

Chapter 8. Urban Areas**Coordinating Lead Authors**

Aromar Revi (India), David Satterthwaite (UK)

Lead Authors

Fernando Aragón (Mexico), Jan Corfee-Morlot (USA / OECD), Robert B.R. Kiunsi (United Republic of Tanzania), Mark Pelling (UK), Debra Roberts (South Africa), William Solecki (USA)

Contributing Authors

Jo da Silva (UK), David Dodman (Jamaica), Andrew Maskrey (UK), Sumetee Pahwa Gajjar (India)

Review Editors

John Balbus (USA), Omar-Dario Cardona (Colombia)

Volunteer Chapter Scientist

Alice Sverdlik (USA)

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

- 1 8.2.4.3. Transportation and Telecommunications
2 8.2.4.4. Built Environment, and Recreation and Heritage Sites
3 8.2.4.5. Green Infrastructure and Ecosystem-based Adaptation
4 8.2.4.6. Health and Social Services
5 8.2.5. Urban Transition to Resilience and Sustainability
6 8.2.5.1. Uncertainty and Surprise
7 8.2.5.2. Extreme Event Probability
8 8.2.5.3. Transitions
9 8.2.5.4. Social Dynamics, Economic Tensions, and Multiple Stressors
10 8.2.5.5. Historical Analogues
11
12 8.3. Adapting Urban Areas
13 8.3.1. Introduction
14 8.3.2. Development Plans and Pathways
15 8.3.2.1. Adaptation and Development Planning
16 8.3.2.2. Disaster Risk Reduction and its Contribution to Climate Change Adaptation
17 8.3.3. Adapting Key Sectors
18 8.3.3.1. Adapting the Economic Base of Urban Centres
19 8.3.3.2. Adapting Food and Biomass for Urban Populations
20 8.3.3.3. Adapting Housing and Urban Settlements
21 8.3.3.4. Adapting Urban Water, Storm, and Waste Systems
22 8.3.3.5. Adapting Electric Power and Energy Systems
23 8.3.3.6. Adapting Transport and Telecommunications Systems
24 8.3.3.7. Green Infrastructure and Ecosystem Services within Urban Adaptation
25 8.3.3.8. Adapting Public Services and Other Public Responses
26
27 8.4. Putting Urban Adaptation in Place: Governance, Planning, and Management
28 8.4.1. Urban Governance and Enabling Frameworks, Conditions, and Tools for Learning
29 8.4.1.1. Multi-Level Governance and the Unique Role of Urban Governments
30 8.4.1.2. Mainstreaming Adaptation into Municipal Planning
31 8.4.1.3. Delivering Co-Benefits
32 8.4.1.4. Urban Vulnerability and Risk Assessment Practices: Understanding Science, Socio-
33 Economics, and Policy Interactions
34 8.4.1.5. Assessment Tools: Risk Screening, Vulnerability Mapping, and Urban Integrated
35 Assessment
36 8.4.2. Engaging Citizens, Civil Society, the Private Sector, and Other Actors and Partners
37 8.4.2.1. Engaging Stakeholders in Urban Planning and Building Decision Processes for Learning
38 8.4.2.2. Supporting Household and Community-Based Adaptation
39 8.4.2.3. Private Sector Engagement and the Insurance Sector
40 8.4.2.4. Civil Society Partnerships and Philanthropic Engagement
41 8.4.2.5. University Partnerships and Research Initiatives
42 8.4.2.6. City Networks and Urban Adaptation Learning Partnerships
43 8.4.3. Resources for Urban Adaptation and their Management
44 8.4.3.1. Domestic Financing: Tapping into National or Sub-national Regional Sources of Funding
45 and Support
46 8.4.3.2. Multilateral Humanitarian and Disaster Management Assistance
47 8.4.3.3. International Financing and Donor Assistance for Urban Adaptation
48 8.4.3.4. Institutional Capacity and Leadership, Staffing, and Skill Development
49 8.4.3.5. Monitoring and Evaluation to Assess Progress
50
51 8.5. Conclusions
52 8.5.1. Introduction
53 8.5.2. What Hinders Adaptation Progress in Urban Areas?
54 8.5.3. What Contributes to the Development of Effective Transformative Adaptation Plans?

1
2 Frequently Asked Questions

- 3 8.1: How does disaster risk reduction relate to climate change adaptation?
4 8.2: Doesn't good development produce urban adaptation?
5 8.3: Wouldn't urban problems be lessened by rural development?
6 8.4: Shouldn't urban adaptation plans wait until there is more certainty about local climate change
7 impacts?
8

9 References
10
1112 **Executive Summary**
13

14 **Successful global climate change adaptation depends centrally on what is done in urban areas (*high***
15 ***agreement, medium evidence*).** Urban areas house more than half the world's population and concentrate most of its
16 assets and economic activities. They also concentrate a high proportion of the population, and economic activities
17 most at risk from climate change. In addition, a high proportion of global greenhouse gas emissions are generated by
18 urban-based activities. Furthermore, projections for the next few decades suggest that it is in and around urban areas
19 that almost all the increase in the world's population and much of the increment in capital formation, economic
20 activity, infrastructure development, ecosystem degradation and emissions will take place. [8.1] Adaptation action in
21 urban areas that delivers mitigation co-benefits is one of the most powerful and resource-efficient means of
22 addressing climate change, as outlined in the AR5 Working Group III report.
23

24 **There has been a very large expansion in the literature of relevance to climate change adaptation in urban**
25 **areas since AR4 (*very high confidence*).** [8.1] This includes documents prepared by many city governments and
26 some international agencies on their initial responses to adaptation. There is also evidence of a greater interest in
27 climate change adaptation from certain professions (including architects, engineers and urban planners and those
28 working on disaster risk management). There is also a new literature underlining the importance of a shift in
29 emphasis from urban adaptation to building resilience at city and regional scale. This will support the capacity to
30 withstand unexpected impacts, flexibility, redundancy and planning for 'safe failure' in response to increasingly
31 extreme climate adaptation as outlined in the AR5 SREX report. [8.1] Beyond this, an emerging literature is
32 exploring urban transformations - adaptation that helps address the key drivers of anthropogenic climate change
33 through combined processes of sound development, disaster risk reduction, increased resilience and ecosystem
34 adaptation. [8.5] There is also some discussion of the adaptation limits that urban centres face and difficult decisions
35 over what can be done that might include resettlement or abandonment of previously developed land. [8.3]
36

37 **Cities are complex inter-dependent systems with potential synergies that could be leveraged to support**
38 **climate change adaptation (*high agreement, low evidence*).** In many cities, adaptation effectiveness is constrained
39 by complex inter-dependencies – for instance the impact of power failures or fuel shortages on water supplies,
40 drainage, transportation, telecommunications and health care services. There is also the dependence of emergency
41 services on all-weather roads, functioning communications systems and robust health care centres and the
42 dependence of urban populations and economies on food and resources from beyond their boundaries. [8.2] A few
43 cities have adaptation initiatives underway for energy systems or are considering what steps are needed to do so;
44 energy policy discussions in the past have been dominated by mitigation concerns. [8.3] Urban enterprises
45 developed within globalized systems of production depend on reliable supply chains which may face particular
46 difficulties. [8.3] Conventional infrastructure investment decision-making may be interventionist or reactive and
47 overlook more open-ended and flexible concepts such as adapting well, climate smart, sustainable adaptation and
48 resilience. [8.5] Thus raising urban adaptive capacity in the context of climate change requires effective multi-level
49 governance (so all levels of government work together) with institutions that facilitate coordination across multiple,
50 nested and poly-centric authorities and have the capacity to mainstream adaptation measures. There are synergies to
51 be encouraged in peri-urban or nearby rural areas where land-use management around a city supports rural
52 livelihoods and protects ecosystem services. [8.3] This is yet to be built in most parts of the world. [8.4, 8.5]
53

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

12
13 **Rising sea levels, associated coastal and riverbank erosion and flooding in conjunction with storm surges**
14 **could all lead to widespread impacts on populations, property and coastal vegetation and ecosystems, and**
15 **threats to commerce, business, and livelihoods (*very high confidence*).** Sea-level rise represents one of the
16 primary shifts in urban climate change risks, given the large and often increasing concentration of urban populations
17 in coastal locations. [8.2] Coastal cities with extensive port facilities and large scale industries in low-elevation
18 coastal zones including petro-chemical and energy related industries are vulnerable to climate change related
19 increased flood exposure. [8.2] Many cities in Asian high growth economies are located on low-lying coastal areas,
20 which are undergoing rapid urban and economic transformation. Without adaptive measures and with rising
21 concentrations of population, infrastructure, and industries along these coasts, there could be a non-linear increase in
22 coastal vulnerability over the next two decades. [8.3] Many cities and smaller urban centres already experience large
23 floods regularly and will be at greater risk of flooding if rainfall intensities increase. This in turn could lead to the
24 destruction of properties and public infrastructure, contamination of water sources, water logging, loss of business
25 and livelihood options and increase in water related diseases as noted in wide range of studies. [8.2]

26
27 **Climate change can influence the dynamics of city microclimates while cities can alter a localized region’s**
28 **climate (*high confidence, based on high agreement and high evidence*).** The dense nature of many large cities,
29 high energy consumption, and regional climate conditions produces pronounced influences on anthropogenic heat
30 emissions. [8.2] Reviews of megacity impact on air flow indicate that megacities, especially coastal cities, influence
31 both internal city environmental and regional weather and air quality. [8.2] Additional environmental impacts have
32 also been observed, such as increased levels of surface run-off. Other coupled processes include the effect of
33 microscale to mesoscale changes in the built environment on Urban Heat Islands (UHI) thereby impacting mesoscale
34 processes such as land-sea breeze effect and katabatic winds, in turn modifying the spatial extent and magnitude of
35 local urban climate change impacts resulting from radiative forcing. [8.2]

36
37 **Increasing city resilience to climate change, building adaptive capacity and adequate resourcing could enable**
38 **cities to ‘bounce forward’ (*medium confidence, supported by high agreement and low evidence*).** Effective
39 multi-level urban risk governance, alignment of multiple (potentially conflicting) policies and incentives, early and
40 appropriate adaptation choices and implementation action could increase city resilience to climate change and build
41 needed local and regional adaptive capacity. This would strengthen development processes, limit maladaptation,
42 support more effective adaptation and build positive synergy with climate mitigation measures. This combined with
43 strengthening of local ecological and built infrastructure and services, better integrated urban and adaptation
44 planning, strengthened local government and community adaptation capacity, synergy with the private sector and
45 appropriate financing and institutional development could enable cities (especially in low- and middle-income
46 countries) to use their limited resources to ‘bounce forward’ rather than respond in a fractured, ad-hoc and poorly-
47 resourced manner to existing or impending climate risks. [8.4, 8.5] “Bouncing forward” is enabled by building
48 transformatory adaptive capacity and climate resilience through a mix of sound development, disaster risk reduction,
49 and ecosystem-based adaptation rather than ‘end-of-the-pipe’ or incremental adaptation interventions.

50
51 **Sound development is a necessary, but not sufficient condition to enable urban climate resilience (*medium***
52 ***confidence, supported by high agreement and medium evidence*).** There is a widespread assumption that sound
53 urban development, especially universal provision of basic infrastructure and services (piped water, provision for
54 sanitation and drainage, solid waste collection, health care, schools, emergency services, policing) are sufficient to

1 enable urban resilience to climate change, based on the perceived experience of some high-income nations. [8.2]
2 These provide an important base from which to build resilience. The importance of harmonization and synergy of
3 climate adaptation and mitigation with poverty reduction, livelihood development, food security, universal access to
4 adequate housing and basic services and disaster risk reduction is slowly being understood. But this is a complex
5 terrain that needs more evidence and experimentation to gauge the effectiveness and limitations of current models of
6 infrastructure and service provision – including ‘social capital’-based and community-led climate adaptation and
7 acceptance of this among national governments and mainstream development agencies. [8.3, 8.5]
8

9 **City-based disaster risk reduction is a strong foundation around which to build urban climate resilience (*high***
10 ***confidence, based on high agreement and supported by medium evidence*).** Many urban areas have long been
11 exposed to a range of hazards and disaster risks that could be exacerbated by climate change: water shortages and
12 droughts in urban regions, geo-hydrological hazards, inland and coastal flooding, windstorms and storm surges, high
13 levels of air pollution, extremes in urban heat and cold and urban heat islands and novel compound and slow onset
14 hazards that impact ecosystem resilience. [8.2] Experience in effective city-level disaster risk reduction to address
15 these challenges largely by vulnerability reduction and exposure modification, has been built in many cities across
16 over the last few decades via local hazard, risks and vulnerability studies and interventions. Some national
17 governments have set up frameworks and financing mechanisms to support local government and civil society
18 implement disaster risk reduction. This is a valuable foundation for climate change adaptation but it will need to also
19 take account of how hazards, risks, slow onset impacts and vulnerabilities change over time and thereby seek to
20 converge development and disaster risk reduction policies, institutional development and investment mobilisation to
21 meet short- to medium-run risk reduction and longer-term urban adaptation goals. [8.3]
22

23 **Urban concentration and agglomeration economies can be a strategic asset in climate adaptation action**
24 **(*medium confidence, based on medium agreement and low evidence*).** Many of the challenges and opportunities
25 for urban adaptation come from the concentration of people and enterprises in locations of high risk. There are
26 agglomeration economies for much of the infrastructure and services for climate change adaptation but they need to
27 be acted on. There is *high agreement*, supported by *high evidence*, that many urban centres are on sites that face high
28 levels of risk with risks exacerbated by built and ecological infrastructure deficits. Many cities in low- and middle-
29 income nations have a high proportion of their population in informal settlements that lack risk-reducing
30 infrastructure and services and that are located on floodplains, alongside rivers, in areas prone to slips and rockfalls
31 or on steep unstable slopes. These sites are settled because their residents cannot afford housing on safer sites.
32 Where local governments are unable or unwilling to act on these, population concentration brings disadvantages.
33 [8.2, 8.3] This has been seen as an argument to incentivize adaptation-led relocation but that can cause very large
34 disruptions to both residents and economic activity. [8.2] Urban agglomeration economies are often discussed in
35 regard to enterprises. Cities may represent a particular centre of interest for private sector engagement around
36 climate change partly because they concentrate large infrastructure investments and related business. [8.4] There are
37 potential urban agglomeration economies around cost-effective adaptation and resilience building via improved built
38 and ecological infrastructure and services and bringing together people, communities and institutions to respond
39 collectively to climate change risks. [8.3] There is also the need to take recognize potential conflicts between the
40 adaptation and mitigation agendas, as well as the establishment of locally specific limits to adaptive interventions.
41 [8.5] The “density conundrum” where increased urban densities could enhance climate mitigation potential can limit
42 the possibilities of ecosystem based adaptation, cross thresholds of acceptable biodiversity change and may
43 exacerbate urban heat island risk. [8.3]
44

45 **Building climate resilience in cities can be well-served by ecosystem-based adaptation with water and food**
46 **systems as foci (*medium confidence, based on high agreement among practitioners and medium evidence*).**
47 Ecosystem-based adaptation is regarded as one of the more cost-effective and sustainable approaches to urban
48 adaptation, although the costs of needed land acquisition can be high. [8.5] This is even though climate change will
49 impact ecosystem services by altering ecosystem functions such as temperature and precipitation regimes,
50 evaporation, humidity and soil moisture levels. Ecosystem-based adaptation is closely linked to sustainable water
51 management ensuring sufficient supplies, increased capacities to manage reduced freshwater availability, flood risk
52 reduction, managing waste water flows and ensuring water quality. [8.3, 8.5] There are considerable knowledge
53 gaps in determining the limits or thresholds to adaptation of various ecosystems and where and how ecosystem
54 based adaptation is best integrated with other adaptation measures. [8.5] There is *high confidence* that urban food-

1 adaptation is linked to progressive public policy on food security and livelihood development; addressing constraints
2 in agricultural production and food supply chains and limiting food price shock impacts caused by extreme eventson
3 the food and nutrition security of low-income groups. [8.3]
4

5 **Good quality, affordable and well-located housing provides one of the bases for city-wide adaptation to**
6 **climate change (*high confidence, supported by high agreement and high evidence*).** Climate change adaptation in
7 urban centres will be built on the bedrock of good quality and affordable housing that conforms to appropriate health
8 and safety and climate-resilient building standards and has sufficient residual structural integrity over its service life
9 to protect its occupants against extreme weather, especially heat waves and storms. Good quality housing should
10 provide its occupants with a comfortable, healthy and secure living environment and protect them from injuries,
11 losses and damage. This requires effectiveland-use planning and regulation to control development in flood-prone
12 and other high risk areas. It is particularly important for vulnerable groups especially children and older residents
13 with chronic health conditions. This can be enabled via a range of structural interventions, interventions that reduce
14 risks to housing and support access to quality housing for low-income groups, non-structural interventions (like
15 insurance) and disaster risk reduction measures. Well-coordinated strategies are required to address a multiplicity of
16 agencies working at various levels, overlapping regulation and lack of committed resources. [8.3]
17

18 **Reducing basic service deficits and building resilient infrastructure systems could significantly reduce global**
19 **climate risk (*very high confidence, supported by high agreement and high evidence*).** Around one billion people
20 live in informal settlements in urban areas with inadequate or no provision for infrastructure and services that
21 provides a foundation for adaptation. Here, poverty and social inequality may be aggravated by climate change and
22 the lack of adaptive capacity. The adaptive capacity of an urban centre is much influenced by the quality and
23 coverage of infrastructure (piped water supplies, sewers or other forms of provision for sanitation, drains, all
24 weather roads and electricity provision) and services that include solid waste collection (vital for keeping drains
25 functioning), policing, health care, emergency services and measures to reduce disaster risk. The extent to which
26 urban and higher levels of governments are able to mobilize resources, choose the most appropriate technical and
27 institutional systems for service delivery influences adaptive capacity and deepens climate resilience. [8.3] The rate
28 and magnitude of urban development in some low- and middle-income countries also brings great challenges that
29 many high-income nations do not have to deal with.
30

31 **Urban governments are the fulcrum of successful urban climate adaptation (*high confidence*).** Local
32 governments are responsible for many of the needed measures for climate change adaptation in urban areas. This
33 makes sense since most risks and vulnerabilities are rooted in local contexts and much of the risk reducing
34 infrastructure and services are within their jurisdictions. [8.3] The incorporation of climate change adaptation into
35 each urban centre's development planning and investments is well served by an iterative process of learning about
36 changing risks and opportunities and drawing in different stakeholders, to inform a balanced assessment of policy
37 options and decisions. Engagement with local stakeholders, built upon openness and transparency about climate
38 change information and its risks, can ensure the needs and priorities of low-income and vulnerable groups get
39 attention and that the private sector is brought into discussions. The role of urban governments in climate adaptation
40 is now more widely recognized, but in many nations, local governments need a stronger financial and institutional
41 base to be able to act on this, including land use management and infrastructure investment. [8.4] Operationalisation
42 will also need a redirection of current priorities, investment and capacity building plans including those that
43 strengthen the investment capacity of urban, city and metropolitan governments. [8.2, 8.3]
44

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

1 Effective ways to engage local government attention have been the demonstration of climate change adaptation's
2 importance for a city's continuing economic success, improved service delivery, job creation and risk management.
3 [8.5]
4

5 **The process of city-based climate adaptation learning is slow, complex and fraught with multiple interlinked**
6 **challenges (*very high confidence*).** Although some city governments have developed innovative adaptation plans,
7 the scale and scope of what is needed is still poorly appreciated. Multiple changes across legal and regulatory
8 frameworks, jurisdictions, policies and intergovernmental flows are needed to mainstream urban climate adaptation.
9 These can be slow to be accepted and slower to implement. The capacity to integrate climate risk, disaster risk
10 reduction, urban infrastructure and planning are being slowly built in some parts of the world. Sector policies need
11 to take account of climate change. Many such policies will require changes to prevent increases in the vulnerabilities
12 of urban populations, infrastructure and natural systems. In most urban centres, these include policies on water,
13 wastewater, solid waste, natural resource management, building regulations, land-use management, transport
14 planning, and disaster management. [8.4] Other challenges that need addressing include: reducing the lack of clarity
15 of multi-level governance mandates; addressing the tension between local and higher-level and sometimes
16 international agency driven priorities; the competition that long-term climate adaptation horizons will face from
17 short-cycle electoral processes, a focus only on growth and competitiveness and local short-run priorities;
18 overcoming the lack of human and financial resources and compartmentalisation and fragmentation of urban
19 government. An openness to emergent and uncertain climate risks via awareness and institutional development can
20 bridge the gap between the need for phased adaptation interventions and the many years it would take for their
21 benefits to become visible. [8.3, 8.4, 8.5] The practice of effective monitoring of development and of the
22 implementation of adaptation plans is still evolving, given the localized nature of most urban adaptation action. [8.5]
23

24 **Locally-relevant adaptation plans, data and feedback mechanisms are important for building urban climate**
25 **resilience (*high agreement and medium evidence*).** Governments, households and the private sector need relevant,
26 reliable local information, including climate projections, to encourage them to act and inform their actions. Despite
27 growing attention, much-needed information and assessment of climate change at urban spatial scales is generally
28 still lacking. Unlike mitigation planning, adaptation programmes are less open to a standard set of requirements,
29 given that actions are often rooted in local circumstances, involve multiple stakeholders, are cross-sectoral, multi-
30 scalar and multi-synchronous, and include a high level of uncertainty. [8.5] Only a small number of cities, largely in
31 high-income countries, have quantified risks in local contexts and even fewer have quantified possible costs of
32 climate change risks under different climate and/or socio-economic scenarios. First and second order impacts such
33 as sea level rise and coastal and riverine flood risk and health and water resources are among the most studied
34 sectors, while third order impacts on energy, transport and built infrastructure receive far less attention, and yet these
35 sectors are often targeted for mitigation-focused interventions. While science and climate change information is
36 increasingly available, socio-economic drivers of vulnerability and impacts, such as an increasing health risk and
37 disease burdens are less well understood. [8.2, 8.4] Tools for risk screening and management, which draw on
38 detailed data and projections both from physical science and the socio-economic domains, can help engage the
39 interest of local governments, businesses and civil society organizations. They can also help the translation into
40 information useful for decision-making. City experience is slowly developing around multi-stakeholder adaptation
41 engagement and awareness generation to build broad based support; mainstreaming climate adaptation processes
42 into municipal planning, land use management and building and infrastructure codes. Improved feedback,
43 monitoring and reporting capacity supported by new generation risk screening, vulnerability mapping and integrated
44 urban climate assessment tools are helping catalyse social-learning to help mainstream climate adaptation into urban
45 policies and planning. [8.4] Assessment tools such as scenario-planning that go beyond spatial and multi-criteria
46 assessment to consider the urban environment as a system to better understand the inter-connections, cascading
47 impacts and vulnerabilities are also recommended [8.4, 8.5]
48

