella 2009). Given this and the pressing development needs in these urban centres (e.g. infrastructure, health care and emergency services, education, housing and energy), climate change adaptation needs are often viewed as marginal in comparison. There is therefore a need to work within the development context of each country and urban area (Kithiia and Dowling 2010, Roberts 2008a) and to demonstrate how adaptation can support development that is safe and cost effective (Kazmierczak and Carter 2010) and prioritises poverty reduction, disaster risk reduction and resilient service provision (Kithiia 2010, da Silva et al 2012).

*Reducing risk can provide a compelling vehicle for adaptation action (*see 8.3.2.2). This can occur by responding to existing challenges (for instance extreme weather events) and opportunities (for instance disaster risk reduction after a disaster that ‘builds back better’ - see Lyons 2009) in ways that enhance adaptive capacity (Kazmierczak and Carter, 2010, Solecki 2012). Experience to date on this is mixed. It is influenced by differences in risk perception and how successfully disaster risk reduction and adaptation become embedded within local development processes and the extent to which they address the structural causes of vulnerability(UN-Habitat 2010, Pelling 2011a, Roberts and O’Donoghue 2013). There is also a widespread assumption that sound urban development and the provision of basic services is sufficient to reduce risk to climate change, but there is a need to interrogate the effectiveness and limitations of current models of infrastructure and service provision. Adaptation can benefit from disaster risk reduction’s more detailed, locally rooted analyses of risk and vulnerability and its recognition that most disasters are the result of a failure to identify problems and act. It can also benefit from multi-level government responses to disaster risk reduction that recognize the central role of local government and other local institutions but also the importance of supportive policies, institutions and legislation at higher levels of government. But disaster risk reduction is informed by analyses of past disasters,while adaptation also has to be informed by knowledge of new risks, vulnerabilities and uncertainties.

Incorporating ecosystem based adaptation: 8.3 noted how a growing number of cities are recognizing that biodiversity and ecological integrity can be used to protect people and the resources on which they depend. Ecosystem-based adaptation is regarded as one of the more cost effective and sustainable approaches to adaptation given what needs to be spent to manage and preserve ecosystems and the climate adaptation value derived from that spend (Nature Conservancy TNC 2009, Mees and Driessen, 2011, da Silva et al 2012, Brown et al 2012). But there are considerable knowledge gaps in determining the limits or thresholds to adaptation of various ecosystems and where and how ecosystem based adaptation is best integrated with other adaptation measures. There is also some indication that the costs of ecosystem based adaptation in urban contexts might be higher than expected, in large part because costs are higher for land acquisition and ecosystem management (Roberts et al 2012, Cartwright et al 2013).

Engaging all stakeholders and awareness raising: There is a need for dialogue and opportunities to advance the adaptation agenda through internal and external collaboration. These range from cross-cutting technical advisory groups often with sectoral or task group focal areas (Lowe et al. 2009, Parzen 2008, Boston 2011, City of New York 2011, Mees and Driessen, 2011, Solecki, 2012) to more broadly representative multi-stakeholder or multi-departmental groups with a core working group (Tyler et al. 2010, Roberts 2010, Brown et al. 2012, Boston 2010, Kazmierczak and Carter 2010, Anguelovski and Carmin 2011). Equally important is building public awareness and support for adaptation as transformation “neighborhood by neighborhood” (Foster et al. 2011, also Kazmierczak and Carter 2010). This is especially important where large sections of the population live and work in informal settlements and include a high proportion of those most at risk from climate change.

Institutional and social learning: For all urban centres, successful adaptation requires a learning organization that adapts to changing environmental factors and incorporates new data on a regular and flexible basis – producing an iterative process of learning about changing risks and opportunities and drawing in different stakeholders (Brown et al 2012). This is difficult to achieve with weak governmental structures, lack of funding and trained staff, where "decisions are delayed, correspondences lost in bureaucratic black-holes and ascription of responsibility is obfuscated" (Kithiia 2009, also Brown 2011). Social learning is also critical to ensure new ideas are popularized and commonly articulated in society (Pelling 2011a), translating stakeholder engagement into adaptation action.