49 **Enabling the agency of low-income households and vulnerable communities is a powerful adaptation strategy**
50 **(*high confidence*).** Informal settlements in low- and middle-income nations are among the largest existing and
51 emerging concentrations of climate vulnerable urban populations, assets, infrastructure and ecosystem services. [8.1,
52 8.2, 8.3] Many urban governments are unable to extend a full range of entitlements, services and the institutional
53 support necessary for effective adaptation to these settlements. For most cities and smaller urban centres in low- and
54 middle-income nations, poverty reduction needs more attention because of the strong association between poverty

1 and environmental health, disaster and climate change risks. [8.5] In many high climate risk locations, community
2 and household-led adaptation have intervened with their limited resources to fill this gap. In informal settlements,
3 engagement with community learning provides a means for participatory community risk assessment, where local
4 capacity to adapt is built in part through accessing their knowledge. The scale and range of what this can achieve is
5 increased with local governments' support; simply shifting the burden of adaptation to the community level is
6 unlikely to bring success. [8.4] It is now more common for local and national governments to work with the
7 inhabitants of informal settlements to install or upgrade infrastructure and services and address insecure tenure; this
8 can strengthen social capital creation processes and build their resilience to climate change impacts. [8.4] Enabling
9 community-led adaptation can be challenging and depends on a number of factors including representativeness of
10 leadership, supportive local governance, community organizations' ability to pressure government and other
11 stakeholders to respond to their concerns, as well as a recognition of the limits of community-based intervention.
12 [8.4, 8.5]
13

14 **Effective local action requires coordinated support from higher levels of governments and other stakeholders**
15 **(*medium agreement supported by medium evidence*)**. To be effective adaptors, urban governments need a mandate
16 around climate change adaptation via supportive policy and enabling legislative frameworks from higher levels of
17 governments (including national, supra-national and state/provincial levels). Universities and research institutions,
18 multilateral and bilateral agencies, financial and insurance and other private sector agencies have successfully
19 assisted urban governments and households to mobilize around climate adaptation. Since effective adaptation for
20 urban centres needs local responses and includes major roles for local governments and civil society (especially
21 those representing those most at risk), consideration needs to be given to mechanisms by which international support
22 for adaptation can work at scale while supporting local processes [8.4, 8.5] Large metropolitan areas and their rapid
23 growth raise the level of complexity of managing adaptation, requiring action to be coordinated across multiple
24 urban jurisdictions. The role of local government champions has often proved critical in providing initial leadership
25 towards promoting and sustaining an adaptation agenda. [8.5] Although there is some evidence of innovative
26 responses at the sub-national levels to plan for extreme weather events and climate change, limited local government
27 capacity and experience suggests a need for support from higher levels of government. [8.4] A phased approach,
28 whereby the most urgent matters, such as rapid-onset disasters, are prioritized first, leaving a longer time period to
29 plan for slow-onset impacts which may be associated with greater uncertainty, is most likely to attract local
30 government attention. [8.5]
31

32 **Building human and institutional capacity for urban climate resilience will accelerate implementation and**
33 **improve outcomes (*high confidence*)**. A binding constraint to effective and timely urban adaptation and building
34 resilience is effective institutions and leadership across government, communities, civil society, knowledge
35 institutions and the media. This can be addressed by a number of structural interventions to enable city-wide
36 alliances and frameworks to be built, institutionalization of processes, building a culture of exchange between
37 learning organizations and a strong emphasis on capacity building. [8.4] The locus of the climate change focal point
38 in government has a strong bearing on its success. There is evidence of expanding urban adaptation leadership, but
39 building a wide support base for adaptation across many sectors, in and outside of government to de-risk the impact
40 of slow institutional development and leadership change is an important priority. Local or regional boundary
41 organisations such as nearby academic or research communities have been shown to have influence and support
42 policy decisions. Networking and sharing experiences among adaptation practitioners and between cities is also an
43 important vehicle to improve city-level outcomes. [8.4, 8.5]
44

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

1
2 **There is limited commitment to and development of urban climate adaptation finance (*high agreement and***
3 ***low evidence*)**. Available finance for urban adaptation span domestic and external public and private sources.
4 Domestic public funding can be raised through a variety of measures ranging from urban fiscal policies (where there
5 is capacity to do this) to revenue transfers from national (and often provincial or state) government. External public
6 funding can come from traditional development finance sources (i.e. multilateral development banks and bilateral
7 development co-operation partners). The need for urban adaptation investments will far exceed available public
8 funding. Smaller cities and other urban centres with weak and fragmented governance structures may be least
9 equipped to access available climate change funding, even as they house some of the most vulnerable populations.
10 Domestic private investment by individuals, households and businesses is expected to be the most sustainable and
11 significant source of funding for adaptation. Its effectiveness depends on what local and higher-level governments
12 do to encourage and support this, as well as helping deliver infrastructure and services. Hence, a range of innovative
13 fiscal instruments, measures to attract ‘climate-smart’ public and private investment and micro-insurance coverage
14 of lower-income households, risk transfer mechanisms and innovative market-based insurance coverage, will be
15 needed to address climate adaptation finance needs. This will need a supportive public policy environment to enable
16 efficient market resource allocation to promote adaptation and overcome persistent market barriers. It also needs
17 frameworks for land-use management to ensure appropriate economic and livelihood development incentives, avoid
18 high-risk zones and implement appropriate building and infrastructure standards. A growing share of current
19 development finance is being committed (in principle) to adaptation, especially towards technological investment
20 and capital projects. However, mechanisms are not yet in place to ensure that it supports locally-driven adaptation
21 practice in urban centres. There is a need to reconcile top-down and bottom-up planning, enabling structured
22 planning, programming and outcome monitoring. A key to improving effectiveness of international public finance
23 will be building the capacity for country-led planning processes that include urban adaptation and are backed by
24 adaptation monitoring and data collection, designed specifically for the complexity of urban projects. The systematic
25 programming of adaptation into international humanitarian and disaster response funding is still to develop. In
26 addition, most national Action Plans under the UNFCCC have little emphasis on urban adaptation. Thus, urban
27 climate adaptation financing and structuring remains an area where innovation and improvement are much needed to
28 deliver demand-driven and responsive solutions, while catering to local contexts and possibilities. [8.4, 8.5]
29
30

31 **8.1. Introduction**

32 **8.1.1. Key Issues**

33
34
35 Successful adaptation to climate change depends centrally on what is done in urban centres – that now house more
36 than half the world’s population and concentrate most of its assets and economic activities. As 8.4 emphasizes, this
37 needs to include responses by multiple levels of government, individuals and communities, the private sector and
38 civil society. The serious impacts of extreme weather on many urban centres each year show risks and vulnerabilities
39 that need to be addressed and climate change will usually add to these. What is done in urban centres also has major
40 implications for mitigation, especially future levels of greenhouse gas emissions and for delivering co-benefits, as
41 discussed in WGIII. This chapter focuses on the connections between urban centres and climate change and on the
42 possibilities for governments, enterprises and populations to adapt to and develop resilience to its direct and indirect
43 impacts.
44

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

1
2 In reviewing adaptation needs and options for urban areas, the documentation points to two key conclusions. The
3 first is how much the adaptive capacity of a city depends on: past plans and investments in infrastructure and
4 services; existing capacities for such investments and land-use management; and for ensuring buildings meet health
5 and safety standards. This provides the foundation for city resilience on which adaptation can be built. For almost all
6 urban centres in low-income and many in middle-income nations; there is little of this foundation of resilience. The
7 second is the importance of city and municipal governments acting now to incorporate climate change adaptation
8 into their development plans and policies. But to do so requires not only building the foundation of resilience (and
9 its institutional and financial underpinnings) but also to mobilize new resources and continuously develop local
10 capacities to respond. This is not to diminish the key roles of other actors including the private sector, the demands
11 and priorities of residents, civil society and higher levels of government. But it will fall to city and municipal
12 government to provide the scaffolding and regulatory framework within which all other stakeholders contribute and
13 collaborate. Thus, adaptation in urban areas depends heavily upon the competence and capacity of local
14 governments and a locally rooted iterative process of learning about changing risks and opportunities, identifying
15 and evaluating options, making decisions, and revising strategies in collaboration with a range of actors (see Chapter
16 2 for more discussion of this).

17 18 19 **8.1.2. Scope of the Chapter** 20

21 This chapter focuses on what we know about how climate change will impact on urban centres and their populations
22 and enterprises, what measures can be taken to adapt to these changes (and protect vulnerable groups) and the
23 institutional and governance changes needed to underpin this. Both this chapter and Chapter 9 on rural areas
24 highlight the multiple linkages between rural and urban areas. This chapter also has overlaps with Chapter 10,
25 especially in regard to infrastructure, although this chapter focuses on urban infrastructure and in particular the
26 infrastructure that comes within the responsibilities or jurisdiction of urban governments.
27

28 This chapter draws its urban statistics from the United Nations Population Division (see United Nations 2012).
29 Urban centres vary from metropolitan areas with more than 20 million inhabitants to those with few thousand (or in
30 some nations a few hundred) inhabitants. There is no international agreement as to how urban centres or populations
31 should be defined or distinguished from rural populations and there is considerable variation in how governments
32 choose to define urban areas (see United Nations 2012). This influences the proportion of the population said to live
33 in urban areas for any nation. Many nations define as urban centres all settlements with populations above a
34 threshold - for instance 1,000 or 2,500 or 5,000 inhabitants. So a nation's urban population and level of urbanization
35 can vary substantially, depending on which threshold is used (or other criteria chosen and applied). Virtually all
36 nations classify settlements with 20,000 plus inhabitants as urban; it is around the proportion of the population that
37 live in settlements between a few hundred and 20,000 inhabitants that national differences emerge. There is also the
38 ambiguity as to the dividing line between rural and urban. In some instances, urban boundaries include large rural
39 areas while in others, urban centres have grown beyond official boundaries and into areas that are within
40 neighbouring jurisdictions and may be defined as rural. Most large cities have more than one boundary – for
41 instance one based on the local government jurisdiction or linked to the built up area, another based on the
42 metropolitan area and another on the metropolitan region or planning region. Boundaries for metropolitan areas or
43 extended metropolitan regions often include substantial rural populations. Most suburban areas are within urban
44 boundaries. In addition, just as urban centres depend on rural resources and eco-system services, it is common for a
45 proportion of the workforce in larger urban centres to live outside the urban centre and commute – and this may
46 include many that live in settlements designated as rural. There is also no agreed definition for what constitutes a
47 city – although the term city implies an urban centre with some economic, political or cultural importance so it
48 would not be applied to most small urban centres.
49
50

51 **8.1.3. Context – An Urbanizing World** 52

53 In 2008, for the first time, more than half the world's population was living in urban centres and the proportion living
54 in urban centres continues to grow (United Nations 2012). Three quarters of the world's urban population and most

1 of its largest cities are now in low- and middle-income nations. UN projections suggest that almost all the increase
2 in the world's population up to 2050 will be in urban centres in what are currently low- and middle-income nations
3 (see Table 8-1). It is within urban centres within most nations and globally that most GDP is generated and most
4 new investment has concentrated (World Bank 2008, Satterthwaite et al. 2010). Clearly, in terms only of the
5 population, economic activities and climate risk they concentrate and the progressive increase in such concentration,
6 adapting urban areas to climate change needs serious attention.

7
8 [INSERT TABLE 8-1 HERE

9 Table 8-1: The distribution of the world's urban population by region, 1950–2010 with projections to 2030 and
10 2050.]

11
12 There is an economic logic underpinning most urbanization as all wealthy nations are predominantly urbanized and
13 as rapid urbanization in low- and middle-income nations is usually associated with rapid economic growth (ibid).
14 Most of the world's largest cities are in its largest economies (ibid). If rapid urbanization and rapid city population
15 growth is associated with economic success, it suggests that more resources can be drawn on to support adaptation.
16 But in most urban centres in low- and middle-income nations, including many successful cities, local governments
17 have been unable to keep up with the economic and physical expansion and there are large deficits in provision for
18 infrastructure and services that have relevance for climate change adaptation. Around one in seven of the world's
19 population live in poor quality, overcrowded accommodation in urban areas with inadequate or no provision for
20 basic infrastructure and services and mostly in informal settlements (UN-Habitat 2003, Mitlin and Satterthwaite
21 2013). Within the world's urban population, it is in these settlements that much of the risk and vulnerability to
22 climate change is concentrated. And a substantial proportion of these settlements are in economically successful
23 cities (Mitlin and Satterthwaite 2013). So this chapter is concerned not only with an adaptation deficit for urban
24 centres but also with a development deficit that has relevance for risk and vulnerability to climate change.

25
26 Many aspects of urban change in recent decades have been so rapid that they have overwhelmed government
27 capacity to manage it. Of the world's cities with 750,000 plus inhabitants in 2010, 52 had populations growing more
28 than twenty fold since 1960 and 116 had populations growing more than tenfold (statistics in this paragraph drawn
29 from data in United Nations 2012). The increasing concentration of the world's urban population and its largest
30 cities outside the nations with the highest incomes that Table 8-1 shows represents an important change. Over the
31 19th and 20th centuries, most of the world's urban population and most of its largest cities were in its most prosperous
32 nations. Urban areas in low- and middle-income nations now have close to two-fifths of the world's total population
33 and close to three-quarters of its urban population. They also have most of the world's large cities. Of the 23 'mega-
34 cities' (cities whose population was reported to exceed 10 million) by 2011, only 5 were in high-income nations
35 (two in Japan, two in USA, one in France). Of the remaining 18, four were in China; three were in India and two in
36 Brazil. However, over three fifths of the world's urban population is in urban centres with less than 1 million
37 inhabitants and it is in these that much of the growth in urban population is occurring.

38
39 Underlying these population statistics are large and often complex economic, social, political and demographic
40 changes including the multiplication in the size of the world's economy and the shift in economic activities and
41 employment structures from agriculture to industry and services (and within services to information production and
42 exchange). One of the most significant changes has been the growth in the size and importance of cities whose
43 economies increased and changed as a result of globalization (Sassen 2006). Another is the many large cities that are
44 now centres of large extended metropolitan regions.

45
46 One difficulty that this chapter faces is in providing a summary of trends for settlements that have more than half the
47 world's population when there is such diversity among these in terms of their current vulnerability to extreme
48 weather, the scale and nature of risks that climate change is bringing or will bring (and who is most at risk), the
49 extent to which their population lives in good quality homes served with conventional infrastructure and services
50 that provides the basis for adaptation (what this chapter terms accumulated resilience) and the extent to which their
51 governments are acting or able to act on adaptation and being supported to do so by higher levels of government and
52 where needed international agencies. Table 8-2 illustrates this diversity and how each urban centre falls within a
53 spectrum in at least four key factors that influence adaptation: local government capacity, the proportion of the
54 population served with risk-reducing infrastructure and services; the proportion of the population living in housing

1 built to appropriate health and safety standards; and the levels of risk from climate change’s direct and indirect
2 impacts. This chapter also draws on detailed case studies of three cities to illustrate this diversity – New York
3 (Solecki 2012a), Durban (Roberts and O’Donoghue, 2013) and Dar es Salaam (Kiunsi, 2013).

4
5 [INSERT TABLE 8-2 HERE

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

12
13 Many attributes of urban centres can be measured and compared. Populations vary from a few thousand inhabitants
14 (or a few hundred in some nations) to the largest cities with 20-36 million inhabitants. Areas vary from less than one
15 to thousands of square kilometres. Average life expectancy at birth for urban centres varies from over 80 years to
16 under 40 years – and under-five mortality rates vary by a factor of 20 or more (Mitlin and Satterthwaite 2013).
17 Average per capita incomes vary by a factor of at least 300; so too do the investment capacities of urban
18 governments (UCLG 2011). Greenhouse gas emissions per person vary by more than 100 (Dodman 2009,
19 Hoorweg et al. 2011). There are large differences between urban centres in the extent to which their economies are
20 dependent on climate-sensitive resources (including commercial agriculture, water and tourism). There are also large
21 variations in the scale and nature of impacts from extreme weather. As Table 8-2 suggests, there are urban indicators
22 that are relevant for accumulated resilience to climate change impacts (the proportion of the population with water
23 piped to their homes, sewers, drains, health care and emergency services) but less so for the scale and nature of
24 climate change related risks and for the quality and capacity of government.

25
26 Recent analyses of disaster impacts show that urban centres concentrate a high proportion of the world’s population
27 most affected by extreme weather events (United Nations 2009, 2011, IFRC 2010). As shown in Table 8-2, a high
28 proportion of such urban centres have local governments that lack the capacity to reduce such disaster risk and very
29 large deficits in the infrastructure and institutions needed to do so. Their low-income households may require
30 particular assistance due to greater exposure to hazards, lower adaptive capacity, more limited access to
31 infrastructure or insurance, and fewer possibilities to relocate to safer accommodation as compared to wealthier
32 residents. There are also many cities that have high resilience to extreme weather and have the infrastructure and
33 institutions that can provide resilience to the exacerbation of extreme weather events and change in resource
34 availabilities associated with climate change.

35
36 All successful urban centres have had to adapt to environmental conditions and resource availabilities, although
37 local resource constraints have often been overcome by drawing resources and using sinks from ‘distant elsewhere’s’
38 (Rees 1992, McGranahan 2007); this includes importing goods that are resource intensive and whose fabrication
39 involves high greenhouse gas emissions. The growth of urban population over the last century has also caused a very
40 large anthropogenic transformation of terrestrial biomes. Urban centres cover only a small proportion of the world’s
41 land surface; Schneider et al 2009 suggested that they cover only 0.51 per cent of the total land area and among the
42 world’s regions only in Western Europe did they cover more than 1 per cent. However, their physical and ecological
43 footprints are much larger, as urban based enterprises and consumers draw on a much larger land area. The net
44 ecological impact includes the decline in the share of wild and semi natural areas from about 70 per cent to under 50
45 per cent of the land area. This was largely to accommodate the demand for crop and pastoral land to support human
46 consumption, leading not only to a decrease in biodiversity but a threat to ecological services that support both rural
47 and urban areas. Future projections (Seto et al 2012) suggest that if current trends continue, that urban land cover
48 will increase by 1.2 million square kilometres by 2030. This would represent nearly tripling the global urban land
49 from around 2000 and would result in a “considerable loss of habitats in key biodiversity hotspots” destroying the
50 green infrastructure that will be key in helping areas adapt to the impacts of climate change (ibid page 16083)

51
52 Many of the challenges and opportunities for urban adaptation are derived from the central features of city life – the
53 concentration of people, buildings, economic activities and social and cultural institutions (Romero-Lankao and
54 Dodman 2011). A key part of urban centres’ adaptive capacity is related to agglomeration economies. These are

1 usually discussed in relation to the advantages for enterprises locating there. But the concentrations of people,
2 enterprises and institutions in urban areas also provides potential agglomeration economies in lower unit costs for
3 providing each building with piped water, sewers, drains and a range of services (solid waste collection, schools,
4 health care, emergency services, policing) and bringing together people, communities and institutions to respond
5 collectively (Hardoy et al. 2001). But these need to be acted on and to have local governments capable of acting on
6 them. In most urban centres in low- and middle-income nations, these are not acted upon and the result is very large
7 deficiencies in infrastructure and services. Although urban centres in high-income nations are much better served,
8 there may also be particular challenges – for instance in addressing aging infrastructure and in adapting energy
9 systems, the building stock and infrastructure and services to the altered risk set that climate change’s direct and
10 indirect impacts will bring (see Zimmerman and Faris 2010 and Solecki 2012a for discussions of this for New
11 York).

12
13 Effective urban governments will also need to work with range of government and civil society institutions at local
14 and supra-local levels and to get support and enabling frameworks from higher levels of government. In addition, as
15 this chapter discusses, the concentration of people and economic activities also presents particular challenges for
16 climate change adaptation – including the management of storm and surface run-off and measures to reduce heat
17 islands. Large cities also concentrate demand and need for ecological services and natural resources (water, food and
18 biomass), energy and electricity and these may rely on supply chains that climate change will disrupt. Thus, the
19 increasing concentration of the world’s population in urban centres will bring increased risk concentration of a range
20 of climate-related hazards for a large and growing proportion of the world’s population – while also having the
21 potential to support more effective adaptation.

22 23 24 **8.1.4. Vulnerability and Resilience**

25
26 For each of the direct and indirect impacts of climate change, there are groups of urban dwellers that face higher
27 health and other risks (illness, injury, mortality, damage to or loss of homes and assets). This can be on the basis of
28 age (for instance infants or elderly people’s greater susceptibility to particular hazards such as heat waves) or health
29 status (for instance those with particular diseases, injuries or disabilities that make them more susceptible to these
30 impacts). Or it may be because they live in locations that face greater risks – for instance on coasts or by rivers
31 where flood risks have increased or will increase. These are often termed vulnerable groups – although to state the
32 obvious, these are only vulnerable to climate change impacts if the hazard poses a risk. Remove the vulnerable
33 population’s exposure to the hazard (e.g. drains preventing flooding) and there is no impact. Infants may face
34 serious health risks when water supplies are contaminated by flooding but rapid and effective treatment for
35 diarrhoea and quickly re-establishing availability of drinking quality water greatly reduces impacts (Bartlett 2008).
36 There are also adaptations by individuals, households, communities, private enterprises or government service
37 providers that may reduce risks or reduce exposure.

38
39 Although there are many definitions of vulnerability (see for instance Fussler 2007), these agree that it centres on an
40 inability to avoid harm when exposed to a hazard – including an inability to avoid the hazard, anticipate it (and take
41 measures to avoid it or limit its impact), cope with it and recover from it (bounce back) (see also the report
42 Glossary). So vulnerable groups may be identified on the basis of any of these four factors. Adaptation can also
43 include ‘bouncing forward’ as resilience is increased and so built to protect against future hazards and uncertainty
44 about such hazards.

45
46 The term vulnerability is also applied to sectors that may include food processing, tourism, water, energy and
47 mobility infrastructure and their cross-linkages e.g. perishable commodities dependent on efficient transport. Much
48 tourism is sensitive to climate change as it may damage key tourist assets e.g. coral reefs and beaches or make
49 particular locations less attractive to tourists because of changes in temperatures or increases in extreme weather. Oil
50 price changes will affect travel costs.

51
52 Certain types of infrastructure on which urban centres rely are more at risk: e.g. most transport, drainage and
53 electricity transmission systems and many water supply abstraction and treatment works. Infrastructure plans and
54 investments generally include some scope for coping with climate variability but in many locations these will need

1 to increase reserve margins, back up capacity and other structural adaptation measures. Conventional infrastructure
2 investment decision-making may overlook or fail to value needed redundancy. Cities as complex, inter-connected
3 systems are vulnerable to intersectoral connections – for instance the dependence of water supplies, drainage, traffic
4 management, telecommunications, health care services and some trains on electricity supply and the dependence of
5 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*

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

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

28 Additionally, a growing literature on successful urban adaptation interventions shows that they recognize the
29 interrelations and interdependence between multiple sectors, levels and risks in a dynamic physical, economic,
30 institutional and socio-political environment (Gasper et al., 2011, Kirshen et al., 2008). Therefore, climate policies
31 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*

36 A literature discussing resilience to climate change for urban centres and what contributes to this has emerged in
37 recent years - and this section draws on this literature (Miller 2007, Pelling 2011a, Leichenko 2011, da Silva et al.
38 2012, Tyler and Moench 2012, Brown et al. 2012). Although resilience is usually considered to be the opposite of
39 vulnerability, vulnerability is often discussed in relation to particular groups within the population whereas
40 resilience is more often discussed in relation to what helps protect them such as infrastructure or climate-risk
41 sensitive land-use management. Addressing resilience for cities is also more than identifying and acting on specific
42 climate change impacts as it looks to the performance of each city's complex and interconnected infrastructure and
43 institutional systems and includes a capacity to withstand unexpected or unpredicted changes. When considered for
44 cities, it is common for certain characteristics of resilience to be identified – for instance flexibility, redundancy,
45 responsiveness, capacity to learn and safe failure (Moench et al., 2012, Tyler et al. 2012, da Silva et al. 2012, Brown
46 et al. 2012). There is also recognition of the complexities of urban systems and the multiple inter-dependencies
47 between different sectors that were noted above.

49 But when considering a specific city, the level and forms of resilience are often related to specific local factors,
50 services and institutions – for instance for each district in a city, will the storm and surface drains cope with the next
51 storm (a particularly pressing issue for cities that have heavy rainfall in particular seasons). During heat waves, will
52 measures to help those most at risk from high temperatures work and reach all high-risk groups? Here, resilience is
53 not only the ability to recover from the impact (bouncing back) but the ability to avoid or minimize the need to
54 recover (United Nations 2011). Thus, a considerable part of resilience is the functioning of institutions to provide the

1 above and the knowledge base needed to do so (da Silva et al. 2012). The emerging literature on the resilience of
2 cities to climate change also highlights the need to focus on resource availabilities and sinks beyond the urban
3 boundaries and it may also require coordinated actions by institutions from other jurisdictions or higher levels of
4 government (for instance watershed management upstream of a city to reduce flood risks see Brown et al. 2012,
5 Ramachandraiah 2011). There are also the slow onset impacts that pose particular challenges and that may also be
6 outside the jurisdiction of urban governments – for instance the impact of drought on agriculture that can raise food
7 prices and reduce rural demand for urban services.

8
9 Cities in high-income nations and many in middle-income nations have become more resilient to extreme weather
10 (and most other potential catalysts for disasters) through a range of measures that have responded to risks and to the
11 political processes that demanded such responses (Satterthwaite 2011). This resilience has been built over many
12 decades and often required intense political negotiation. The resilience accumulated through this in what was built
13 and in the capacity of institutions provides resilience to some climate change impacts, even though the measures that
14 built resilience were not in response to climate change impacts (see for instance Hardoy and Ruete 2013 on Rosario,
15 Argentina). What strongly influences resilience to extreme weather for urban dwellers is the quality of buildings
16 (homes and workplaces), the effectiveness of land-use planning and regulation to control development in flood-
17 prone and other high risk areas, the quality and coverage for key infrastructure and services, early warning systems
18 for extreme weather and adequate public response measures, whether their incomes are sufficient to invest part in
19 resilience (living in healthy homes, life insurance, insurance for possessions and home, savings, pensions, asset
20 ownership...), what safety nets are available if income is insufficient and the regulatory framework for ensuring the
21 application of the above. Urban governments have importance for most or all of these, although their provision
22 usually depended on changes at national level – for instance in legislation and in financial support (although political
23 change at national level was also in part driven by political pressure from urban dwellers and innovation by city
24 governments). Private companies or non-profit institutions may provide some of the key services and private
25 companies have key roles in provision and often maintenance of infrastructure -but the framework for provision and
26 quality control is provided by local government or local offices or national or provincial government.

27
28 A city's accumulated resilience can be assessed by the extent to which it has reduced hazards, reduced risk and
29 reduced exposure, with particular attention to how this serves or protects vulnerable groups and at-risk areas. Also
30 by the measures in place to enhance capacity to cope and adapt. Such an assessment can also consider how well this
31 'accumulated resilience' will serve climate change adaptation. Of course, there are hazards that city governments
32 cannot reduce (for instance earthquakes) or that need global action (eg reducing greenhouse gas emissions).

33
34 Although the components of accumulated resilience were not in response to risks from climate change, the web of
35 institutions and finances that produced and maintain them provide a base for climate change adaptation (and more
36 broadly for resilience). Building and infrastructure standards can be adjusted if needed (there is infrastructure in
37 place that can be adjusted - for instance increasing capacity for storm and surface water drainage systems), existing
38 service provision can be adjusted for new risks or risk levels (measures to reach populations vulnerable to heat stress
39 during heat waves and within heat islands) and city planning and land-use management can be adjusted to any new
40 or heightened risk (keeping building and city expansion away from areas facing new risk levels). This can be
41 supported by changes in private sector investments (over time shifting away from high-risk areas) and changes in
42 insurance premiums and coverage. So the web of institutions and the buildings, infrastructure and services that have
43 developed in response to non-climate change risks provide a foundation for developing resilience to climate
44 change. They provide the basis on which to build adaptive capacity to withstand climate-change related direct and
45 indirect disturbances. They can also go beyond this and "bounce forward" by building climate resilience through a
46 mix of sound development, disaster risk reduction and ecosystem-based adaptation, rather than incremental
47 adaptation interventions..

48
49 Whether they will do so depends on whether urban governments take this on – and whether the demands of their
50 inhabitants and these inhabitants' capacity to organize and get change promote this; also whether the institutions and
51 their complex inter-relationships have the capacity to learn. Obviously, the extent to which these provide or can
52 provide resilience in the future also depends on global agreements that slow and stop the increases in risk from GHG
53 emissions and other drivers of climate change.

54

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

7
8 For urban centres with little accumulated resilience, *resilience as a process* has importance, both to help reduce over
9 time the (often very large) deficiencies in most or all the infrastructure, services and regulatory frameworks that
10 provide resilience in high-income nations and to build resilience to climate change impacts. For around a third of the
11 world's urban population, this has to be done in a context of limited incomes and assets and poor living conditions
12 and little resilience to any stress or shock. Just an increase in prices of food staples or a drop in income (an income
13 earner being ill or injured) or a new cost (medicines needed for a sick family member) can quickly mean inadequate
14 food and thus hunger and reduced capacity to work and to resist infections.

15
16 The above also implies a different perspective on how climate change adaptation needs to be supported. It
17 emphasizes how resilience to climate change impacts is intimately tied to the quality of governance (in which local
18 governance has particular importance) and in the government capacity and willingness to listen to, work with,
19 support and serve those who lack resilience. Here too, the idea of resilience as 'bouncing forward' has importance –
20 as shown by the many successful partnerships between local government and grassroots organizations formed by
21 residents of informal settlements that have built or improved homes and neighbourhoods. This would also be part of
22 the shift from resilience to transformation (see Pelling 2011a, Shaw and Theobald, 2011, Manyena et al 2011).

23
24 Thus, resilience can be considered in relation to individuals/households, communities and urban centres. In each, it
25 includes the capacity to take action that avoids a climate change impact (live in safe location, have a safe house,
26 have risk reducing infrastructure), to take action before climate impact takes place to reduce its impact (especially
27 relevant for extreme weather events), to cope with the impact and to bounce back (to the previous state) and to
28 'bounce forward' to a more resilient state that would lay the ground for transformative adaptation. For urban centres,
29 bounce back includes a government capacity to rapidly restore key services and repair infrastructure and 'bounce
30 forward' is building the socio-institutional processes and capacities that enable the accumulation of resilience.

31 32 33 **8.1.5. Conclusions from the Fourth Assessment (AR4) and New Issues Raised by this Chapter**

34
35 AR4's chapter on Industries, Settlements and Human Society noted that these are accustomed to variability in
36 environmental conditions but more at risk if change is more extreme (e.g. beyond what had been experienced in the
37 past), persistent or rapid, especially if not foreseen and where capacities for adaptation are limited.

38
39 Except for abrupt extreme events, climate change impacts are not dominant issues for urban centres but their
40 importance is in their interaction with other stressors that may include rapid population growth, political instability,
41 poverty and inequality, ineffective local governments, jurisdictional fragmentation and aging or inadequate
42 infrastructure. Key challenges to getting attention to adaptation include the difficulties of estimating and projecting
43 the magnitudes of climate risk in particular places and sectors with precision and a weak knowledge base on the
44 costs of adaptation.

45
46 AR4 described how the interactions between climate change and global urbanization has led to concentrations of
47 urban populations in low-income nations with weak adaptive capacity. It also described the interactions between
48 climate change and a globalized economy that include long supply chains and impacts spreading from directly
49 impacted areas and sectors to other areas and sectors through complex linkages. Many impacts will be unanticipated
50 and total impacts are also poorly estimated by considering only direct impacts. Key global vulnerabilities include
51 interregional trade and migration patterns. AR4's Chapter 7 also described how climate change impacts and most key
52 vulnerabilities are influenced by local contexts including geographic location, the sensitivity to climate of
53 enterprises located there, development pathways and population groups unable to avoid dangerous sites and homes.

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

5
6 Individual adaptation may not produce systemic adaptation. In addition, adaptation of systems may not benefit all
7 because of differential vulnerability of particular groups and places. Adaptation will require a greater awareness of
8 threats and alternatives beyond historical experience and current access to finance.

9
10 Technological innovation for climate adaptation comes largely from industry and services motivated by market
11 signals and these may not be well matched with adaptation needs and residual uncertainties. Many are incremental
12 adjustments to current business activities. Planning guidance and risk management by insurers will have roles in
13 locational choice for industry.

14
15 Certain types of infrastructure are more at risk – including most transport, drainage and electricity transmission
16 systems and many water supply abstraction and treatment works. There is a need to increase reserve margins and
17 develop back up capacity. Adaptation of infrastructure and building stock is often dependent on changes in the
18 institutions and governance framework e.g. in planning regulations and building codes. Climate change has become
19 one of many changes to be understood and planned for by local managers and decision makers.

20 21 22 *8.1.5.1. Key Uncertainties and Research Priorities*

23
24 A range of key uncertainties and research priorities emerge from recent literature:

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

36 37 38 *8.1.5.2. What has Changed since AR4*

39
40 There is now a much larger and more diverse literature on current and potential climate change risks for urban
41 populations and centres and the vulnerabilities of different urban centres and their structure and functioning. There
42 has also been a very large expansion in the literature on urban ‘adaptation,’ and on building resilience at city and
43 regional scales. This includes a large increase in the number of city governments that have published documents on
44 adaptation. There is more engagement with urban adaptation by some professions (including architects, engineers,
45 urban planners and disaster risk reduction specialists). There are also books that focus specifically in climate change
46 and cities with a strong focus on adaptation (see Bicknell et al 2009, Rosenzweig et al 2011a and UN-Habitat 2011a,
47 Cartwright et al 2012). This makes a concise and comprehensive summary more difficult. But this has also produced
48 more clarity in what contributes to resilience in urban centres and systems. Specifically:

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

- 1 • More nuanced understanding of the many ways by which poverty and discrimination exacerbates
- 2 vulnerability to climate impacts (see also Chapter 13)
- 3 • More detailed studies for particular issues of built environment responses to promote adaptation (see for
- 4 instance the growth in the literature on green and white roofs)
- 5 • More case studies of community-based adaptation in its potential contributions and in its limitations
- 6 • More consideration of the role of ecosystem services and of green and blue infrastructure in adaptation
- 7 • More considerations on the financing, enabling and supporting of adaptation for households and enterprises
- 8 • More on learning from innovation in disaster risk reduction
- 9 • A greater appreciation of the inter-dependencies between different infrastructure networks and of the need
- 10 for adaptation both in ‘hard’ infrastructure and in the ‘soft’ institutions that plan and manage it.
- 11 • More examples of city governments and their networks contributing to national and global discussions of
- 12 climate change adaptation (and mitigation) including establishing voluntary commitments (see for instance
- 13 the Durban Adaptation Charter for local governments) and engaging with the Conference of Parties
- 14
- 15

16 **8.2. Urbanization Processes, Climate Change Risks, and Impacts**

17 **8.2.1. Introduction**

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

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

35 **8.2.2. Urbanization – Conditions, Processes, and Systems within Cities**

36 **8.2.2.1. Magnitude and Connections to Climate Change**

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

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

11
12 Urbanization alters local environments via a series of physical phenomena that can result in problems such as heat
13 islands and local flooding that can be exacerbated by climate change. It is critical to understand the interplay
14 between the urbanization process, current local environmental change and accelerating climate change. For example,
15 the past long-term trend in surface air temperature in urban centres has been found to be associated with the intensity
16 of urbanization (Kalnay et al 2006; Ren et al., 2007; Fujibe, 2009; Kolokotroni et al., 2010; Chen et al., 2011; Iqbal
17 and Quamar 2011; Fujibe, 2011; Rim, 2009; Santos and Leite 2009; Tayanc et al., 2009; Sajjad et al., 2009; Jung,
18 2008; He et al., 2007; Stone, 2007). Climate change can influence the dynamics of the microclimate associated with
19 a given city and a city may likewise alter a localized region’s climate. Some coupled processes that may be
20 influenced by the interaction of urbanization and climate change include: changing the effect of urbanization
21 (microscale to mesoscale) by strengthening and/or increasing the range of a UHI, altering small scale processes,
22 such as a land-sea breeze effect, katabatic winds, etc., modifying synoptic scale meteorology (e.g. changes in the
23 position of high pressure systems in relation to UHI events), and the spatial extent and magnitude of climate change
24 (on a city) resulting from global radiative forcing from GHGs.

25
26 The dense nature of many large cities (including megacities) produces pronounced urban influences on
27 anthropogenic heat emissions and surface roughness. The level of this impact is linked to the level of wealth, energy
28 consumption and micro and regional climate conditions. Anthropogenic heat fluxes for large cities can be very high:
29 up to 50-500 W m⁻² has been observed in a global analysis (Flanner, 2009; Allen et al., 2011) in London (Iamarino
30 et al., 2011) and Singapore (Quah and Roth, 2012), with values locally reaching 1500 W m⁻² in Tokyo (Ichinose et
31 al., 1999). Under clear skies and light wind conditions, large cities can be more than 10°C warmer than surrounding
32 rural environments (Oke, 1982). There is strong seasonal, diurnal, and meteorological variability in temperature
33 which influences the level of significance that these urbanization related changes have on a specific city.

34
35 In a review of relationships between coastal megacities and environmental change, Grimmond (2011) found
36 increasing evidence that cities can influence weather (e.g. rainfall, lightning) through complex urban land use–
37 weather–climate feedbacks (see also Ohashi and Kida, 2002). Megacity impact on air flows, especially for coastal
38 cities has been modelled, for New York and Tokyo (Holt et al., 2009; Holt and Pullen, 2007; Thompson et al.,
39 2007). Megacities influence both internal city environmental and regional weather and air quality. Megacity-coastal
40 interactions may also impact the hydrological cycle and pollutant removal processes through the development of
41 fog, clouds, and precipitation in and around megacities and coastal areas (Landsberg, 1970; Ohashi and Kida, 2002;
42 Shepherd et al., 2002). Other modelling efforts define building density and design and the scale of urban
43 development are important local determinants of the influence of urbanization on local temperature shifts (Oleson et
44 al., 2012; Trusilova et al., 2008).

45
46 The results of climate modelling exercises indicate an ‘urban effect’ that leads locally to higher temperatures and
47 reduced humidity while additional warming also marginally increases rainfall over large cities. The replacement of
48 vegetation with urban surface outweighs this positive impact to reduce the overall land carbon sink (Grimmond,
49 2011). With respect to temperature specifically, Jackson et al. (2010 and 2012) confirm that building material
50 properties are influential in creating different urban climate temperature regimes, which have the potential to alter
51 energy demand for climate control systems in buildings. These results suggest that climate impacts of large cities,
52 including the megacities, are open to change should they be redesigned and use of energy-efficient building
53 materials, passive design technologies and appropriate land-use are scaled up. Urbanization and climate change also
54 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 Nations 2012; Hasse and Lathrop, 2003). Rapid urban population growth in the last decade has been increasingly marked by growth in vertical density (high-rise living, and working) in many nations, especially in Asia. Higher density living can offer opportunities for resource conservation but also challenges for planning and urban management (see 8.3.3.7).

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). Water allocation 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 tCO₂ 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

1 change. For example in sub-Saharan Africa, the combination of relatively high population growth rates and
2 increasing levels of urbanization (projected to reach 46 percent by 2030) will bring a corresponding rise in exposure
3 to climate change impacts. The conflation of local environmental change resulting from urbanization with climate
4 change shifts make the identification and implementation of effective adaptation strategies more difficult. For
5 example, water shortages are already a chronic concern for many cities in low and middle income nations and this
6 typically worsens as the population and demand continue to grow (Muller, 2007). Overlaying climate change-related
7 reductions in supply or heightened uncertainties facing water managers with this existing instability creates the
8 conditions for greater management and governance crises (Gober, 2010, Milly et al., 2008).

11 8.2.2.4. *Urbanisation and Ecological Sustainability*

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

22 Climate change can accelerate ecological pressures in cities, as well as interact with existing urban environmental,
23 economic, and political stresses (Leichenko, 2011; Wilbanks and Kates, 2010). For example, New Orleans’
24 geophysical vulnerability is shaped by its low-lying location, accelerating subsidence, rising sea levels, and
25 heightened intensity or frequency of hurricanes due to climate change—a combination of natural phenomena
26 exacerbated by “settlement decisions, canal development, loss of barrier wetlands, extraction of oil and natural gas,
27 and the design, construction, and failure of protective structures and rainfall storage” (Wilbanks and Kates,
28 2010:726) ; Ernston et al., 2010). Cities in arid regions already struggle with water shortages often in the context of
29 rising demand, but for many such cities, climate change will further reduce water availability because of shifts in
30 precipitation and/or evaporation (Gober, 2010).

33 8.2.2.5. *Regional Differences and Context-Specific Risks*

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

45 The global distribution of urban risks is highly context-specific, dynamic, and uneven between and within regions.
46 Absolute exposure to extreme events over the next few decades will be concentrated in large cities and countries
47 with urban populations in low-lying coastal areas, as in many Asian nations (McGranahan, Balk, and Anderson,
48 2007). Settlements located in river flood plains also are prone to flooding during extreme or persistent precipitation /
49 severe storm conditions. Urban populations’ exposure to climate change related risks is influenced by the scale of
50 the population concentration in cities and the proportion of the population in urban areas. However, recent
51 improvements in urban governance and rising wealth in Latin America (one of the world’s most urbanized regions)
52 have helped to strengthen adaptive capacity (Hardoy and Romero-Lankao, 2011).

1 Studies from different cities confirm how much the scale and nature of climate change risks will differ; Section 8.1
2 and Table 8-2 also emphasized the very large differences between cities in their current resilience to such risks, in
3 the capacity to adapt and in the proportion of their population in informal settlements, most of which lack risk-
4 reducing infrastructure. Many are on dangerous sites including steep slopes and low lands adjacent to unprotected
5 river banks, ocean shorelines and have structures that do not meet building codes (Hardoy et al., 2001; Pelling,
6 2003). However, those who are generally most vulnerable to climate change impacts are women, children, health
7 compromised and the elderly among this population in informal settlements due to the fact that either they are less
8 mobile (e.g., women with child care responsibilities), have less resources, or are physically weak. Hence, the
9 combination of a lack of infrastructure access, low incomes and limited assets puts them at high risk from disasters
10 (Moser and Satterthwaite, 2008).