The importance of mainstreaming climate change adaption requirements into municipal planning and land-use management systems: This chapter opened with an acknowledgement that local governments must provide the planning, management and regulatory frameworks to ensure that investments and actions by businesses and households contribute to adaptation (Kazmierczak and Carter 2010, Brown 2011, Mees and Driessen, 2011, Sussman et al., 2010). But this must avoid overloading already complex and inadequate planning systems (Kithiia 2010, Roberts 2008a) stressed by lack of information, institutional constraints and resource limitations with unrealistic new requirements. Mainstreaming adaptation ensures that limited financial resources are spent "with adaptation needs in mind" (Lowe et al. 2009) and fosters a move to a risk-based design for a range of future projected climate conditions. This can be enhanced by encouraging each sector to consider its need for and role in adaptation action. A sectoral approach makes the climate message easier for local governments and other stakeholders to understand and the associated responsibilities and actions clearer and simpler to identify and assign (Roberts 2010, UN-Habitat 2011a, Roberts and O'Donoghue 2013). As each sector in local government comes to understand its roles and responsibilities, so the basis for integration and cross-sectoral coordination is formed.

The importance of champions. Champions, regardless of their location or affiliation are important in driving successful adaptation action (Kazmierczak and Carter 2010). The role of local government champions has often proved critical in providing initial leadership (e.g. Sydney, Chicago, New York, Durban, London) and promoting and sustaining the adaptation agenda both at a sectoral level (e.g. Durban) and in buildingbroader institutional memory and purpose (e.g. Chicago, Toronto)(Lowe et al. 2009, Roberts 2008a, Parzen 2008, Rosenzweig and Solecki 2010, Shaw and Theobald 2011, Anguelovski and Carmin 2011, Carmin et. al. 2012, Mees and Driessen, 2011, Martins and Ferreira 2011, Roberts and O'Donoghue 2013). This may face a lack of continuityas champions change position orleave office. It is important to plan for this so that progress is not stalled or undermined. This can be helped by developing a broad base of support for adaptation across many sectors - within and outside government and other local stakeholders such as civil society groups or universities can help ensure continuity (Hardoy 2013).

The need for scientific support andan evidence base for adaptation action (Lowe et al, 2009, Roberts 2008a, Kazmierczak and Carter 2010, Horton et al 2011, Blake et. al, 2011, Moffet et al 2011):Despite growing attention, useful information and assessment of climate change at urban spatial scales is still lacking (Hunt and Watkiss 2011; Kehew 2009). Local governments need to access reliable, accurate, useable scientific data. Even where these are available, their staff often cannot utilize them because of the language gap between information producers (scientists) and information users (local decision makers) (Lowe et al. 2009, Opitz-Stapleton 2010). Practitioners often relymore on informal information sources and formats such as colleagues and the internet (Corfee-Morlot et al. 2011). Here, local risk assessments of existing hazards, challenges and vulnerabilities that could be exacerbated by climate change offer a useful alternative starting point and facilitate the creation of an appropriate evidence base (Tyler et al. 2010, Kazmierczak and Carter 2010). Collaboration and partnership with researchers and research institutes (especially those with local knowledge) (e.g. Durban,Chicago, Seattle, Manchester) can help each urban centre gainknowledge about climate impacts (Lowe et al. 2009, Kazmierczak and Carter 2010).

Catalytic role of multilateral and bilateral funding: While conventional multilateral development banks and bilateral agencies appear have the biggest role in adaptation financing (Ayers 2009), there is an emerging argument that finance for urban resilience and adaptation needs to respond to local demands, contexts and possibilities. This poses a challenge to conventional global finance mechanisms that work through national governments to determine which local actions are eligible for funding (ICLEI 2011a, Brugmann 2012). There is also evidence of substantial spend on adaptation from local and national governments in some nations (Kazmierczak and Carter 2010).

Phased approaches: A phased approach is more likely to attract local government attention (Foster et al. 2011, City of Copenhagen 2011, Boston 2011, Wajih et al. 2010, Solecki 2012). In each urban centre, this prioritizes the most urgent matters (usually rapid onset disasters) or near term climate impacts, leaving a longer time period to plan for those impacts that may occur in the future and be associated with greater uncertainty (including slow onset disasters). For slow-onset impacts, strategic forward planning is critical, and existing planning instruments such as land use planning may need to be altered to take changes in climatic stressors into account. Often the initial phases of action are made possible by the existence of previous or current environmental initiatives, or strong environmental traditions at the local level (Kazmierczak and Carter 2010).