13 8.2.3. *Urbanization and Climate Change and Variability – Primary (Direct) and Secondary (Indirect) Impacts*

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

23 8.2.3.1. *Urban Temperature Variation: Means and Extremes*

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

35 8.2.3.2. *Urban Heat Islands*

37 Urban heat islands are difficult to quantify and there is debate within the literature on how to define them (Stewart,
38 2011). Many studies indicate that the UHI will decrease or at least stay constant in the future (Oleson et al., 2012).
39 In London, urban heat islands were observed with recorded night-time temperatures up to 7°C higher in central
40 London than in Wisley, a rural location 32 km to the southwest (Wilby, 2007). Although small urban centres may
41 also experience the UHI, the extent of urban-rural temperature different are not linearly related to urban population
42 size (Smith and Levermore, 2008). Studies have also linked the extent and expansion of urbanization with past UHI
43 trends, urban heating, current variability, and projected climate change. Recent studies with physically based models
44 such as Oleson (2012) and McCarthy et al. (2010) show mixed signals with reductions in UHI in many areas of the
45 world and increases in some areas in response to climate change simulations. McCarthy et al. (2011) looks
46 specifically at London and Manchester and does not find an increase in UHI in the 2050s.

48 Future projections of UHI under global warming conditions were conducted for Tokyo. The air temperature of
49 Tokyo in August is projected to increase about 2°C by the 2070s according to an average of 5 GCMs under the
50 SRES A1b scenario (the range of uncertainty in GCMs is about 2°C). Another warming of about 0.5°C is projected
51 due to the maximum possible land-use change. As a result, total UHI intensity is projected to increase from 1.5°C to
52 2.0°C through the 2070s (Adachi et al., 2012).

1 London's annual number of nights with heat islands stronger than 4°C has increased by 4 days/decade since the late
2 1950s; meanwhile, the average nocturnal heat island intensity rose by just ~0.1°C/decade over the same period
3 (Wilby, 2007). Projections suggest that by 2050, London's nocturnal UHI in August could rise another 0.5°C,
4 representing a 40 percent increase in the number of nights with intense UHI episodes (*ibid*). For New York City,
5 climate change is expected to exacerbate the existing UHI conditions via increase of extended heat waves
6 (Rosenzweig et al., 2009).

7
8 For cities in India, connections between urbanization and the development of UHI, and the implications with future
9 climate have been defined (Mohan et al., 2011a; 2011b; 2012). Overall, there is evidence that a current trend of
10 increasingly frequent extreme events will increase with climate change (Manton, 2010). The inter-comparison of the
11 annual mean minimum temperatures of two stations within Delhi (Safdarjung and Palam) post 1970's onwards show
12 that night time temperature trends are synchronized with the city's pace of urban expansion (Mohan et al., 2011b).

13 14 15 8.2.3.3. *Drought and Water Scarcity: Means and Extremes*

16
17 Drought can cause many impacts in urban areas, including increases in food prices and food insecurity because of
18 reduced supply, water shortages, electricity power shortages for urban areas that depend mostly on hydropower and
19 an increase in water related diseases; these may also lead to a wide set of economic impacts as well as increased
20 rural to urban migration (Farley et al., 2011; Herrfahrtd-Pahle, 2010; Vairavamoorthy et al., 2008). Averaging across
21 all climate changescenarios, recent findings suggest that nearly 100 million more city-dwellers "will live under
22 perennial water shortage under climate change conditions than under current climate" (McDonald et al., 2011:2).
23 The study also notes the role of demographic growth: The model results show that currently 150 million people live
24 in cities with perennial water shortage, defined as having less than 100 L per person per day of sustainable surface
25 and groundwater flow within their urban extent" and by 2050, this figure could increase to almost 1 billion (*ibid.*).
26 Drought and water scarcity also affect cities in high-income countries. A detailed economy-wide, 70-industry
27 analysis of the economic impacts of climate change on water availability in the USA for 2010 through 2050
28 highlighted the interacting industry-level effects, employment impacts, consequences to personal income, and
29 ramifications for the U.S. Gross Domestic Product (GDP). When compared to a baseline economic forecast, the
30 calculations produced an average risk of damage of \$1 trillion to the U.S. economy from climate change over the 40
31 years, with losses in employment equivalent to nearly 7 million full-time jobs (Backus et al., 2012).

32 33 34 8.2.3.4. *Coastal Flooding, Sea Level Rise, and Storm Surge*

35
36 Sea-level rise represents one of the primary shifts in urban climate change risks, given the increasing concentration
37 of urban populations in coastal locations and within low-elevation zones (McGranahan et al., 2007). Rising sea
38 levels, the associated coastal and riverbank erosion, or flooding in conjunction with storm surge could all lead to
39 widespread impacts on populations, property and coastal vegetation and ecosystems, and threats to commerce,
40 business, and livelihoods (Nicholls 2004, Hanson et al., 2011; Carbognin et al., 2010; Pavri et al., 2010; El Banna
41 and Frihy, 2009; Zanchetting, 2007; Dossou and Glehouenou-Dossou, 2009). It is the lowland areas in coastal cities
42 such as Lagos, Mombasa, or Mumbai that are usually more at risk of flooding, especially if a city also has less
43 provisions for drainage (Adelekan, 2010; Awuor et al., 2008; Revi, 2009). Structures constructed on infilled soils in
44 the lowlands of Lagos, Mumbai and Shanghai are more exposed to risks of flood hazards than similar structures
45 built on consolidated materials (*ibid.*). Many coastal cities have sites at risk from both riverine and coastal storm
46 surge (Mehrotra et al., 2011a).

47
48 Cities with extensive port facilities and large scale petro-chemical and energy related industries are vulnerable to
49 climate change's increased flooding potential. Hanson et al. (2011) estimate the change in flooding, by the 2070s in
50 the exposure of large port cities to coastal flooding with scenarios of socio-economic growth, sea level rise and
51 heightened storm surge, and subsidence. They find that population at risk could more than triple while asset
52 exposure is expected to increase more than ten-fold with a 0.5 meter rise in sea-level. The study identifies the "top-
53 20" cities for both population and asset exposure to coastal flooding. The high risk cities in both the current and
54 2070 rankings are spread across low, middle, and high-income nations, but are concentrated in Asian deltaic cities.

1 The cities include: Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, New York, Osaka-Kobe,
2 Alexandria, Tokyo, Tianjin, Bangkok, Dhaka, and Hai Phong. Using asset exposure as the metric, cities in high-
3 income nations and in China figure prominently - Miami, New York City, Tokyo and New Orleans as well as
4 Guangzhou, Shanghai and Tianjin. These analyses which highlight the large number of assets and population which
5 will be exposed and vulnerable underscores the need for long-term urban risk reduction measures.
6
7

8 *8.2.3.5. Inland Flooding and Hydrological and Geo-Hydrological Hazards at Urban Scale*

9

10 The exposure to climate related hazards will vary due to differences in the geomorphologic characteristics of the city
11 (Luino and Castaldini, 2010). Heavy rainfall and storms surges would impact urban areas through flooding which in
12 turn could lead to the destruction of properties and public infrastructure, contamination of water sources, water
13 logging, loss of business and livelihood options and increase in water borne and water-related diseases as noted in
14 wide range of studies (Revi, 2007; Dossou and Glehouenou-Dossou, 2007; Kovats and Akhtar, 2008; Sharma and
15 Tomar, 2010; Adelekan, 2010; Hardoy and Pandiella, 2009; de Sherbinin et. al., 2007; Douglas et al., 2008; Roberts,
16 2008; Nie et al., 2009; Shepherd et al., 2011). Case studies of inland cities have considered the elevated risk of
17 flooding due to climate change, such as in Kampala (Lwasa, 2010; Lwasa, 2013) and travel disruptions in Portland
18 (Chang et al., 2010). Significant research focus has been on attempts to improve modeling of the frequency and
19 condition of extreme precipitation events and resulting flooding (Ranger et al., 2011; Onof and Arnbjerg-Nielsen,
20 2009; Nelson et al., 2009; Olsson et al., 2009; Sen, 2009).
21
22

23 *8.2.3.6. Air Pollution: Means and Extremes*

24

25 Climate change is associated with implications for urban air quality (Athassiadou et al., 2010), air pollution, and
26 health policy (see Chapter 11 of WGI AR5 for more discussion). Urban air quality in most cities already is
27 compromised by localized air pollution from industry and transportation, and often commercial and residential
28 sources. Air quality can be adversely affected by limited ventilation within and around structures. Emerging
29 literature on climate change and air quality shows that there is strong evidence that climate change would generally
30 increase ozone in the US and Europe, but that the pattern of that change is not clear, with some areas increasing and
31 some decreasing. The effects on particulate matter (PM) are also unclear, as are the effects on ozone and PM outside
32 of the US and Europe. Effects on particular urban areas are highly uncertain and may include increases and
33 decreases of certain pollutants (Weaver, 2009; Jacob and Winner, 2009).
34
35

36 *8.2.3.7. Emerging Human Health, Disease, and Epidemiology Issues in Cities*

37

38 Good evidence exists that temperature extremes (heat and cold) affect health, particularly mortality (see 11.2.2). The
39 impacts vary by setting, but populations in urban areas appear more sensitive to heat effects than rural areas in
40 temperate zone countries. Since AR4, there have been more studies on urban populations in low and middle income
41 countries (see for instance Burkart et al 2011 for urban populations in Bangladesh and Egondi et al 2012 for children
42 and non-communicable disease deaths in Nairobi's informal settlements). Heat waves are known to have significant
43 impacts on health that can be exacerbated by drought conditions or high humidity. Studies in high-income countries
44 suggest a greater vulnerability among the elderly to heat-related mortality (see Åström et al 2011 for a review of
45 this). In urban settings where child mortality is high, high and low temperatures have been shown to have an impact
46 on mortality (e.g. Egondi et al. 2012). Furthermore, some occupations are more at risk as they are exposed to higher
47 temperatures for long durations and low-income households are more at risk when heat waves disrupt or limit
48 income-earning opportunities (Kovats and Akhtar 2008) (see also 11.2.7 for more detailed discussion of
49 occupational heat stress).
50

51 WHO (2012) notes that climate change may affect the future social and environmental determinants of health,
52 including clean air, safe drinking water, sufficient food and secure shelter. All these are relevant to urban areas.
53 Increased risks from water scarcity, heat waves and flooding were discussed ready. The incidence of asthma
54 exacerbation may be affected by any climate-change related increases in ground level ozone exposures (Barata et al.,

1 2011; O'Neill and Ebi, 2009; Reid et al., 2009; Gamble, 2009b; Kinney, 2008); other pollutants may also be affected
2 particularly in those cities with PM10 and ozone levels far above WHO guidelines (WHO 2011b). Climate change
3 may affect the distribution, quantity, and quality of pollen in urban areas, as well as altering the timing and duration
4 of pollen seasons. WHO (2012) also noted that diarrhoeal diseases, malnutrition, malaria and dengue are climate-
5 sensitive and in the absence of appropriate adaptation responses, could be adversely affected by climate change (see
6 chapter 11).

9 **8.2.4. Urban Sectors: Exposure and Sensitivity**

11 This section assesses how the observed and forecasted direct impacts of climate change influence the exposure of
12 city residents, infrastructure, and systems to risk by considering key affected sectors and populations and possible
13 interrelations. Direct impacts include all costs and losses attributed to the impact of hazard events, but exclude
14 systemic impacts for example on urban economies through price fluctuations following disaster or the impact of
15 disaster losses on production chains (see UN-ECLAC 1991). Both the temporal and spatial scale of the shifts in
16 climate risk across cities and urbanizing sites in the next few decades are considered. In addition, we analyze how
17 the scale and character of risks change and grow in cities as shifts in climate extremes, means and long-term trends
18 (e.g. sea-level rise) take place.

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

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

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

1 Recent assessments have projected the rising population and asset exposure in large port cities (see 8.2.3.4; also
2 Hanson et al.,2011; Munich Re, 2004), alongside case studies in Copenhagen (Hallegatte et al.,2011) and Mumbai
3 (Ranger et al.,2011). By 2070, the exposed assets in cities such as Ningbo (China), Dhaka (Bangladesh) and Kolkata
4 (India) may increase by more than 60-fold (Hanson et al., 2011).

7 8.2.4.1. Water Supply, Wastewater, and Sanitation

8
9 Water and sanitation systems strongly shape household well-being and health, while exerting a wider influence upon
10 urban economic activities, energy demands and the rural-urban water balance(Gober, 2010). Climate change will
11 impact residential water demand and supply and its management (O’Hara and Georgakakos, 2008).Among the
12 projected impacts of climate change on water are: altered precipitation and runoff patterns in cities, sea level rise and
13 resulting saline ingress, constraints in water availability and quality, and heightened uncertainty in the assumptions
14 that underpin long-term planning and investment in water and waste water systems (Muller, 2007; Fane and Turner,
15 2010; Major et al., 2011).Local government departments and water utilities responsible for water supply and waste
16 water management must confront these new climatic patterns and major uncertainties in availabilities and learn to
17 respond to a dynamics and evolving sets of constraints (Milly et al.,2008).

18
19 Climate change will increase the risk and vulnerability of urban populations to groundwater and aquifer quality
20 reduction (e.g. Praskievicz and Chang, 2009; Taylor and Stefan, 2009) and subsidence and increased salinity
21 intrusion. High levels of groundwater extraction have led to serious problems of subsidence in cities such as
22 Bangkok (Babel et al 2006) and Mexico City (Romero-Lankao 2010) that damages buildings and fractures pipes and
23 can increase flood risks (see also Jha et al., 2012). This problem can be compounded in coastal cities when saline
24 intrusion reduces ground water quality and erodes structures.

25
26 In many rapidlydeveloping cities, climate change’s impacts on water supplies will interact with growing population,
27 growing demand and economic pressures. This will potentially heighten water stress and increase negative impacts
28 on the natural resource base with impacts on water quality and quantity. Caribbean nations are urbanising with an
29 expanding middle class. This is sharply raising the demand for water and increasing the associated challenges of
30 managing runoff, storm water, and solid wastes (Cashmanet al., 2010). Aggravating such water stresses, climate
31 change could significantly reduce rainfall levels especially during the Caribbean’s crucial rainy season (*ibid.*).

32
33 In Shanghai, climate change is expected to bring decreased water availability, as well as flooding, groundwater
34 salinization and coastal subsidence. The city’s population of 17 million is projected to continue expanding, often
35 within areas that are “likely increasingly flood-prone” (de Sherbinin et al. 2007: 60). Groundwater depletion has
36 contributed to land subsidence in these already vulnerable areas, reinforcing the water stresses and risks of erosion,
37 but Shanghai’s wealth and correspondingly greater adaptive capacity may help to manage these complex risks
38 (*ibid.*). In several large Andean cities, declining volumes of glacial melt water and expected further declines have
39 been observed for several cities (Chevallier et al. 2011; Buytaert et al. 2010).

40
41 Several studies estimate how climate change will alter the relationship among water users and the implied tensions
42 over the supply and the demand for water (Tidwell et al., 2011; Roy et al., 2012). Large-scale critical infrastructure
43 such as sanitation systems for cities (e.g. Cape Town – Ziervogel et al., 2010) may also be affected. In small and
44 mid-sized African cities, threats from floods on drinking water quality taken fromwells, is a growing concern (Cisse
45 et al., 2010).

46
47 Water shortages will exacerbate existing tensions and conflicts between the various end-uses (residential,
48 commercial, industrial, agricultural, and infrastructural) (Tidwell et al., 2011; Roy et al., 2012).Floods, droughts and
49 heavy rainfall have also impacted agriculture and urban food sources, and climate change can exacerbate food and
50 water scarcity in urban areas (Gasper et al., 2011). Some water systems, under some scenarios and short-term time
51 frames, are not projected to experience negative impacts. For instance, Chicago’s Metropolitan Water Reclamation
52 District (MWRD) found that reduced precipitation due to climate change would decrease pumping and general
53 operations costs, since sewers will contain less rainwater in drier seasons (Hayhoe et al.,2010).

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

22 8.2.4.2. *Energy Supply*

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

33 Past experiences with power outages indicate some of the knock-on effects (Chang et al., 2007). New York City’s
34 blackout of 2003 lasted 28 hours and halted electricity, mass transport, surface vehicles due to signalling outages,
35 “and water supply for a much longer period” (Rosenzweig and Solecki, 2010). Low-income households in
36 Chittagong utilize candles or kerosene lamps during the city’s frequent power outages, which were found to disturb
37 children’s studies, increase expenses, and overheat homes (Rahman et al., 2010). A review of climate change
38 impacts on the electricity sector (Mideksa and Kallbekken, 2010) projects reductions in the efficiency of cooling for
39 thermal power, changes in hydropower and wind power potential, and changing demand for heating or cooling in the
40 US and Europe.

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

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

1 summertime electricity demand from climate change will exceed reductions in winter energy demand reductions
2 (Hammer et al., 2011).

3
4 Many cities' economies will be impacted if climate change induces water scarcity and variability that interrupt
5 hydropower supplies. If climate change reduces Brazil's hydroelectric generation, this will have negative impacts on
6 the economies of the many urban centres supplied in Brazil as well as across national to neighboring
7 counties (Lucena et al., 2009; Lucena 2010; Schaeffer et al., 2009). Cities in sub-Saharan Africa often rely on
8 hydropower for their electricity, and failures in hydropower supplies "can lead to a more general 'urban failure' "
9 (Muller, 2007). Discussing supply side concerns, Laube et al. (2006) identify water shortages in Ghana following
10 low precipitation periods and competition with hydropower between energy and water provision including to
11 downstream urban centres as a possible impact. Declining water levels in the Hoover Dam have raised the
12 possibility that Los Angeles will lose "a major power source as hydroelectric turbines shut down," and that Las
13 Vegas will experience a severe decline in drinking water availability (Gober, 2010).

14
15 Summer heat waves are associated with spikes in demand with extensive use of air conditioning, resulting in
16 brownouts or blackouts (Mideksa and Kallbekken, 2010; Mirasgedis et al., 2007). Cities in the temperate regions of
17 Australia are already experiencing regular blackouts on hot summer days, largely due to increased residential air-
18 conditioner use (Maller and Strengers, 2011). Research in Boston (Kirshen et al., 2008) suggested that rising energy
19 demands in Boston's hotter summers have a "disproportional impact on (the) elderly and poor, increased energy
20 expenditures; loss of productivity and quality of life" (*ibid*:241). Any increase in the frequency or intensity of
21 storms may disrupt electricity distribution systems because of the collapse of power lines and other infrastructure
22 (see for instance Rosenzweig et al., 2011a; 2011b; 2011c; see also Chapter 10).

23 24 25 8.2.4.3. *Transportation and Telecommunications*

26
27 Climate change related extreme events will affect transportation and telecommunication infrastructure including a
28 variety of capital stock in urban areas such as bridges, roads, railways, pipelines, and port facilities, data sensors,
29 and wire and wireless networks (Major et al., 2011; Jacob et al., 2011; Hallegatte et al., 2011; Koetse and Rietveld,
30 2009). Assessing possible disruptions of transport networks within cities and urban systems is critical. Loss of
31 telecommunication access during extreme weather events can inhibit disaster response and recovery efforts because
32 of its critical role in providing logistical support for such activity (Jacob et al., 2011).

33
34 The literature on transport and climate change focuses more on mitigation, with limited attention within the urban
35 literature to adaptation (Hunt and Watkiss, 2011). Existing studies on climate change impacts are often limited to the
36 short term demand side, particularly in passenger transport (Koetse and Rietveld, 2009). However climate change
37 creates several challenges for transport systems. The daily functioning of most transport systems is already sensitive
38 to weather fluctuations including extreme precipitation, temperature, winds, visibility, and for coastal cities, rising
39 sea levels with the associated risks of flooding and damages (Mehrotra et al., 2011b; Love et al., 2010). Transport is
40 thus highly vulnerable to climate variability and change, and the economic importance of transport systems has
41 increased with the rise of just-in-time delivery methods, heightening the risk of losses due to extreme weather
42 (Gasper et al., 2010). In addition to adapting road transport, it will be necessary to ensure bridges, railway cuttings,
43 and other hard infrastructure are resilient to climate change over their service lifespan (Jaroszowski et al., 2010). For
44 railways, few studies have examined the effects of climate change but weather-related rail system failures may be
45 caused by high temperatures, icing, and storms (Koetse and Rietveld, 2009; see also Dobney et al 2010 for future
46 heat related delays in UK railways). Very few studies have examined the vulnerability of air and seaborne transport
47 and infrastructure. The impacts of climate change could translate into a greater number and longevity of weather-
48 related delays with extreme weather possibly occurring more frequently and more severely. This would bring further
49 disruptions for aviation (Eurocontrol, 2008) and maritime transport (Becker et al., 2012).

50
51 Most cities in low and middle-income nations are still developing their transport systems (Dimitriou and
52 Gakenheimer, 2011), especially in their larger and more rapidly growing cities. For example, Asian cities and the
53 transportation networks located within and around them are often at risk from extreme weather events (Regmi and
54 Hanaoka, 2011). India's transportation and telecommunications networks are still being built, and adaptation as well

1 as mitigation measures “will need to be integrated within the design of these systems” (Revi, 2009: 329) to
2 maximise co-benefits and synergies and minimise trade-offs (Biesbroek et al., 2009; Hamin and Gurrán, 2008).

3
4 Loss of sea ice can benefit some cities as it increases opportunities for developing road networks or ports, although
5 it may be costly to adapt the road, air and water transport networks in addition to the known environmental risks
6 associated with such redevelopment (Larsen et al., 2008). For industries and communities in Northern Canada,
7 reduced freshwater-ice levels creates economic benefits such as longer shipping seasons (Prowse et al., 2009). Lost
8 sea ice could also promote new seaports in marine environments, but inland towns require sizable investments in
9 land-based roads to replace winter ice roads that formerly utilised small lakes and stream networks (ibid.). Thawing
10 of permafrost can result in instability and major damage to roads, infrastructure, and buildings in and around
11 northern cities and towns (ibid.).