Poorly developed Monitoring and Evaluation systems: Monitoring and evaluating the development and implementation of adaptation plans is still evolving (Jacob et al 2010) and not well developed or widely implemented in urban areas (Kazmierczak and Carter 2010). Work is required in this regard, but it is likely to be challenging given the localized nature of adaptation and hence the difficulty of standardizing performance requirements and measurements (Anguelovski and Carmin 2011).

Role of international institutions: The lack of skills and resources in local governments gives international institutions an important role in initiating and shaping the adaptation agenda. These international programmes are often the main form of institutional and financial support to mitigation and adaptation work at local level, although in some local governments internal motivations (e.g. perception of threat, city agendas, leadership, improving city image) (Anguelovski and Carmin, 2011, Carmin et. al. 2012, Kazmierczak and Carter 2010) appear equally influential. The danger of the donor driven model is that the funding agency's agenda may not coincide with local priorities, resulting in little lasting local ownership once support is withdrawn.

Local action involving all local stakeholders, addressing local issues, tapping local knowledge and other resources and respecting local limits is the key to transformative adaptation. Urban areas, because of their size, number, economic importance and social and environmental characteristics, are the geography where this has to happen. So they will have a critical role in the success or failure of the global adaptation project. Mobilising this local level capacity is challenging for international agencies. But if done in ways that are equitable and co-operative and that respect the limits of natural ecosystems, it has the potential to improve human well-being, maximize innovation and help define and implement development paths that converge in a more sustainable and low carbon future.

Frequently Asked Questions

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

There is a long experience with urban governments implementing disaster risk reduction that is underpinned by locally-driven identification of key hazards, risks and vulnerabilities to disasters and that identifies what should be done to reduce or remove disaster risk. Its importance is that it encourages local governments to act before a disaster – for instance for risks from flooding, to reduce exposure and risk as well as being prepared for emergency responses prior to the flood (eg temporary evacuation from places at risk of flooding) and rapid response and building back afterwards. In some nations, national governments have set up legislative frameworks to strengthen and support local government capacities for this (see 8.3.2.2). This is a valuable foundation for assessing and acting on climate-change related hazards, risks and vulnerabilities, especially those linked to extreme weather. So urban governments with effective capacities for disaster risk reduction (with the needed integration of different sectors) provides an important component of adaptive capacity. But climate change adaptation needs to take account of how hazards, risks and vulnerabilities will or might change over time. Disaster risk reduction also covers disasters resulting from hazards not linked to climate or to climate change such as earthquakes.

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

Adaptation is well served by good quality infrastructure and services that reach all of an urban centre's population and the institutional capacity to provide, and manage these and expand them when needed. Poverty reduction can also support adaptation by increasing individual and household resilience to stresses and shocks and enhancing their capacities to adapt. These provides a foundation for building climate change resilience but additional knowledge, resources, capacity and skills are generally required, especially to build resilience to changes beyond the ranges of what have been experienced in the past.

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

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

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

More reliable, locally specific and downscaled projections of climate change impacts and tools for risk screening and management are needed. But local risk and vulnerability assessments that include attention to those risks that climate change will or may increase provide a basis for incorporating adaptation into development now, including supporting policy revisions and more effective emergency plans. In addition, much infrastructure and most buildings have a life of many decades so investments made now need to consider what changes in risks could take place during their lifetime. In addition, the incorporation of climate change adaptation into each urban centre's development planning and investments is well served by an iterative process within each locality of learning about changing risks and uncertainties that informs an assessment of policy options and decisions

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

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

Source: Derived from statistics in United Nations 2012.

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

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

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

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

Table 8-3: The possibilities and limitations of focused activity for community groups on climate change coping and adaptation.