12
13 The direct impacts of extreme weather on transport are often more easily assessed than the indirect impacts or
14 possible knock-on effects between systems. Studies have often examined the direct impacts of flooding upon
15 transport infrastructure, but the indirect costs of delays, detours, and trip cancellation “may also be substantial”
16 (Koetse and Rietveld, 2009). During Mumbai’s 2005 floods, there were serious direct impacts in terms of injuries,
17 deaths and property damage but also serious indirect impacts as most city services were shut down for 5 days
18 without contact via rail, road or air (Revi, 2005). Transport and other urban infrastructure networks are often
19 interdependent and located in close physical proximity to one another (Kirshen et al., 2008). Yet only a few
20 assessments have jointly considered the impacts upon transport and other associated sectors (Hayhoe et al., 2010 for
21 Chicago, Kirshen et al., 2008 for Boston). Implementing adaptation strategies in the transport sector requires
22 “coordination at national, regional, and local levels”, since climate change impacts are widespread and extend across
23 scales (Regmi and Hanaoka, 2011).

24
25 Transportation systems are critical for effective disaster response – for example, where there is an urgent need for
26 evacuating populations prior to an approaching storm or where disaster response requires an urgent need to ensure
27 provision for food, water and emergency services to affected populations.

30 8.2.4.4. *Built Environment, and Recreation and Heritage Sites*

31
32 Good quality housing should provide its occupants with a comfortable, healthy and secure living environment and
33 protect them from injuries, losses and damage (Haines et al. 2013). For many low-income households, home-based
34 enterprises are also important components of livelihoods. As such, housing has a key role in protecting urban
35 populations and their assets – and has particular importance for protecting vulnerable groups including infants and
36 young children (Bartlett 2008), older residents or those with disabilities or chronic health conditions. This also
37 means protection against displacement since low-income urban dwellers are particularly at risk from disruptions to
38 household income.

39
40 Urban housing is “often the major part of the infrastructure affected (by disasters)...” (Jacobs and Williams,
41 2011:176). Extreme events like cyclones and floods inflict a heavy toll on housing, particularly those structures built
42 with informal building materials and built outside of safety standards (United Nations, 2011). Dhaka’s 1998 floods
43 damaged 30% of the city’s units and of these, 32% were permanent/semi-permanent homes belonging to wealthier
44 households, but 36% were lower-quality owned by the lower-middle classes and 32% by the poorest (Alam and
45 Rabbani, 2007). Adelekan (2012) shows how a relatively modest increase in wind speeds during storms caused
46 widespread damage and high costs of rebuilding or repairs in central Ibadan. In addition, increased climate
47 variability, warmer temperatures, precipitation shifts, and increased humidity will accelerate the deterioration and
48 weathering of many stone and metal structures in cities (Stewart et al., 2011; Bonazza et al., 2009; Smith et al.,
49 2008; Thornbush and Viles, 2007; Grossi et al., 2007).

50
51 Recreational sites such as parks and playgrounds will also be affected. In New York City, recreational sites are
52 defined as critical infrastructure and often located in low elevation areas subject to storm surge flooding
53 (Rosenzweig and Solecki, 2010). Although climate change may have significant impacts on traditional tourist
54 destinations, little research has examined the effects upon urban tourism in particular (Gasper et al., 2011).

1
2 The increased risks that climate change is bringing to the built environment (Wilby, 2007; Spennemann and Look,
3 1998) also means risks to the built heritage. This has led to the Venice Declaration on Building Resilience at the
4 Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies which brings together
5 UNESCO, UN-HABITAT, EC and individual city mayors. One example of this is Saint-Louis in Senegal, a coastal
6 city that is also on the mouth of the Senegal river that has frequent floods and large areas at risk from river and
7 coastal flooding. It is a World Heritage Site and there are initiatives to reduce flooding risks and to relocate families
8 from locations most at risk but the local authority has very limited investment capacity (Diagne 2007, Silver et al.,
9 2013).

10 11 12 8.2.4.5. *Green Infrastructure and Ecosystem-based Adaptation* 13

14 A wide variety of ecosystem services and green infrastructure will be impacted by climate change. Climate change
15 will alter ecosystem functions such as temperature and precipitation regimes, evaporation, humidity, soil moisture
16 levels, vegetation growth rates (and allergen levels), water tables and aquifer levels, and air quality. These can
17 influence the effectiveness of pervious surfaces used in storm water management, green/white/blue roofs, coastal
18 marshes utilized for flood protection, food and urban agriculture and overall biomass production. Mombasa will
19 experience more variable rainfall as a result of climate change, making initiating and expanding green infrastructure
20 more difficult (Kithiia and Lyth, 2011). Trees in British cities will be increasingly prone to heat stress and to attacks
21 by pests, including non-native pathogens and pests that could survive for the first time under warmer or wetter
22 conditions (Tubby and Webber, 2010). Urban coastal wetlands will be inundated with sea level rise. In New York
23 City, remnant coastal wetlands will be lost to sea-level rise because the wetlands will not be able to migrate inland
24 due to bulk heading and intensive coastal development (Rosenzweig et al., 2012).
25
26

27 8.2.4.6. *Health and Social Services* 28

29 The effects of climate change will also be evident across several urban social and public services such as health and
30 social care provision, education, police and emergency services including firefighting and ambulances (see Health,
31 Chapter 11 in this volume for more discussion). Many low and middle-income cities lack adequate social and public
32 service provision (Bartlett, 2008; Satterthwaite et al., 2007) while higher-income cities are only beginning to consider
33 climate change in their health or disaster management plans (Brody et al., 2010). Although there are few studies on
34 adapting education, police, or other key services, a growing public health literature has discussed multi-sectoral
35 adaptation strategies (Huang et al., 2011). Cities' existing public health measures provide a foundation for adapting
36 to climate change, such as heat warning systems or disease surveillance (Bedsworth, 2009; McMichael et al., 2008).
37 Negative climate impacts on some of the most vulnerable in society— the very young and children (Sheffield and
38 Landrigan, 2011; Watt and Chamberlain, 2011; Ebi and Paulson, 2010) the elderly (Oven, 2012; White-Newsome et
39 al., 2011) and the severely disadvantaged (Kenny et al., 2010; Ramin and Svoboda, 2009) have been highlighted
40 (see Chapter 11)
41
42

43 8.2.5. *Urban Transition to Resilience and Sustainability* 44

45 The question of how to promote increased resilience and enhanced sustainability in urban areas (as illustrated in
46 Table 8-2) has become a central research topic and policy consideration. What information is needed and what steps
47 should be taken to promote this type of transition are central to this discussion. It is well recognized that climate
48 change risks affect this process by heightening uncertainties and altering longstanding patterns of environmental
49 risks in cities, many of which continue to face other significant stressors such as rapid population growth, increased
50 pollution, resource demands, and concentrated poverty (Mehrotra et al., 2011a; Wilbanks and Kates, 2010). This
51 section discusses how climate change increasingly affects municipal decision-making frames and alters local
52 conceptions of cities as vehicles for economic growth, for political change, for meeting livelihoods and basic needs
53 as well as larger-scale goals of resilience and sustainability.
54

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' repositories around 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). Conversely Jakarta has several early-warning disaster systems in place but no adaptation plans have been developed; Jakarta's Spatial Plan does not incorporate climate change and the local government's focus is on disaster management rather than preparing for climate change (Firmana et al., 2011).

Urban decision-makers have widely divergent motivations and strategies for incorporating extreme events into local adaptation plans. Cities have implemented adaptation measures in response to "specific local or regional natural disasters, which may or may not be climate-related", such as enhancing preparedness measures in the Greater Mumbai Disaster Management Plan after the City's 2005 floods (Revi, 2006; Bulkeley 2010,). 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 context of climate change emerge in two situations. The first is a systems-level perspective where urban systems could reach a tipping point in which a failure or collapse could occur. The second is a broader scale societal transition to enhanced resilience and adaptive capacity (and attention to mitigation) in the face of accelerated climate change (Solecki and Murphy, 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 human security (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,

1 and international funding agencies is needed (Braman et al., 2010). Holistic strategies help to link development
2 goals with adaptation, so that “multi-dimensional and multi-scale approaches (can) better guide the construction of
3 adaptation responses to climate change and integrate them to development strategies” (Sánchez-Rodriguez, 2009).
4

5 Climate change also creates implications for equity from different management solutions (Pelling et al, 2012). For
6 example, the privatization of urban water supply and sanitation systems advantages specific groups over others.
7 Conversely, community-based solutions that also build social capital can be a component in generating generic
8 urban resilience. However, these may exacerbate inequality at the city level with those local areas with strong levels
9 of social capital being able to benefit most from local community led action or support for local initiatives from
10 international and national partners (UN Habitat 2007; Pelling et al, 2012).
11

12 13 8.2.5.5. *Historical Analogues* 14

15 The experience of cities in coping with environmental/resource crises in the past provides a useful analog to
16 understand climate change impacts and shifts in urbanization process (Solecki, 2012; Ranger et al., 2011; Ford et al.,
17 2010; McLeman and Hunter, 2010; Hallegate et al., 2007; Gibbons et al., 2006). Cities often have been able to
18 respond to localized risks and vulnerabilities such as resource shortages and environmental quality issues by
19 externalizing the problems either through expansion of the resource catchment or by externalising the environmental
20 quality threats (e.g. sewerage, rubbish) to more remote and distant locations (McGranahan, 2007; Tarr, 1997). This
21 is more complex in the case of climate change in that the source of the risk and vulnerability is external to individual
22 cities and outside their span of control. City governments have dealt with many environmental health problems by
23 reducing or removing the hazard, but this is beyond their capacities to accomplish with respect to climate change.
24

25 Urban development and urbanization has been dramatically impacted by past changes associated with large scale
26 exogenous factors which have either been pervasive (e.g. globalization) and/or profound e.g. wartime devastation,
27 civil war and natural hazards such as earthquakes, cyclones, as well as the application of new technologies (e.g.,
28 automobiles, electricity, the internet). Identity is particularly important in this context because the physical fabric
29 can be rebuilt, but in so-doing the identity of a city may be changed. In these situations,, it is evident that well-
30 governed cities demonstrate a capacity to adapt and to learn from crises (Solecki, 2012). As described in 8.3, there is
31 increasing evidence of policy, practice and scientific interest in urban adaptation as a core strategy to address
32 climate change risks.
33

34 35 **8.3. Adapting Urban Areas** 36

37 **8.3.1. Introduction** 38

39 The literature on urban climate change adaptation has increased very significantly since the Fourth Assessment (AR
40 4). The growing interest in urban adaptation is mainly evident in three aspects. The first is a literature examining
41 risks and vulnerabilities for particular cities. The second, overlapping with this, are papers discussing what might
42 constitute resilience. The third is documentation produced by or for particular city governments on adaptation. There
43 is less documentation of local government decisions to include climate change adaptation in plans and investment
44 programmes, although some city governments report on this (see Solecki 2012, Roberts 2008a and 2010).
45

46 Planning urban climate change adaptation faces uncertainties about the magnitude and location of present and future
47 hazard risk and vulnerability at the urban scale as most climate models function at a lower resolution than most
48 cities. The availability of relevant risk data continues to be challenging as it is often not collected. Or if it is, it is
49 rarely quantitative or at the appropriate scale and often fragmented across city departments (Hardoy and Pandiella
50 2009). Many suggested adaptation measures are in response to specific local or regional hazard risks, which may not
51 be directly climate-related (Bulkeley 2010). Climate data needs to be integrated geographically, across time-scales,
52 and consider the range of regional benefits and costs of climate policy if it is to be useful to and spark local dialogue
53 in adaptation (Ruth 2010).
54

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

12 8.3.2. *Development Plans and Pathways*

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

24 8.3.2.1. *Adaptation and Development Planning*

26 Urban adaptation is becoming important for some national, regional and city governments although the first steps
27 may have come from stakeholders outside the state sector. In high-income countries, interactions between national
28 climate policies and local level and the division of responsibilities have been examined (see, for instance, Massetti et
29 al 2007 for Italy). There is also attention to local adaptation implementation through subsidies and flexible schemes
30 in different city contexts and the transfer of authority and resources to city level (for the Netherlands see Gupta et al.
31 2007). The design of new decision making strategies for local governments considers the complexity and dynamics
32 of evolving social-ecological systems (Kennedy et al. 2010). Examples include adaptation plans and local responses
33 in Sydney to cope with sea level rise and storms (Hebert and Taplin 2006) and adaptation planning in California
34 (Bedsworth and Hanak 2010). In China, adaptation programmes are being developed and implemented at national
35 and local level. The debate emphasizes the policy space and the division of responsibility between national and local
36 levels (Teng and Gu. 2007).

38 Since AR4, there has been a growing literature on urban adaptation in low and middle-income nations. A review of
39 the literature on climate change impacts and adaptation in cities (Hunt and Watkiss 2011) could draw on eight case
40 studies in Asia, five in Africa and four in South America – as well as from case studies from Europe, Northern
41 America and Australasia. Among the papers and books considering climate change adaptation in urban areas since
42 2007 are those on Cape Town (Mukheibir and Ziervogel 2007, Ziervogel et al 2010 and Cartwright et al 2012),
43 Durban (Roberts 2008a, 2010, Roberts et al 2012, Cartwright et al 2013 and Roberts and O'Donoghue 2013) and
44 other urban centres in Africa (Douglas et al., 2008, Wanget al 2009, Lwasa 2010, World Bank 2011, Kithiia and
45 Lyth 2011, Adelekan 2012, Kiunsi 2013, Castán Broto et al 2013, Silver et al 2013), urban centres in Bangladesh
46 (Alam and Rabbani 2007, Jabeen et al 2010, Banks et al 2011, Haque et al 2012, Roy et al 2013), India (Revi
47 2008, Sharma and Tomar 2010, Saroch et al 2011), Latin America (Hardoy and Pandiella 2007, Romero Lankao
48 2007, 2010, Hardoy and Romero Lankao 2011, Luque et al 2012, Hardoy 2013, Hardoy and Ruete 2013). Other
49 papers or books with discussions of urban adaptation in low- and middle nations include Blanco 2007, Carolini
50 2007, Martine et al. 2007, McGranahan et al. 2007, de Sherbinin et al. 2007, UN-Habitat 2007, United Nations
51 Population Fund 2007, Agrawala and van Aalst 2008, Bartlett 2008, Ayers 2009, Bicknell et al. 2009, Kovats and
52 Akhtar 2008, Tanner et al., 2009, Hardoy and Pandiella 2009, Wong 2009, World Bank 2010b, 2010c, 2011,
53 Manuel-Navarrete et al. 2011, UN-Habitat 2011a, Rosenzweig et al 2011a, Moench et al 2011 and Bulkeley and Tuts
54 2013. Four relevant issues can be highlighted: the fact that these nations have most of the world's current and future

1 urban population; the need to consider key development issues of poverty and social inequality as multidimensional
2 problems that may be aggravated by climate change; the need to consider human agency among low-income
3 inhabitants and their organizations as an important resource in building local responses to climate change; and the
4 relevance of well-functioning multilevel governance in developing adaptation strategies (Sánchez-Rodríguez 2009).
5

6 Although few publications suggest specific operational strategies, they stress the importance of the linkage between
7 climate adaptation and development. We noted already how development deficits in urban areas can contribute to
8 adaptation deficits. Manuel-Navarrete et al. (2011) explores the interplay between visions of development,
9 governance structures and strategies to cope with hurricanes in the Mexican Caribbean where exposure and
10 vulnerability are influenced by political decisions and contingent development paths. Similarly there are few reports
11 on multidimensional approaches to guide operational adaptation. There is growing attention to integrating adaptation
12 with development interventions and addressing structural drivers of social and urban vulnerability – see for instance
13 Climate Action Plans of Mexico City, Cartagena and San Andrés de Tumaco (Sánchez-Rodríguez 2009).
14

15 Two factors help explain the lack of detailed attention to urban climate change adaptation in low- and middle-
16 income nations. The first is the lack of attention to urban adaptation within national policies on climate change in
17 comparison with sectors like agriculture. Responsibility for climate change policies is often with ministries or
18 agencies that have little in their work that is urban and little influence on others whose cooperation is essential e.g.
19 for social policies, public works and local government (Ojima 2009, Roberts 2010, Hardoy and Pandiella 2007).
20 Governments' social policies and priorities influence the social and spatial distribution of climate related risk and
21 vulnerability – for instance provisions for health care, emergency services and safety nets - yet few agencies
22 recognize their potential role in reducing risk and vulnerability. Adaptation in informal settlements and the
23 incorporation of individual and group agency in bottom-up adaptation strategies is of particular relevance in low-
24 income and most middle-income nations (Sánchez-Rodríguez 2009, Bicknell et al 2009). Recent experiences of
25 Central American cities like Tegucigalpa and in some cities in the Philippines show that the involvement of low-
26 income communities in risk reduction may be the first steps towards climate change adaptation (Aragón-Durand
27 2011, Carcellar et al. 2011).
28

29 The second factor explaining the lack of attention to urban adaptation is that the initial focus for many cities was on
30 mitigation, in part because international support was available for this (although this is changing). Local decision-
31 makers frequently view climate change as a marginal issue, with adaptation usually ranked lower than mitigation on
32 the urban policy agenda (Bulkeley 2010, Simon 2010). For instance, Mexico City's climate change agenda focuses
33 on mitigation with adaptation still a vague concept that is not incorporated into concrete actions and decisions (GDF
34 2006, 2008). Adaptation is seen as a capacity to withstand weather-related impacts such as floods through early
35 warning systems rather than comprehensive, long-term measures such as watershed management to reduce the speed
36 and volume of flood waters. There is little academic and policy literature on climate change adaptation for Brazilian
37 cities (Ojima 2009, Soares Moura da Costa 2009). In Sao Paulo, more attention has been given to mitigation with
38 adaptation action limited to broad declarations about needed actions in different sectors even as the city often gets
39 impacted by floods, landslides and water scarcity (Puppin de Oliveira 2009, Nobre et al 2010, Martins and Ferreira
40 2011). The pressure on national and local governments to act is lessened by the absence of public awareness of the
41 importance of addressing climate change adaptation (see Nagy et al. 2007). There is also a “knowledge gap”
42 between policymakers and scientists regarding knowledge needed to enhance adaptation as in the case of Tijuana
43 (see Sanchez-Rodríguez, 2011).
44
45

46 8.3.2.2. *Disaster Risk Reduction and its Contribution to Climate Change Adaptation* 47

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

1
2 Exposure to disaster risk from weather events in expanding urban areas increases when local governments fail to
3 implement their responsibilities, including needed expansion or upgrade in infrastructure and services and risk
4 reduction through implementing building standards and appropriate land-use management (ibid). This is typically in
5 countries with low per capita GDPs and weak local governance (i.e., in the first two categories of Table 8-2). It may
6 be exacerbated by rapid urban population growth.

7
8 The most urbanized nations generally have the lowest mortality to extreme weather events (United Nations 2009).
9 Urbanization accompanied by more capable and accountable local governments can reduce disaster risk as is evident
10 in the declines in mortality from extreme weather (and other) disasters in many middle and all high-income nations
11 (United Nations 2011).

12
13 While local government investment usually represents a small proportion of total investment in and around an urban
14 centre, it has particular importance in risk reduction through investments in risk-reducing infrastructure and public
15 services that need to be combined with planning and regulation that ensures buildings and infrastructure meet
16 needed standards and guide development away from high-risk areas. Urban governments have explicit
17 responsibilities for many assets, some of which may be risk prone. The exact list differs between countries because
18 of different allocations of responsibilities between government levels but it often includes schools, hospitals, clinics,
19 water supplies, sanitation and drainage, communications and local roads and bridges. Where private provision for
20 infrastructure and services is significant, it usually falls to local government to coordinate such provision and hence,
21 enhance its role and responsibility for urban adaptation.

22
23 From the late 1980s, a new approach to reducing disaster risk in urban areas was developed in some Latin American
24 nations that is relevant to climate adaptation. It involved three processes: detailed analyses of local records of
25 disasters that include smaller disaster events than those reported in international databases; recognition that most
26 disasters were the result of local failures to assess and act on risk; and the recognition of the central roles of local
27 governments in disaster risk reduction but with support from national and local civil defence organizations working
28 with civil society and community organizations within the settlements most at risk (United Nations 2009, IFRC
29 2010). These led to institutional and legislative changes at national or regional level to support disaster risk
30 reduction (Gavidia 2006, IFRC 2010). In Colombia, a national law supports disaster risk reduction and a National
31 System for Prevention and Response to Disasters with a shift in the main responsibility for action to municipal
32 administrations. In Nicaragua, the National System for Disaster Prevention, Mitigation and Response (SINAPRED)
33 was set up in 2000 to work with local governments to strengthen disaster preparedness and management by
34 integrating disaster mitigation and risk reduction into local development processes (Von Hesse, et al., 2008). There
35 are other initiatives and action programmes in Central and South America on urban risk management and disaster
36 preparedness, including the influence of La Red (IFRC 2010), the DIPECHO project, “Developing Resilient Cities”
37 and UNDP and GOAL in Central America.

38
39 In growing numbers of cities in Asia (Shaw and Sharma, 2011) and Africa (Pelling and Wisner 2009), experiences
40 with community-driven ‘slum’ or informal settlement upgrading has led to a recognition of the potential of these to
41 reduce risk and deep rooted vulnerability to extreme weather events. This is most effective when supported by local
42 government and civil defence/emergency response agencies (see Boonyabancha 2005 for urban centres in Thailand;
43 also Archer and Boonyabancha 2011, Carcellar et al. 2011).

44
45 The Homeless People’s Federation of the Philippines developed a series of effective responses following major
46 disasters, which included: community-rooted data gathering (assessing the severity and scope of destruction and
47 victims’ immediate needs); trust and contact building; support for savings; the registering of community
48 organizations; and identifying needed interventions, including building materials loans for house repairs. The
49 effectiveness of risk reduction is also much enhanced where local governments work to support these (Carcellar et
50 al. 2011) and experiences such as these have helped inform community-based adaptation (see 8.4).