Capacity/Focus of Action	Coping (drawing on existing resources to reduce vulnerability, hazardousness and contain impacts from current and expected risk)	Adaptation (using existing resources and especially information to reorganize future asset profiles and entitlements to better position the household in the light of anticipated future risk, and to prepare for surprises)
Physical – buildings and critical community-level infrastructure	Often possible to improve these although tenants will have little motivation to do so	Amber; limits in how much risk reduction is possible within settlement
Physical – land and environment	Local hazard reduction through drain cleaning, slope stabilization etc is a common focus of community based action(although there are less incentives where the majority of residents are short-term tenants or threatened with eviction) (Green)	External input required to design local hazard reduction works in ways that will consider the impacts of climate change 20 years or more in the future (Amber)
Social – health, education	Many examples of community based action to improve local health and education access and outcomes, often with strong NGO and/or local government support (Green)	Health care and education are amenable to supporting adaptation by providing long-term investments in capacity building. They are rarely framed in climate change adaptation terms (Amber)
Economic – local livelihoods	Livelihoods routinely assessed as part of assessments of coping capacity in urban areas. More rarely is there a local livelihood focus for community based coping (Amber)	Livelihoods and wider economic entitlements are key to individual adaptive profiles, but are seldom considered as part of urban community based adaptation programmes (Red)
Institutional – community organization	Local community strengthening is a common goal of interventions aimed at building coping capacity. Risk mapping, early warning, risk awareness, community health promotion and shelter training are common foci increasingly applied to urban communities. Local savings groups may have important roles. Green	Local community strengthening is a core element of planning for adaptation but there are few assessments of the medium/long-term sustainability of outcomes. Where these have been undertaken close ties to wider civil society networks or supportive local government is evident for community organizations to persist Amber
Institutional – external influence	It is unusual for coping programmes to include an element of external advocacy aimed at changing policy or practices in local government. Amber	Despite being core to determining future adaptation there are very few examples of urban community based adaptation projects that include a targeted focus or parallel activity aimed at shifting priorities and practices in local government and beyond to support community capacity building Red

Key: green = many cases of activity, amber = few cases of activity, red = very few cases of activity

Table 8-4: Main sources of funding and financial instruments for urban adaptation.

Sources of funding	Types	Instruments	Examples of what can be funded	Urban capacity required to access funding
Local - public	Local revenue raising policies: Taxes, fees and charges, or use of local bond markets	♦ Local taxes (eg on property, land value capture, sales, businesses, personal income, vehicles….) ♦ User charges (eg water, sewers, public transport, refuse collection) ♦ Other charges or fees (eg parking, licenses)	♦ Urban infrastructure and services ♦ Urban adaptation programmes and planning processes ♦ Urban capacity building	♦ Cities with well-functioning administrative and institutional capacity and adequate funding from local revenue generation and inter-governmental transfers
Local – public-private	Public-Private-Partnerships (PPP) contracts and concessions	♦ Concessions and private finance initiatives (PFIs) to build, operate and/or maintain key infrastructure ♦ Energy performance contracting	♦ Medium to large-scale infrastructure with strong private goods (to allow rents for private sector)	♦ Cities with strong capacity for legal oversight and management
Local or national - Private or Public	National or local financial markets	♦ Commercial loans, ♦ Private bonds ♦ Municipal bonds	♦ Basic Physical Infrastructure (need for collateral)	♦ Well-functioning local or national financial markets that city governments can access
National - public	National (or state/provincial) revenue transfers or incentive mechanisms	♦ Revenue transfers from central or regional government ♦ PES or other incentive measures	♦ Urban Payment for Environmental Services in Brazil ♦ Sweden's KLIMP Climate Investment programme	♦ Cities with good relations with national governments, strong administrative capacity to design and implement policies and plans
International – private	Market-based investment	♦ Foreign Direct Investment, Joint Ventures	♦ Industrial infrastructure ♦ Power generation infrastructure	♦ Cities with strong national enabling conditions and policies for investment
International sources	Grants, concessional financing (e.g. Adaptation Fund)	♦ Grants, concessional loans and loan guarantees through bilateral and multilateral development assistance ♦ Philanthropic grants	♦ Urban capacity building ♦ Urban infrastructure adaptation planning	♦ Typically requires strong MLG – cities with good relations with national governments ♦ Cities with low levels of administrative and financial market capacity

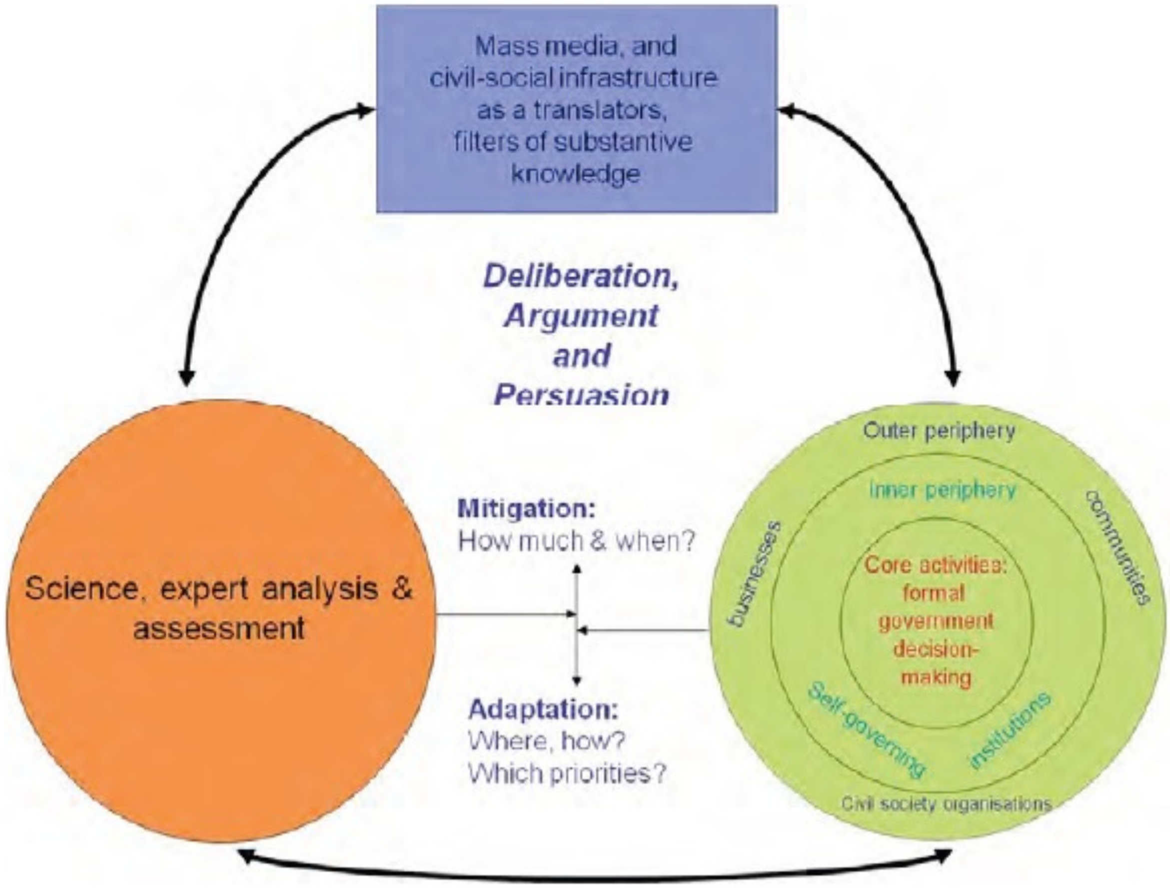

Figure 8-1: Circulation of power for public decisionmaking on climate change. Source: adapted from Corfee-Morlot, Cochran, Teasdale, and Hallegatte, 2011.