51
52 There are also international networks supporting innovation in disaster risk reduction and/or climate change
53 adaptation and inter-city learning. These include la Red in Latin America that has been operating for 3 decades
54 (IFRC 2010), the Earthquakes and Megacities project which includes multi-hazard risk assessment and the cities

1 programme of the Asian Disaster Preparedness Centre. As donor interest has grown in supporting disaster risk
2 management as a vehicle for climate change adaptation, a number of resilience oriented urban programmes have
3 developed including the Asian Cities Climate Change Resilience Network (Brown et al. 2012), the UN ISDR
4 Resilient City network (Johnson and Blackburn,2013) ICLEI’s city adaptation network and UN-Habitat’s Cities and
5 Climate Change Initiative.
6

7 Despite growing international support for urban disaster risk management, it can be difficult for local governments
8 to access the human and financial resources needed to make real change on the ground (Von Hesse et al. 2008).
9 Local governments do not get recognition for the disasters their programmes prevented – so risk reduction
10 investments are not seen as priorities and have to compete for scarce resources with what are judged to be more
11 pressing needs. Effective policies are often tied to the terms in office of particular mayors or political parties
12 (Mansilla et al. 2008, Hardoy et al. 2011). In most cases, disaster risk reduction is still not integrated into
13 development plans and not drawing in all relevant departments and divisions of local government. Manizales in
14 Colombia is an exception as disaster risk reduction has long been seen as part of local development and where
15 collective interests overcome individual and party political interests (Hardoy and Velásquez Barreto 2014)
16

17 As detailed in IPCC SREX (2012), disaster risk management is increasingly positioned as a frontline sector for the
18 integration of climate change adaptation into everyday decision-making and practices. This can be seen in the plans
19 of municipalities such as Tegucigalpa and Montevideo (Aragón-Durand 2011). Where disaster risk management is
20 taken seriously by government or civil society this offers real opportunities for synergy as the long-range nature of
21 climate change concerns and its policy visibility can enhance local support for disaster risk management. The still
22 common disjuncture in international frameworks and national responsibilities mean there is much scope for better
23 coordinated efforts to make urban disaster risk management climate smart (SREX 2012, Aragón-Durand 2008).
24
25

26 **8.3.3. Adapting Key Sectors**

27 *8.3.3.1. Adapting the Economic Base of Urban Centres*

28 8.2 described how climate change will bring changes to the comparative advantages of cities and regions – for
29 instance through influencing climate sensitive resources and changes in locations of extreme weather, water
30 availability and flooding risks. Many case studies show how extreme weather and storm surges can impede
31 economic activities such as damaging industrial infrastructure and disrupting coastal ports and supply chains (see
32 8.2.3.4). Vugrin and Turnquist (2012) discuss how to design for resilience in infrastructure distribution networks
33 such as electric power, gas, water, food production and manufacturing supply chains. Increasing the resilience of
34 networks (and settlements) needs absorptive capacity (for instance to withstand extreme weather), adaptive capacity
35 (for instance service provision through alternative paths) and restorative capacity (quick and cheap recovery).
36
37
38

39 The importance of effective climate adaptation is that it can help reduce risks from such changes, deepen resilience
40 and limit disadvantages. For urban centres facing climate-related risks, a failure to adapt may discourage new
41 investments. Over the long term this could lead enterprises moving or expanding to other safer, better adapted
42 locations. Multinational corporations and many national businesses have long been adept at changing the location of
43 their production (and regional headquarters) in response to changing opportunities and risks so they can choose to
44 avoid urban centres facing high risks linked both to climate change and a failure to adapt. Investments in urban
45 centres with higher risks may also be discouraged by high insurance costs,
46

47 Disasters can change perceptions of risk and discourage new investments. For instance, businesses may avoid
48 disaster impacts in their own facilities but find that the disaster has impacted other businesses and services that they
49 use (including utilities) or impacted their workforce and the services they use (including schools, and hospitals)
50 (Hallegatte et al, 2011). A lack of capacity within an urban centre to reconstruct means increased vulnerability to
51 succeeding extreme weather events and less new investment that in turn weakens the urban economic base (Benson
52 and Clay 2004, Hallegatte et al. 2007, Hallegatte et al. 2011).
53

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

7
8 Climate change adaptation is generally cheaper and easier to implement in greenfield sites – for instance as low-risk
9 sites are chosen, trunk infrastructure to appropriate standards installed and building and land-use regulations
10 enforced. Retrofitting existing infrastructure and industries is generally more expensive (McGranahan et al.,2007).

11
12 Within and around urban centres, local governments may need to utilise several strategies to strengthen urban
13 centres' resilience including selective relocation, land use planning to reduce exposure, shifting development from
14 floodplains, and revised building regulations to retrofit or flood-proof structures (Hanson *et al.* 2011). There are also
15 synergies to be encouraged in peri-urban or nearby rural areas where land-use management around a city supports
16 rural livelihoods (and where appropriate urban agriculture and forestry) and protects ecosystem services (see
17 8.3.3.7). There may be opportunities for proactive adaptation outside larger cities where much of the future urban
18 growth will occur. For instance, in Manizales, Colombia, local government has begun incorporating climate change
19 and environmental management into its local development agenda, including the establishment of city climate
20 monitoring systems, although this is a city that has long had innovative environmental and disaster risk reduction
21 policies (Hardoy and Velásquez Barreto 2014). However, smaller urban centres are often institutionally weaker and
22 lack investment capacity and critical infrastructure.

23
24 Adapting the urban economic base may require short- and long-term strategies to assist vulnerable sectors and
25 households. The consequences of climate change for urban livelihoods may be particularly profound for low-income
26 households who generally lack assets or insurance to help them cope with shocks (Moser and Satterthwaite 2008).
27 For most urban centres, the informal sector is a significant part of its economy and provides employment for large
28 sections of the population. But the effects of extreme weather on the informal economy are rarely considered as in
29 the case of 2003 floods in Santa Fe, Argentina (Hardoy and Pandiella 2009). One example where it was considered
30 was in Kelurahan Pabean Pekalongan in Central Java where batik production provides livelihoods for three quarters
31 of adults and this is disrupted by floods that residents suggest are becoming increasingly frequent (UN-Habitat
32 2011b). Cash transfers and safety nets for vulnerable groups and those with inadequate incomes may be needed to
33 help them cope with the short-term impacts of climate change (Sánchez and Poschen 2009) as well as climate
34 variability. But these do not address the risks they face or support the needed collective or public investments in
35 risk-reducing infrastructure and services (Mitlin and Satterthwaite 2013).

36
37 There is a growing discussion and literature of the importance of support for a 'green economy' combined with
38 green infrastructure to help shift nations' economic and employment base towards lower carbon, more climate
39 resilient patterns that also respect regional and global ecological and resource limits. For urban centres, this seeks to
40 highlight new business opportunities as it requires existing and new businesses and employment opportunities to
41 help limit anthropogenic climate change, resource depletion and environmental degradation. Other goals are
42 sometimes added – for instance also supporting social inclusivity and eco-efficiency as mutually reinforcing
43 principles (e.g. Allen and Clouth, 2012). The literature has begun to explore the changes that are needed in
44 production systems (especially in regard to carbon intensity, waste generation and management), buildings, transport
45 systems and electricity generation and in consumption patterns by wealthier groups (Hammer,*et al.* 2011, UNEP
46 2011a and b, UN-Habitat 2012 a,b,c and d, World Economic Forum 2013). But as yet, there is too little detailed
47 discussion of how a green economy can be fostered in relation to particular cities or in regard to the incentives and
48 regulations needed to shift private investment to this.

49
50 The 'waste economy' in cities in low- and middle-income nations should be an important sector in the green
51 economy as it provides livelihoods to a large number of people (Hasan et al 2001, Hardoy et al. 2001, Medina 2007)
52 along with contributing to waste reduction and GHG emission reduction (Ayers and Huq 2009). In Brazil's main
53 cities, over 0.5 million people are engaged in waste picking and recycling (Fergutz et al. 2011); an estimated 17,000
54 people in Lima and 40,000 in Cairo earn their livelihoods from informal recycling (Scheinberg et al.2011). The

1 mechanisms by which city governments choose to work with those working in this waste economy or ignore them
2 have obvious implications for employment and for resource use.
3

4 For some cities, there is documentation of the kinds of adaptation needed to protect or enhance their economic base.
5 For instance, in Mombasa, local authorities may need to redesign and reconstruct the city's ports, protect cement
6 industries and oil refineries and relocate some industries inland, all of which requires major capital investments
7 (Awuor et al. 2008). There are many parts of Rio de Janeiro's diverse economy (including manufacturing, oil
8 refineries, shipyards and tourism) that adaptation will need to protect along with the urgent need to address the
9 vulnerability of large populations living in informal settlements (favelas) on land at risk of landslides (de Sherbinin
10 et al. 2007). Defences needed to help safeguard coastal industries and residential areas could threaten the city's
11 beach tourist industry and cause further erosion to other unprotected areas. It is also difficult to focus the attention of
12 politicians and civil servants on adaptation when their planning for city development is focused on hosting the
13 World Cup and the Olympics. As in most cities, making Rio's economic base more resilient to climate change will
14 need to resolve such tensions and trade-offs, necessitating dialogue amongst local stakeholders (Ruth 2010).
15

16 As yet, there is little evidence that climate-change related risks or cities' adaptive capacities have an influence on the
17 location of private sector investments. They are however, influenced by the availability of infrastructure and services
18 that are an essential part of adaptive capacity. Many cities in Asian high growth economies are located in low-
19 elevation coastal zones which are undergoing rapid urbanisation and economic transformation (McGranahan et al.,
20 2007). Many of these coastal settlements are also within areas where cyclones are common. Without adaptive
21 measures and with rising concentrations of population, infrastructure, and industries along India's coasts, there could
22 be a non-linear increase in coastal vulnerability over the next two decades (Revi 2009). The same is true for China
23 (McGranahan et al. 2007). In most nations, urban governments have found it difficult to prevent new developments
24 on sites at risk of flooding, especially where these are attractive locations for housing or commerce; this is even
25 when there is legislation and plans to that regulate land use (see Olcina Cantos et al 2010 for a study of this in
26 Alicante in Spain)
27

28 Few economic assessments of climate change risks have been completed in West African coastal cities. National and
29 city governments will face difficulties protecting many cities or particular districts and their industries, infrastructure
30 and tourism as in the case of Cotonou (Doussou and Gléhouenou-Doussou 2009) . Lagos, Dakar, and other
31 important economic centres in the Gulf of Guinea have large areas on the coast that are close to mean sea level,
32 leaving them highly vulnerable to erosion and rising sea levels (Simon 2010). Compounding the climate change-
33 induced flooding risks are the cities' rapid coastal construction, destruction of mangrove swamps, and inadequate
34 refuse collection (ibid.).
35

36 37 8.3.3.2. *Adapting Food and Biomass for Urban Populations* 38

39 Large sections of the urban population in low- and middle-income countries suffer hunger while a larger number
40 face food and nutrition insecurity (Montgomery et al. 2004, Ahmed et al. 2007, Cohen and Garrett 2010, Crush et
41 al., 2012). This is due more to their low incomes and limited capacities to access food than to overall food shortages
42 (Cohen and Garrett 2010, Crush et al., 2012). Among low-income urban households in such nations, food
43 expenditures generally represent more than half of total expenditures (Cohen and Garrett 2011). This makes them
44 particularly at risk from food price inflation.
45

46 Climate change impacts can have far-reaching influences on food security and safety, but these “will crucially
47 depend on the future policy environment for the poor” (Schmidhuber and Tubiello 2007: 708, see also Douglas
48 2009). Globally, agriculture has managed to keep up with rising demands worldwide, including the rapid growth in
49 the population, the rapid increase in the proportion of non-agricultural workers to agricultural workers that
50 accompanies urbanisation and consumer dietary shifts that are far more meat and carbon intensive and often land
51 intensive (Satterthwaite et al. 2010). However, food security may be eroded by competing pressures for water or
52 bio-fuels (Godfray et al, 2010). Although adjustments in farming practices are essential, adapting urban food
53 systems represents a major challenge and will necessitate radical changes in food production, storage, processing,
54 distribution, and access (ibid).

1
2 Urban food-related adaptation needs to consider both supply and demand side constraints. Climate-change related
3 constraints on agricultural production and the food supply chain can impact urban consumers through reduced
4 supplies or higher prices. Falling agricultural production or farmer incomes also reduces their demand for the urban
5 producer and consumer goods and services they use. Disruption to urban centres may also mean disruption to the
6 markets, services or remittance flows on which agricultural producers rely (Tacoli 2003). Thus, food policies for
7 climate change adaptation need to take account of complex rural-urban linkages (Revi 2009). Thus, a portfolio of
8 responses that can bridge rural and urban boundaries, as well as action at the household, local, national, and
9 international levels, is needed to strengthen urban food security.

10
11 Urban centres that are seriously impacted by extreme weather also face serious challenges in ensuring that the
12 affected population have access to adequate and safe food and water supplies. Flooding, drought, or other extreme
13 events often lead to food price shocks in cities (Bartlett 2008) as well as spoiling or destroying food supplies for
14 many households. After the 2004 floods in Bangladesh, Dhaka's rice prices increased by 30 percent and vegetable
15 prices more than doubled (Douglas 2009). Bangladesh's urban slum-dwellers and rural landless poor were the
16 groups worst-affected by food insecurity (*ibid.*).

17
18 When facing increased food prices, the urban poor in low and most middle-income nations adopt a range of coping
19 strategies such as reduced consumption, fewer meals, purchasing less nutritious foods, or increasing income earning
20 work or work hours, particularly by women and children (Cohen and Garrett 2011). But these erode nutrition and
21 health status, especially of the most vulnerable and fail to strengthen resilience, particularly in the context of more
22 frequent disasters.

23
24 Adaptive local responses have included support for urban or peri-agriculture, green roofs, local markets and
25 enhanced safety nets. Food price increases may be moderated by improving the efficiency of urban markets,
26 regulations to promote farmers' markets, or investing in infrastructure and production technologies (Cohen and
27 Garrett 2011). Food security may be enhanced by government support for urban agriculture and street food vendors
28 (*ibid.*, Lee-Smith 2011). Food security for urban dwellers with low incomes is also increased if they have access to
29 cheaper food or to social incomes – for instance cash transfers (e.g. Brazil's Bolsa familia programme) or, for older
30 groups pensions (Soares et al. 2010). While initially rural-focused, cash transfer programmes have been expanded in
31 urban areas and in some nations reach a large proportion of the low-income urban population (Johanssen *et al.* 2009,
32 Niño-Zarazúa 2010, Satterthwaite and Mitlin 2013).

33 34 35 8.3.3.3. *Adapting Housing and Urban Settlements*

36
37 Urban adaptation will be built on the bedrock of good quality and affordable housing that conforms to appropriate
38 health and safety and climate-resilient building standards and has sufficient residual structural integrity over its
39 service life to protect its occupants against extreme weather (United Nations 2009, 2011).

40
41 Section 8.2.4.4 noted how poor quality housing is often at risk from extreme weather. Its resilience can be enhanced
42 via a range of structural interventions (for instance retrofitting existing buildings and revising standards for new-
43 build), interventions that reduce risks (for instance expanding drainage capacity to limit or remove flood risks) and
44 non-structural interventions (including insurance). The need for attention to all three of these are obviously greatest
45 where housing quality is low, where settlements have developed on high-risk sites and for cities in locations where
46 climate change impacts are greatest. However, enhancing the resilience of the buildings that house low-income
47 groups also faces many political challenges (see Roaf et al., 2009).

48
49 Most of the city governments that have developed climate change adaptation strategies include measures to adapt
50 the building stock. But even in the cities with such discussions, there is still a need to act on the risks and
51 vulnerabilities identified. The range of actors in the housing sector, the myriad connections to other sectors and the
52 potential to promote mitigation, adaptation and development goals all suggest the need for well-coordinated
53 strategies that can support resilience (Maller and Strengers 2011).

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

17
18 *Housing and extreme heat:* More attention is being paid to understanding and addressing risks from extreme heat in
19 particular cities – see for instance Chicago 2008 and 2010, Tomlinson et al 2011 for Birmingham, Matzarakis and
20 Endler 2011 for Freiburg and Giguère 2009 for Quebec. Attention is needed to buildings that provide protection
21 from heat waves, especially in urban heat islands and for populations that are more vulnerable to extreme heat. In
22 locations that have large daily variations in temperature, this includes upgrading homes with limited ventilation and
23 with low thermal mass. Interventions that reduce heat gain are also needed including passive cooling and other
24 design measures (Roberts 2008b, Hacker and Holmes 2007) as well as modifications to buildings and open spaces in
25 areas that are heat islands (see later discussion on green and white roofs). Chicago's 2008 Climate Action Plan
26 discussed the need to "pursue innovative cooling," which will "seek out innovative ideas for cooling the city and
27 encourage property owners to make green landscape and energy efficiency improvements" (Chicago 2008: 52). Air
28 conditioning and other forms of mechanical cooling can provide relief but these are too expensive or not available
29 for the many urban households with no electricity supplies. They are also mal-adaptive if they rely on electricity
30 whose generation is contributing to greenhouse gas emissions. Residents' vulnerabilities may be exacerbated if
31 electricity supplies are unreliable and "if blackouts occur on the hottest days when peak demand is at its worst"
32 (Maller and Strengers 2011: 3). To date, the literature on adapting housing and neighbourhoods to extreme heat
33 focuses on cities in high-income nations although many of the cities already experiencing periods of extreme heat
34 are in low- and middle-income nations.

35
36 Passive cooling can be used in both new-build and retrofitted structures to reduce solar gain and internal heat gains,
37 while enhancing natural ventilation or improving insulation (Roberts 2008b and 2008c). Although developments
38 such as the Beddington Zero Energy Development (BedZED) in London (Chance 2009) or Germany's PassiveHaus
39 standard (Rees 2009) have set precedents for mitigating household emissions, these passive designs can
40 simultaneously contribute to adaptation. The designers of BedZED sought to reduce energy demand for heating,
41 cooling and ventilation while also utilising super-insulation, ventilation, and other measures to ensure energy is not
42 required for most of the year (Chance 2009). Thermal mass can be used for residential cooling, "because it
43 introduces a time-delay between changes in the outside temperature and the building's thermal response necessary to
44 deal with the high daytime temperatures" (Hacker and Holmes 2007: 103). Structures in southern Europe already
45 utilise solar shading, ventilation, and thermal mass in the building fabric to promote cooling (ibid.). Simulations for
46 London buildings (under UKCIP02 Medium-High emissions scenarios) suggest that utilising shade, thermal mass,
47 control of ventilation and other advanced passive designs are an "eminently viable option for the UK, at least over
48 the next 50 years or so" (ibid., : 111). Nevertheless, there are several obstacles to the incorporation of passive
49 designs. Opening windows may be hampered by security concerns or noise pollution in cities (Hacker and Holmes
50 2007). Modern windows "often do not ventilate well," and site restrictions, cost, or other constraints may impede the
51 use of passive cooling "particularly in the refurbishment of existing buildings" (Roberts 2008b: 4554).

52
53 *Housing and disaster-preparedness measures:* If populations are displaced by disasters or need to be evacuated
54 temporarily from their homes, provision for emergency shelters and services need to be able to respond with

1 particular attention to vulnerable residents. For instance, housing agencies established shelters and recovery centres
2 after Cyclone Larry in Queensland (in 2006) and New South Wales' coastal flooding (in 2007). Interviews with
3 officials recalled the strains facing 24-hour providers in the shelters and coordination difficulties with emergency
4 health workers, police, insurance, and other agencies (Jacobs and Williams 2011). While not addressing climate
5 change explicitly, the study helps highlight the range of social support, structural strategies, and interagency efforts
6 that local authorities may need to develop to adapt to climate change. For many urban centres, there is also the issue
7 of how to move populations at risk when needed (and to get their agreement to do so) and this presents many
8 challenges (Roaf et al., 2009).
9

10 Urban centres facing extreme heat need heat-wave plans that warn citizens of what is anticipated and what measures
11 they can take and ensure adequate water provision, emergency healthcare, and other public services that focus on
12 vulnerable residents. This includes special attention to infants and to the elderly in hospitals, residential facilities
13 (Hajat et al. 2010, Brown and Walker 2008) or living alone. It should include back-up electricity although large
14 sections of the urban population in low- and middle-income nations do not have electricity (Johansson et al., 2012)
15 and this also means no access to devices that help with cooling. Here too, the examples of cities with responses to
16 heat waves that focus on those most at risk (see for instance Toronto 2012) are mainly from high-income nations.
17

18 19 *8.3.3.4. Adapting Urban Water, Storm, and Waste Systems* 20

21 The challenge of this section (and this chapter), is summarizing key adaptation issues drawn from examples that
22 come from a highly heterogeneous mix of urban areas across the globe with order of magnitude variations in the
23 quality and extent of provision for water, sanitation and drainage. In high-income and some middle-income nations,
24 virtually all the urban population is served by drinking quality water piped to the home 24 hours a day, by sewers or
25 other systems of sanitation that minimize risks of faecal contamination and by storm and surface drainage. As noted
26 in 8.2, there are many urban centres in such nations that face serious climate change-related challenges for water.
27 But their plans do not have to address the fact that a significant proportion of their population do not have piped
28 water or toilets in their homes, or storm drains. They also have in place billing systems that generate a substantial
29 proportion of the funds needed for water provision and management.
30

31 At the other extreme are a very large number of urban centres in low-income and middle-income nations with very
32 large deficits in provision for water, sanitation and drainage and with weak, under-resourced institutions (UN
33 Habitat 2003, WHO and UNICEF 2012). There is also the billion or so people living in informal settlements where
34 authorities or companies responsible for water and sanitation provision are often unwilling to invest or not allowed
35 to do so. In considering how to adapt water and waste water systems to climate change, there are not only large
36 differences between nations and cities in the scale and nature of likely impacts but also in the quality and extent of
37 provision and resources available to local water and sanitation providers. New York City can develop a ten billion
38 dollar plan to assure it receives adequate water supplies (Solecki 2012) while many cities in sub-Saharan Africa not
39 only have very large deficits in piped water provision, sewers and drains but also very limited investment capacities
40 (see for instance Kiunsi 2013 for Dar es Salaam).
41

42 Some studies have sought to estimate the costs of adapting urban water and sanitation systems. Muller 2007
43 discusses the direct and indirect impacts of changes in rainfall patterns and stream flows on sub-Saharan African
44 cities. He suggests that \$1-2.7 billion is needed annually to adapt existing urban water infrastructure and this does
45 not include the cost of addressing deficient infrastructure. Another \$1-2.6 billion a year is needed to adapt new
46 developments (including water storage, waste-water treatment and electricity generation). Other research also
47 suggests significant investments needed in low- and middle-income nations to overcome current shortfalls in water
48 and sanitation as well as to cope with climate change (Arnell et al. 2009).
49
50

51 *8.3.3.4.1. Adapting urban water supply systems* 52

53 Major et al (2011) lists a range of cities that have begun to plan for and adapt water systems and other infrastructure
54 including Boston, London, Halifax (Canada), New York, Seattle and Toronto. For cities with climate change

1 adaptation plans, water and waste water management are usually important components (see for instance Helsinki
2 Region Environmental Services Authority 2012). But developing such measures is not yet commonplace.

3
4 Supply-side approaches to seasonal water shortages such as increasing reservoirs are frequently advocated. An
5 analysis of 21 draft Water Resources Management Plans in the UK found that agencies usually favoured reservoirs
6 and other supply-side measures to adapt to climate change (Charlton and Arnell 2011). The authors suggest that
7 additional demand-side interventions may be needed to cope with reductions in water availability. Although based
8 upon draft plans from 2008 rather than implemented strategies, the study indicates some key trade-offs and a
9 portfolio of responses currently under consideration. To expand its reservoir capacity, Rotterdam developed plans
10 that combine the goals of adaptation and urban renewal (van der Brugge and de Graaf 2010). Floods in 1998
11 exposed the inadequacies of existing water infrastructure, particularly in the context of climate change, and
12 municipal water authorities committed to expand retention capacity by mixing economic activities with water-based
13 adaptive designs, including ‘water retention squares’ and green roofs; floating houses; and networks of channels.
14 Seattle has utilised demand-side strategies to curtail water consumption including aggressive conservation measures,
15 system savings and price increases linked to consumption levels (Vano et al. 2010). A simulation exercise suggested
16 the system can withstand climate change-induced alterations in reservoir inflows, and the authors note that the
17 “primary reason” for such robustness is the successful reductions in demand (ibid. p. 283).

18
19 In Mexico City, government programmes on climate change have suggested actions regarding the water sector
20 although some of these have been proposed many times since the 1950s but not acted on. These include measures to
21 decrease water use and the restoration and management of urban and rural micro-basins (Romero-Lankao 2010).
22 Since these programmes prioritize mitigation over adaptation, adaptation measures for the water sector have been
23 conceived as too general and with a lack of institutional commitment. In Durban, the importance of getting climate
24 change adaptation within the water sector was recognized as a priority – and the water sector is influential within the
25 city government because of its importance in delivering development benefits and also it is revenue-earning, well-
26 resourced and retains skilled staff (Roberts 2010). The water sector has also shown an interest in developing its
27 municipal adaptation programme (ibid).

28
29 Cape Town faces profound challenges in ensuring future supplies (Mukheibir and Ziervogel 2007). The city
30 responded by commissioning water management studies, which identified the need to consider stresses including
31 climate change as well as population and economic growth (ibid.). During the 2005 drought, the local authority
32 substantially increased water tariffs, and such mechanisms may represent “one of the most effective ways” to
33 promote efficient water usage (Mukheibir 2008: 1271). Additional measures may include water restrictions; reuse of
34 grey water; consumer education; or technological solutions such as low-flow systems or dual flush toilets (ibid).

35
36 Research in Phoenix, Arizona sought to improve water forecasting data and inform adaptation interventions (Gober
37 et al.2010). This rapidly-expanding desert city is projected to reach 11 million people by 2050, with most growth in
38 peripheral areas that depend on groundwater (Bolin et al.2010). Simulations explored how water usage may be
39 reduced to achieve safe yield while accommodating future growth (ibid). Reducing current high per capita water use
40 may be achieved through urban densification, increased water prices and water conservation measures (ibid). Gober
41 et al 2010 agree that stringent demand and supply policies can forestall “even the worst climate conditions and
42 accommodate future population growth, but would require dramatic changes to the Phoenix water supply system”
43 (ibid: 370). Quito’s local government has formulated a range of adaptation plans to address water shortages (Hardoy
44 and Pandiella 2009). The city is projected to experience reduced freshwater supplies as a result of glacier retreat and
45 other impacts of climate change. Among the municipality’s responses are developing dams; encouraging a culture of
46 rational water use; reducing water losses; and developing mechanisms to reduce water conflicts (ibid.). However,
47 Quito has not sought to incorporate community participation in planning and implementation (ibid.). Participatory
48 water planning has occurred elsewhere in Latin America: stakeholders in Hermosillo, Mexico, identified and
49 prioritized specific adaptations such as rainwater harvesting and water-saving technologies (Eakin et al.2007).

50
51 Several cities are considering the potential of rainwater harvesting to enhance water supplies. In Sydney, new houses
52 are required under a 2004 law to save 40% of reticulated water for use in gardens and toilets and subsidies were
53 available to install household roof tanks (Warner 2009: 235). Many low-income Caribbean households rely on
54 rainwater collection systems for domestic use, yet upper-income groups in Barbados have voiced resistance to the

1 practice (Cashman et al. 2010). Extending existing communal collection and distribution systems would require
2 community financing or governmental interventions, as well as overcoming such resistance (*ibid.*).
3
4

5 8.3.3.4.2. *Waste and storm water management* 6

7 Most of the adaptations mentioned above are to help ensure sufficient water supplies. Less attention has been given
8 to adaptations needed in sewer and drainage systems whose capacities will often need to be increased substantially
9 and, for coastal cities, adapted to allow for the impacts of sea-level rise. We noted earlier the very large deficiencies
10 in provision for drainage for urban centres in low- and many middle-income nations.
11

12 In St. Maarten, Netherlands Antilles, the government initiated a storm water modelling study and is developing a
13 flood warning system (Vojinovic and Van Teeffelen 2007). Other options under consideration include institutional
14 adaptations such as a new decision-support framework, centralised GIS to enhance all infrastructure planning
15 measures and public education, alongside structural measures such as improving the channel network and draining of
16 areas with a high groundwater table (*ibid.*). City management in Toronto, Canada has prioritised an upgrade of storm
17 water and wastewater systems to circumvent the direct and indirect stresses from climate change (Kessler 2011).
18 Deak and Bucht (2011) analyse past hydrological structures in the city of Lund, Sweden and use the concept of
19 indigenous blue infrastructure to raise questions concerning current storm water management in the urban core.
20 Cities in California have a range of flood management methods but will need to augment these with forward-looking
21 reservoir operation planning and floodplain mapping, less restrictive rules for raising local funds, and improved
22 public information on flood risks (Hanak and Lund 2012).
23

24 The last 20 years have seen more attention by most governments to water sector reform (UN Water 2012). Many
25 have developed integrated water resource management (*ibid.*) with linkages between provisions for water, sanitation
26 and drainage and other sectors. This recognizes that water adaptation plans need to work with a range of partners,
27 consider broader development goals, identify tensions or trade-offs and implement low-regret anticipatory solutions.
28 For cities, this often has to include groundwater use management and water catchment management in areas that are
29 outside their jurisdiction and thus collaboration with other local governments in integrated flood management
30 (WMO 2009). Most examples of this are in high-income nations (for an exception see Bhat et al., 2013).
31

32 Urban water systems usually depend on reliable electricity supplies and can be energy intensive – for instance
33 utilizing water from distant or low-quality sources that require high levels of energy for conveyance or
34 treatment. Water adaptation planning will need to be developed in concert with energy conservation, water
35 catchment management and green infrastructure strategies. Integrated strategies can minimize possible conflicts
36 between water-intensive parks or gardens, support local industries, and ensure equitable access to water in cities.
37
38

39 8.3.3.5. *Adapting Electric Power and Energy Systems* 40

41 The heavy dependence of urban economies, infrastructure, services and residents on electricity and fossil fuels
42 means far-reaching consequences if supplies are disrupted or unreliable (see 8.2.4.2). With the energy literature and
43 urban energy policy discussions dominated by mitigation concerns, “relatively few assessments in the energy sector
44 focus on adaptation issues” (Mdluli and Vogel 2010: 206; see also Carmin et al 2009). The UNFCCC’s estimates for
45 investment to address climate change (UNFCCC 2007) did not estimate the costs of adapting the energy sector
46 (Fankhauser 2010). Key issues relating to adaptation for the energy sector including electricity generation and
47 distribution are usually national or regional and so are discussed in Chapter 10. But urban governments and urban
48 dwellers’ responses still have importance. Research has suggested that “private autonomous measures will dominate
49 the adaptation response as people adjust their buildings, [or] change space-cooling and -heating preferences...”
50 (Hammer et al 2012,27) so this suggests a need for policies that encourage these measures to contribute to
51 adaptation and mitigation and serve those with limited incomes. A few cities have adaptation initiatives underway
52 for energy systems while some others have begun to consider the steps needed to adapt local energy systems (*ibid.*).
53

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

7
8 There is also the adaptation agenda needed for industries related to the supply of fossil fuels that involve or should
9 involve urban governments. For instance, in the State of Veracruz, Gulf of Mexico, cities such as Coatzacoalcos and
10 Minatitlan are surrounded by oil, gas and petrochemical plants that can be affected by the impact of weather-related
11 events REF. Even though there is a growing concern about the potential impact that climate change and extreme
12 weather events will have in the oil industry in Canada, US and Mexico and how floods and sea level rise will disrupt
13 oil, gas and petrochemical installations, few climate change adaptation studies on this theme have been
14 undertaken. There are also important potential co-benefits between mitigation and reduced air pollution from thermal
15 power stations, motorized transport and other industries.

16 17 18 8.3.3.6. *Adapting Transport and Telecommunications Systems*

19
20 Adapting urban transport and telecommunications systems to the many impacts of climate change (including rising
21 average temperatures, more or more intense heat waves and storms and sea-level rise) poses many challenges
22 (Mehrotra et al 2011b). Urban centres depend on road and often rail, air and waterway transport systems for daily
23 functioning – including the movement in and out of the urban centre or core by commuters and consumers and daily
24 deliveries. Many cities depend on underground electric rail systems which may be at considerable risk from flooding
25 including New York and London (Eichhorst 2009).

26
27 The development of reliable low-cost transport has also increased the dependence of prosperous cities and
28 businesses on regional, national and international supply chains; for instance, 80 percent of the food consumed in
29 London is imported (Bioregional and London Sustainable Development Commission 2010). Most large and
30 successful cities have also spread spatially with the expansion of transport systems supporting a decentralization of
31 the workforce and businesses, most of which depend on a well-functioning transport system. The importance of
32 adapting transport infrastructure to climate change is highlighted by the 60,000 jobs and US\$ 3 billion worth annual
33 movement of goods in the Great Lakes–St. Lawrence route in the USA (Ruth 2010). This includes a need to adapt to
34 lower water levels. The study also notes the scale of indirect and direct job losses that could result from decreased
35 connectivity of the shipping network (Ruth 2010).

36
37 *Transport systems:* Cities that have developed climate change adaptation plans usually include attention to more
38 resilient transport systems (UN Habitat 2011a). Melbourne’s adaptation plan notes that intense storms and wind may
39 lead to blocked roads and disrupt traffic lights, trains, and trams and how the extent of the disruption may be
40 “further exacerbated by any additional compounding factors such as large-scale events, power disruptions or
41 emergency situations, such as multiple deaths or injuries” (Melbourne 2009:60).

42
43 Adaptation will require transport planners to account for climate uncertainties, utilise a whole-of-life approach to
44 managing infrastructure, and constantly update risk assessments (Love et al. 2010: 144). An interdisciplinary
45 approach can incorporate not only changing meteorological hazards but also consider the social and political values
46 and governance framework that can shape more resilient transportation systems (Jaroszweski et al. 2010).

47
48 *Adapting roads:* Climate change may increase the costs of maintaining and repairing road transport networks (see
49 Hayhoe et al. 2010 for a discussion of this for Chicago due to rising average temperatures and more severe rainfall).
50 In Durban, “it may be necessary to revise road construction standards and avoid routes at high risk of flooding”
51 (Roberts 2008a: 531). Coastal road adaptation may require strengthening barriers, increasing design parameters to
52 cope with sea-level rise, or realigning existing roads to a higher location (Regmi and Hanaoka 2011).

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

10
11 Informal settlements frequently lack all weather roads and paths within the settlement and connection to the wider
12 road system for emergency vehicle access and rapid evacuation. For instance, informal settlements in Chittagong
13 have extremely narrow roads so that “ambulance and fire services cannot enter most of these neighbourhoods, thus
14 exacerbating the existing health and fire risks at household level” (Rahman *et al.*, 2010: 572). Roads in Lagos’s
15 informal settlements are often poorly maintained and lack all-weather surfaces; a 2006 resident survey ranked roads
16 second to drainage in terms of needed facilities (Adelekan 2010). Evacuations in low-income areas may be
17 hampered by hazardous locations, poor quality roads, absence of public transport, prevailing insecurity, and
18 inadequate governance. Following the 2003 and 2006 floods in Santa Fe, Argentina, the lack of information and
19 official evacuation mechanisms prevented a timely response while some low-income residents chose to stay in their
20 homes to protect these and their possessions from looters (Hardoy and Pandiella 2009).

21
22 Low-income urban residents can also be profoundly affected by transport disruptions during and after extreme
23 weather events that damage critical public transit links, prevent access to work, and heighten exposure to health
24 risks. Interviews in Georgetown, Guyana, found that low-income households mainly rely on public transport and
25 their limited transport access during floods made them more likely to lose time from work or school, as compared to
26 wealthier households (Linnekamp *et al.* 2011). Better-off households were more likely to possess their own vehicles,
27 while poorer households rarely owned cars, waded through floodwaters in bare feet, and were thereby exposed to
28 waterborne pathogens (*ibid.*). Some studies suggest that urban women are more likely than men to walk or utilise
29 public transport (World Bank 2010d), so that the gendered impacts of transport disruptions may merit greater
30 consideration (see also UN Habitat 2011a, Levy 2013).

31
32 *Adapting surface and underground railways:* Underground transport systems are specific to urban areas and may
33 have “particular vulnerabilities related to extreme events, with uniquely fashioned adaptation responses” (Hunt and
34 Watkiss 2011: 14). Heat impacts are often significant in underground railways, as these systems may be gradually
35 warming due to engine heat, braking systems, and increased passenger loads (Love *et al.*, 2010). To cope with
36 increasing frequency of hot days due to climate change, “substantial investment” in ventilation or cooling may be
37 necessary (*ibid.*). Some of New York City’s subways are located in coastal or river floodplains, and the system’s
38 age, fragmented ownership, and current overcapacity may augment the challenge of adaptation (Zimmerman and
39 Faris 2010: 69-70). Pumps have been installed throughout the subway system and these helped to cope with severe
40 floods in August 2007 during the morning commute (*ibid.*).

41
42 Rail systems that have struggled to cope with existing climate variability may need considerable investment to
43 withstand changes in extreme events and higher temperatures (see Baker *et al.* 2010). Railway systems may also be
44 more vulnerable to climate variability and change than the road system, as the latter can more easily redirect traffic
45 during extreme weather events (Lindgren *et al.* 2009). The costs of delays and lost trips due to extreme weather
46 events were analysed in Boston (Kirshen *et al.* 2008) and Portland (Chang *et al.* 2010) and were found to be small
47 relative to the damages upon infrastructure and other property. Portland’s nuisance flooding is projected to increase
48 although floodplain restoration, use of porous pavements, or detention ponds may help address this (*ibid.*).

49
50 In flood-prone cities, more stringent construction standards, design parameters, or relocation may be needed to adapt
51 transport systems. Much of central Mumbai is built on landfill (as the area was originally seven islands); the landfill
52 areas are prone to flooding, but they contain the main train stations and train lines as well as large populations and a
53 large part of the city’s economy (de Sherbinin *et al.* 2007). Rising sea levels may cause shifts at the sub-surface level
54 of landfill areas and structural instabilities (*ibid.*).

1
2 *Telecommunications*:8.2.2.2 noted how key elements in cities' communications systems may be at risk from climate
3 change impacts so they may need to be strengthened to avoid toppling due to strong winds and electrical support
4 facilities may need to be moved or protected against flooding (see Zimmerman and Faris 2010: 74).

7 8.3.3.7. *Green Infrastructure and Ecosystem Services within Urban Adaptation*

8
9 The greater attention to understanding, utilizing and protecting ecosystem services includes examples of ecosystem-
10 based adaptation in urban and peri-urban areas. These use opportunities for the management, conservation and
11 restoration of ecosystems to provide needed services and increase resilience to climate extremes. They can also
12 deliver multiple development co-benefits (e.g. purifying water, absorbing runoff for flood control, cleansing air,
13 moderating temperature, preventing coastal erosion) while helping contribute to food security and carbon
14 sequestration (Newman 2010, Foster et al 2011, GLA 2011, Roberts et al 2012; see also Wilson et al. 2011, Oliveira,
15 Andrade and Vaz 2011, Tallis et al 2011, City of New York 2011, Helsinki Region Environmental Services
16 Authority 2012, Institute for Sustainable Communities, undated). An ecosystem services based approach is
17 particularly important in low- and many middle-income countries where livelihoods for sections of the urban
18 population and much of the peri-urban population depend on natural resources. Box 8-1 describes how ecosystem
19 based adaptation is being developed in Durban. Another example is the contribution of catchment management to
20 addressing flood risk that includes community-based partnerships supported by full cost accounting and payment for
21 ecosystem services – rather than the more conventional canalisation of rivers (Kithiia and Lyth 2011, Roberts et al.
22 2012).

23
24 _____ START BOX 8-1 HERE _____

26 **Box 8-1. Ecosystem-based Adaptation in Durban**

27
28 In Durban, ecosystem based adaptation is part of its climate change adaptation strategy. This seeks to move beyond
29 a focus on street trees and parks to a more detailed understanding of the ecology of indigenous ecosystems. From
30 this can be identified the ways in which biodiversity and ecosystem services can help reduce the vulnerability of
31 ecosystems and people in the face of the adverse effects of climate change. Strategies to achieve biodiversity goals
32 such as developing corridors to facilitate species migration, enlarging core conservation areas and identifying areas
33 for improved matrix management to enhance ecological viability of these core areas can have adaptation co-benefits.
34 There is also a recognition that the adaptation deficit is both in the lack of conventional infrastructure and the loss of
35 ecological infrastructure (wetlands, forests, grasslands, soil). It includes an interest in how ecosystem restoration and
36 conservation can contribute to food security, urban development, water purification, waste water treatment climate
37 change adaptation and mitigation.

38
39 The development of ecosystem based adaptation in Durban requires a series of steps that include:

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

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

3
4 Source: Roberts et al. (2012).

5
6 _____ END BOX 8-1 HERE _____
7

8 “Green infrastructure” refers to interventions that seek to preserve the functionality of existing green landscapes
9 (including parks, forests, wetlands or green belts) as well as transforming the built environment through the use of
10 photo-remediation and water-management techniques and by introducing productive landscapes (La Greca et al.
11 2011, Zhang et al 2011, Foster et al 2011). Its importance for adaptation is increasingly recognized, although much
12 of the early innovation was in response to the need for cost effective and sustainable mechanisms to address water
13 shortages or flooding and not directly linked to climate change adaptation. Case studies of green infrastructure aim
14 to measure their effectiveness and assess the potential of urban planning and environmental conservation policies to
15 create cityscapes that can adapt to a changing climate.

16
17 Green spaces in cities are considered beneficial for absorbing rainfall and moderating high temperatures. For
18 instance, in the USA, the cities of Portland and Philadelphia have used green infrastructure (including
19 encouragement of green roofs, porous pavements and disconnection of downspouts) to reduce storm waters at much
20 lower costs than increasing storm water capacity (Foster et al 2011). Some cities have made investments in green
21 infrastructure, linked both to regeneration and to climate change adaptation. For instance, the Green Grid for East
22 London seeks to create “a network of interlinked, multi-purpose open spaces” to support the wider regeneration of
23 the sub-region. It is being developed to enhance the potential of existing and new green spaces to connect people
24 and places, absorb and store water, cool the vicinity, and provide a diverse mosaic of habitats for wildlife (GLA
25 2008:80). New York has a well-established programme to protect and enhance its water supply through watershed
26 protection. This includes city ownership of land that allows crucial natural areas to remain undeveloped and work
27 with land owners and communities to balance protecting drinking water quality with facilitating local economic
28 development and improving waste water treatment. To this has been added an ambitious green infrastructure plan
29 (that includes porous pavements and streets, green and blue roofs and other measures to control stormwater (New
30 York 2010). The city government suggests that while the Program is costly, compared to the costs of constructing
31 and operating a filtration plant, as well as the environmental impacts of the additional energy and chemicals required
32 by filtration, it is the most cost-effective choice for New York (Foster et al 2011, New York 2010).

33
34 The coastal city of QuyNhon in Vietnam is seeking to reduce flood risks by restoring a 150 hectare zone of
35 mangroves (Brown et al. 2012). Singapore has used several anticipatory plans and projects to enhance green
36 infrastructure including its Streetscape Greenery Master Plan, constructed wetlands or drains and community
37 gardens (Newman 2010). Authorities in England and the Netherlands are recognising the linkages between spatial
38 planning and biodiversity, though “there is less evidence of direct response to the needs of climate change
39 adaptation” (Wilson and Piper 2008: 143). Barriers to action included short-term planning horizons, uncertainty of
40 climate change impacts, and problems of creating habitats due to inadequate resources, ecological challenges, or
41 limited authority and data (*ibid.*,145).