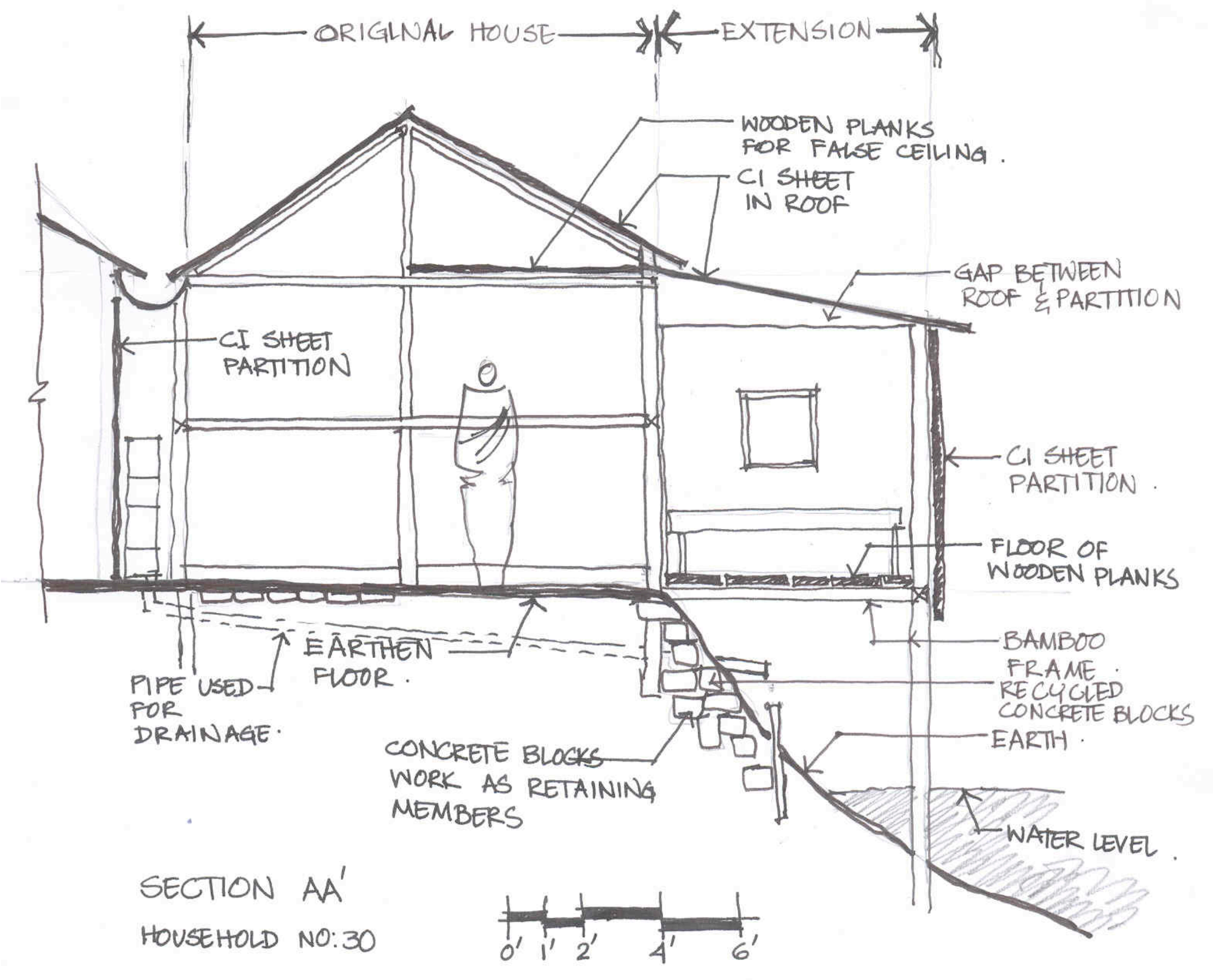

Figure 8-2: Household adaptation - a cross section of a shelter in an informal settlement in Dhaka (Korail) showing measures to cope with flooding and high temperatures. Source: Jabeen et al, 2010.

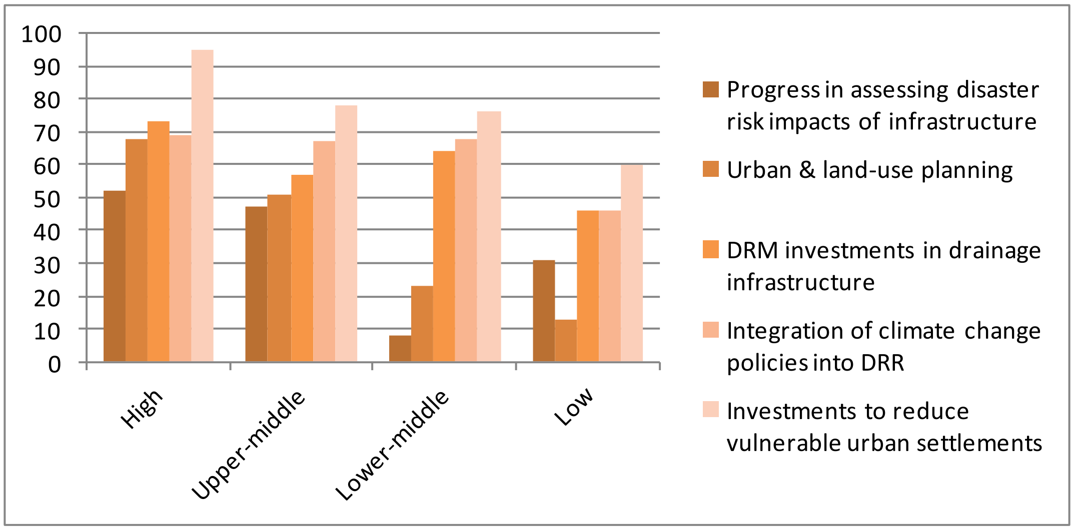

Figure 8-3: Progress reported by 82 governments in addressing some key aspects of Disaster Risk Reduction by countries' per capita income. Source: United Nations, 2011.

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