42
43 In Mombasa, the Bamburi Cement Company rehabilitated 220 hectares of quarry land now known as Haller Park
44 (Kithiia and Lyth 2011). The park attracts over 150,000 visitors per year, with “the potential to create adaptation co-
45 benefits despite this not being the original intent” (*ibid.*,260). Cape Town has initiated community partnerships to
46 conserve biodiversity, including the Cape Flats Nature project with the para-statal South African National
47 Biodiversity Institute (Ernstson *et al.* 2010: 539). The participating schools and local organisations explore
48 ecosystem services (such as flood mitigation and wetland restoration), and the project facilitates “champion forums”
49 to support conservation efforts (*ibid.*).

50
51 Dedicated green areas within urban environments compete for space with other city-based needs and developer
52 priorities. The role of strategic urban planning in mediating among competing demands for land use is highlighted as
53 potentially useful for the governance of adaptation as presented in planning forerunners London, Toronto, and
54 Rotterdam (Mees and Driessen 2011). The experience in Durban discussed in Box 8-1 also faces many challenges

1 (Roberts et al. 2012). These include an assumption that ecosystem based adaptation is an easy answer to the
2 technological, financial, institutional and skill constraints that limit the implementation and effectiveness of “hard
3 engineering” solutions (ibid., Kithiia and Lyth, 2011). Experience in Durban shows that implementing an
4 ecologically functional and well-managed, diverse network of bio-infrastructure needs knowledge, new data
5 collection, expertise and resources. It needs to have direct and immediate developmental co-benefits for local
6 communities and ensure integration across institutional and political boundaries. Substantial knowledge gaps need to
7 be addressed, such as the need to determine where the limits or thresholds lie; many ecosystems have been degraded
8 to the point where their capacity to provide useful services may be drastically reduced(TEEB 2010).
9

10 Burley et al’s (2011) review of the wetlands of South East Queensland, Australia indicates that adaptations focused
11 on wetland and biodiversity conservation may impact urban form in coastal areas. A study of the change in tree
12 species composition, diversity and distribution across old and newly established urban parks in Bangalore, India
13 aims to find ways to increase ecological benefits from these biodiversity hotspots (Nagendra and Gopal 2011).A
14 new methodology that seeks to evaluate the impacts on local climate of current land uses and proposed planning
15 policies using evapotranspiration and land surface emissivity as indicators when applied in Leipzig found that green
16 areas and water surfaces had cooling effects, as expected but some policies were found to increase local
17 temperatures (Schwarz et al 2011).
18

19 It is generally accepted that mitigating climate change will require a dense urban form to maximize agglomeration
20 economies in more efficient resource use and waste reduction and to reduce land for urban expansion, reliance on
21 motorized transport and building energy use. But adaptation requires an urban form that favours green infrastructure
22 and requires provision of open space for storm water management, species migrationand urban cooling (Hamin and
23 Garrun, 2009, Mees and Driessen 2011). This suggests that there is a “density conundrum” (Hamin and Garrun
24 2009: 242) in that higher densities can prevent the maintenance of ecologically viable and biodiverse systems and
25 exacerbate the urban heat island which in turn generates the need for more cooling and may increaseenergy
26 use,further escalating the urban heat island effect. But at which point will densities be too high to maintain
27 ecologically viable and biodiverse systems, especially given that urbanization has already compromised the ability
28 of ecosystems to buffer urban development from hazards? This situation will be further exacerbated by new hazards
29 (e.g. floods, fires) to which systems are or will be exposed as the result of climate change (Depietri et al. 2012).
30

31 *Green and white roofs:*Green and white roofs have been introduced in a range of cities, with the potential to create
32 synergies between mitigation and adaptation.Rooftop vegetation helps decrease solar heat gainwhile cooling the air
33 above the building (Gill *et al.* 2007). This improves the energy performance of buildings (Mees and Driessen, 2011,
34 Parizotto and Lamberts 2012) and can reduce cooling demand and often the use of air conditioning with its local
35 contribution to heat gain (Zinzi and Agnoli 2011, Jo et al. 2010) and its implications for greenhouse gas emissions if
36 utilizing electricity from fossil fuelled power stations. Rooftop vegetation can also retain water during storms,
37 reducing storm water run-off (see studies conducted by Palla et al 2011, Schroll et al 2011, Voyde et al. 2010) and
38 promote local biodiversity and food production (adaptation). Studies which measure the thermal and hydrological
39 responses of green roofs have compared the performance of living roofs across different plant cover types, levels of
40 soil water, and climatic conditions (see e. g. Jim 2011, Simmons et al. 2008). Hodo-Abalo et al. (2012) confirmed
41 that a dense foliage green roof has a greater cooling effect on buildings in Togolese hot-humid climate conditions.
42 Several field experiments combined with simulated modelling of impacts in the US also confirmed the positive
43 thermal behaviour of green roofs when compared to alternative roof coverings (for example Getter et al. (2011)
44 compared green roofs with a traditional gravel inverted roof, Scherba et al. (2011) compared the heat flux into the
45 urban environment of vegetated roofs, white roofs and black membrane roofs, with PV panels elevated above
46 various roofs, Susca et al. (2010) compared black, green and white roofs, in four areas of New York City and
47 assessed the positive effects of vegetation at both urban and building level.
48

49 Durban has a pilot green roof project on a municipal building; indigenous plants are also being identified for the
50 project and rooftop food production is being investigated (Roberts 2010). New York’s lack of space for street-level
51 planting helped encourage the adoption of living roofs, which can provide additional area for cooling vegetation
52 (Corburn 2009). Under its Skyrise Greenery project, Singapore has provided subsidies and handbooks for rooftop
53 and wall greening initiatives (Newman 2010).
54

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

7
8 However, a recent meta-analysis suggests that green roofs and parks may have limited effects on cooling (Bowler *et al.*
9 *et al.* 2010). Findings on green roofs were “mixed, with some evidence of lower air temperatures above green sections
10 in some studies, but not in others” (*ibid.*, 153). Additionally, an urban park was found to be “around 1°C cooler than
11 a non-green site” (*ibid.*) and larger parks had a greater cooling effect. Yet studies were mainly observational, lacking
12 rigorous experimental designs, and “it is not clear if there is a minimum size threshold or if there is a simple linear
13 relationship” between the park’s size and cooling impact (*ibid.*). While different types of vegetation have stronger
14 effects, the analysis could not demonstrate “exactly how green infrastructure should be designed in terms of the
15 abundance, type, and distribution of greening” (*ibid.*)

16
17 Cool roofs or white reflective roofs use bright surfaces to reflect short-wave solar radiation, which lowers the
18 surface temperature of buildings compared to conventional (black) roofs with bituminous membrane (Saber et al
19 2012). There is also some work on roads and pavements with increased reflectivity (Foster et al 2011).
20 Quantification of the cooling benefits from white roofs in various urban settings has been undertaken - for instance
21 the study in Hyderabad (Xu et al. 2012), comparison of white and black roofs in the North American climate (Saber
22 et al. 2012) and a Sicilian case study (Romeo and Xinzi 2011). Comparisons between green and white roofs have
23 been undertaken in various climatic zones: Ismail et al. (2011) investigated their cooling potential on a single-storey
24 building in Malaysia and Zinzi and Agnoli (2011) explored the comparative applicability of the two roof treatments
25 in a Mediterranean climate. Results suggest that local conditions play a dominant role in determining which
26 treatment is best for improving internal conditions as well as moderating the urban heat-island phenomenon. For
27 instance, Hamdan et al. (2011) found a layer of clay on top of the roof as the most efficient for passive cooling
28 purposes in the Jordanian climate, compared to two different types of reflective roofs.

31 8.3.3.8. *Adapting Public Services and Other Public Responses*

32
33 It will fall to the public services network and public policy to ensure that climate change adaptation addresses the
34 needs of those most at risk and most vulnerable. Many aspects of this have already been covered – for instance
35 ensuring adequate provision for water, sanitation, drainage and solid waste collection and provision for rapid
36 response to disasters. Health care services and emergency services (including ambulance, police and fire fighting)
37 will have their workload increased while also needing to ensure that their systems can themselves adapt. They also
38 need good working relationships with other key government sectors and with civil protection services – including
39 the armed forces and Red Cross and Red Crescent societies.

40
41 As city risk and vulnerability assessments become more common and detailed, these provide a basis for assessing
42 how public policies and services need to adapt – for instance, the levels of risk exposure of key health care facilities
43 from flooding. Availability of data on and the personnel to reach vulnerable urban populations with effective
44 responses e.g. protecting groups particularly vulnerable to heat waves which will be challenging in many cities.
45 There is little evidence of consideration being given to needed changes in public services in response to climate
46 change e.g. the risk of fires is likely to increase in and around many urban centres because of increased drought and
47 rising temperatures.

48
49 Enhanced emergency medical services may help cope with extreme events while health officials can also improve
50 surveillance, forecast the health risks and benefits of adaptation strategies, and support public education campaigns.
51 Public health systems may need to increase attention to disease vector control (e.g. screening windows, eliminating
52 breeding grounds for the mosquitoes that are vectors for malaria and dengue) and bolster food hygiene measures
53 linking to increased flooding and temperatures.

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

8
9 For cities without a robust emergency response network, adapting to Climate Change may require significant
10 improvements in staffing, resources, and preparedness plans. This will include particular attention to providing
11 emergency services in informal settlements lacking adequate roads or infrastructure and where needed, temporary
12 evacuation plans that serve all those that have to move.

13
14 Many sections of 8.2 noted health impacts that can arise or be exacerbated by climate change that will increase
15 demands on health care systems – including those linked to air pollution, extreme weather, food or water
16 contamination and climate sensitive disease vectors. For air quality, additional research is still needed to understand
17 the complex links between weather and pollutants in the context of climate change (Harlan and Ruddell 2011).
18 Important synergies can be achieved through combining mitigation and adaptation strategies to improve air quality,
19 reduce private transport and promote healthier lifestyles (*ibid.*, also Bloomberg and Aggarwala 2008).

20 21 22 **8.4. Putting Urban Adaptation in Place: Governance, Planning, and Management**

23
24 This section discusses what we have learnt about introducing adaptation strategies into the core of urban government
25 investment and management with a buy-in from key sectors and departments within local government and support
26 from non-state actors. This includes experiences with integrating development, disaster risk reduction and climate
27 change adaptation. It includes consideration of household and community based adaptation and of where local
28 processes are or can be supported by higher levels of government and for low- and middle-income nations, by
29 international agencies. It also includes a review of the resources needed to adapt to climate change at urban levels,
30 ranging from human to financial resources.

31
32 A share of what is needed for effective urban adaptation falls within the responsibilities of municipal governments.
33 Many aspects of adaptation can only be implemented at the urban level through what local governments do,
34 encourage, allow, support and control. This requires support from regional (sub-national) and national institutions
35 and policies, suggesting that urban adaptation will necessarily be nested and policy-centric, with overlapping
36 responsibilities and authority operating across levels of governance, relevant sectors and themes (Ostrom 2009,
37 Dietz et al., 2003; Blanco et al., 2011; Corfee-Morlot et al. 2011; McCarney et al., 2011; Kehew et al. 2013,
38 forthcoming). There are important precedents here in the way that new national legislation and institutions on
39 disaster risk reduction have helped to strengthen and support local government capacity (see 8.3.2.2), though these
40 often show that without associated budgetary support and increases in human resources, legislation has limited
41 effect on local planning and practice (Johnson, 2011).

42
43 Approaches to adaptation include new urban policies and incentives for action as well as measures to mainstream
44 climate considerations or auditing for climate impacts through existing policies to ensure that they reduce risk and
45 vulnerability (Urwin and Jordan 2008, Brugmann 2012, OECD 2008, Satterthwaite et al. 2009). This can include
46 consideration of transformation (where development is a main determinant of risk or risk mitigation), as well as
47 difficult decisions over what can be done where there are limits to adaptation (Pelling and Navarrete, 2011). These
48 limits might include, for example, resettlement or abandonment of previously developed land (see Section 8.3).
49 Capacity constraints, including limited funding and technical expertise, ill-designed or inadequate institutional
50 mechanisms, limited information on climate predictions and risk and lack of leadership will limit the ability of local
51 authorities to work effectively on this (see Gupta et al., 2010) as well as working with others at the local, regional
52 and national level on adaptation. Many national governments face comparable capacity constraints and still do not
53 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).

1
2 [INSERT FIGURE 8-1 HERE

3 Figure 8-1: Circulation of power for public decisionmaking on climate change.]
4

5 From an institutional and policy perspective, urban governments have authority in relevant domains for adaptation
6 decisions but many of their decisions will be enabled, bounded or constrained by national, sub-national or supra-
7 national laws and policies, land use and infrastructure planning decisions (ARUP/ C40 report; OECD 2010; Kehew
8 et al. 2013). Large metropolitan areas raise the level of complexity of managing climate adaptation, especially when
9 they are growing rapidly – and this requires action to be coordinated across multiple urban jurisdictions; the number
10 of relevant jurisdictions varies by city but they are often in the dozens (e.g. Mexico City, Sao Paulo, London and
11 Buenos Aires) and occasionally in the hundreds (e.g. Abidjan and Tokyo) (McCarney et al. 2011). Although there is
12 some evidence of innovative responses at the sub-national levels to plan for extreme weather events and climate
13 change, limited capacity and experience at the local government level also suggests a need for support from higher
14 levels of government (Norman and Nakanishi 2011, Guran et al 2012). In large metropolitan areas, it will also be
15 ineffective for a single urban jurisdiction to act in isolation of neighbouring jurisdictions; there is a need to
16 coordinate and harmonise actions across metropolitan jurisdictions – for instance to implement flood protection of
17 contiguous land areas or evacuation planning in response to an approaching storm or in the event of a disaster.
18

19 Adaptive capacity in cities therefore depends upon the alignment of policies and incentives such that they work
20 coherently across multiple levels of government and on multilevel governance to define and deliver effective urban
21 adaptation (McCarney et al. 2011; Corfee-Morlot et al. 2011, Mukheibir and Ziervogel 2007, Urwin and Jordan
22 2008, Cash et al. 2006, Young 2002, Bulkeley and Kern 2006, Kern and Gotelind 2009). Institutions operating at
23 different levels and with different scopes of authority may be responsible for key decisions in relevant urban
24 adaptation sectors (e.g. coastal zone management and buildings). Water authorities may operate at waterbasin level
25 and as such represent both national and local interests while also operating independently of urban authorities. This
26 points to a need to audit and align (pre)existing policies and screen new policies across levels of government to
27 ensure the consistent integration of urban climate change risk management. Failing to do so can lock-in outcomes
28 that raise the vulnerability of urban populations, infrastructure and natural systems to climate change (mal-
29 adaptation) even where pro-active adaptation policies exist (Benzie et al. 2011; OECD 2009, Urwin, Jordan 2008).
30 Raising urban adaptive capacity requires local government capacity as well as the institutions that facilitate
31 coordination across multiple, nested and poly-centric authorities in making decisions to address urban vulnerability
32 and risk, and which have potential to mainstream adaptation measures.
33

34 Opportunities for accelerating learning and action may stem from horizontal coordination and networking across
35 actors, professions and institutions in different municipalities and metropolitan areas, many of whom are facing
36 similar challenges (Lowe et al., 2009, Aall et al., 2007, Schroeder and Bulkeley 2008). Local contexts and
37 implementation agendas also underscore the need for tailoring of national goals and policies to local circumstances
38 and preferences. Consultation and awareness raising are essential to avoid the kind of public backlash that occurred
39 in response to the French government’s attempt to ban urban development and require strategic retreat in areas of
40 current and increasing risk to coastal flooding following the storm Xynthia in 2010 (Laurent 2010; Pryzyluski and
41 Hallegatte, 2012). Urban adaptation planning has also to recognise the influence of vested interests and trade-offs,
42 where near-term development may appear to conflict with longer-term adaptation and resilience goals. Public
43 engagement, openness and transparency about climate change information and its risks can help to ensure
44 democratic debate to balance public interests and longer-term sustainability goals against the short-term benefits of
45 unconstrained development.
46

47 Urban governments are uniquely situated to understand local contexts, raise local awareness, respond to citizens and
48 civil society pressures, strengthen planning and build capacity to take actions in some areas. They can work closely
49 with local stakeholders through an analytic-deliberative process to build a policy space (Brunner 1996, Brunner et
50 al. 2005, Cash and Moser 2000, Grindle and Thomas 1991, Healy 1997). Within this, it is possible to generate a
51 good understanding of local contextual factors that will matter to decisions about how to manage climate change
52 adaptation (Healy 1997, Ostrom 2009). Urban governments can also promote understanding of climate change risk
53 and drivers of vulnerability for adaptation and help to create a common vision for the future (Corfee-Morlot et al.
54 2011, Moser 2006, Moser and Dilling 2006, Ostrom 2009). The fact that preferences of different actors tend to be

1 more homogenous across smaller than larger units (Ostrom 2009) provides opportunities for leadership and
2 flexibility to innovate that may not exist at higher levels of governance. Thus, some evidence suggests that urban
3 governments may be unique in their ability to provide accountable leadership, to innovate and to promote learning-
4 by-doing (OECD 2010).

5
6 Beyond setting out a vision for the future, urban governments are central to the interface between climate change
7 and development, including provision for essential services (water, sanitation, drainage, solid waste management,
8 shelter, mobility services as well as education and health services) (Bulkeley 2010; Bulkeley and Kern 2006). Urban
9 governments often have responsibilities for a substantial share of urban infrastructure to provide these services
10 (ARUP/C40 2012). An essential step is to integrate and mainstream adaptation plans and risk management into
11 urban and development planning from local to national levels with a clear time frame, mandate and resources for
12 implementation (Brugmann 2012, OECD 2008, Satterthwaite et al. 2009). This includes influencing territorial
13 development planning and infrastructure planning even if functional authority is at the national or sub-national
14 regional levels (Vigue and Hallegatte 2012, Hall et al. 2012).

15
16 Despite the unique opportunities to support adaptation, local government decisions are often driven by short-term
17 priorities of economic growth and competitiveness (Carmin and Dodman 2012, Moser and Luers 2008). Addressing
18 climate change requires shifting ways of thinking about the future to take a longer-term perspective and reconcile
19 this with near-term priorities (Leichenko 2011, Pelling 2011a, Romero-Lankao and Quin 2011). Tension also exists
20 between focusing on economic growth and the large and often growing numbers of the urban poor that are ill-served
21 or unserved by infrastructure and services; for much of the urban population, resilience to climate change will
22 depend on this being addressed (Bicknell et al. 2009). The challenges of advancing adaptation through urban
23 governance processes in low- and middle-income countries are exacerbated by inattention from international donors
24 to urban policy and development concerns, as they work almost uniquely with national governments. Donors may
25 also have preferences for physical infrastructure projects with visible results over local institution and capacity
26 building investments. Similarly, national governments in high-income countries have yet to fully embrace and find
27 ways to support local adaptation initiatives (McCarney et al. 2011).

28
29 While there is evidence of growing awareness and analytical capacity (i.e. in the form of adaptation planning) within
30 many urban governments and governance processes, there is much less evidence of action in the form of adaptation
31 implementation and influence on key sectors (Roberts 2010). This may be because adaptation planning is often done
32 separately from urban and territorial development planning making it difficult to gauge progress in efforts to
33 mainstream adaptation into urban planning.

34 35 36 *8.4.1.2. Mainstreaming Adaptation into Municipal Planning*

37
38 Whether and how urban governments mainstream climate change into municipal planning and land-use management
39 and legal and regulatory frameworks for development is key to successful adaptation in all countries (Lowe *et al.*,
40 2009: 6; Kehew *et al.* forthcoming). Mainstreaming has particular importance in countries where much of the
41 vulnerability and risk from climate change comes from inadequate provision of infrastructure and services (Kithiia
42 2010, Roberts 2008a). Integrating climate change adaptation in urban development could help planners rethink
43 traditional approaches to land use and infrastructure design based on past trends and move towards a new approach
44 of forward looking risk-based design for a range of future climate conditions (Kithiia 2010; Solecki, Leichenko and
45 O'Brien 2011). Important opportunities also exist in high-income countries to use ongoing planning processes to
46 climate-proof infrastructure, spatial form and land use decisions in cities and to build resilience through existing
47 policy channels (Benzie *et al.* 2011; Blanco *et al.* 2011; Urwin and Jordan 2008).

48
49 Some have argued that adaptation planning should be an integrated, cross-sectoral process (Parry *et al.* 2007;
50 Sanchez-Rodriguez 2011) yet initiating mainstreaming may best be achieved through encouraging pilot projects and
51 supporting key sectors to take initiatives. Assigning responsibilities and actions to specific departments can make
52 the climate message easier to understand and more transparent (Roberts 2010, UN-Habitat 2011a). Pilot projects
53 ground the imperative of adaptation in practical reality (Roberts 2010, Tyler *et al.* 2010; Brown *et al.* 2012). Sectoral
54 approaches and pilot projects can be a pragmatic way to build more comprehensive and cross-sectoral and

1 approaches. Urban authorities in India can see climate change adaptation as a priority if they see co-benefits
2 between adaptation and measures to address development and environmental health concerns (Sharma and Tomar
3 2010) (see also section 8.4.3). Local governments may be able to address both adaptation and mitigation using the
4 same policy levers such as building standards, transport infrastructure, and other urban planning tools (Hallegatte et
5 al., 2011). Addressing adaptation and mitigation together can also avoid tradeoffs when designing policies and build
6 response capacity by developing institutional links (Swart and Raes, 2007). A further challenge is to develop
7 methods to evaluate emerging adaptation measures in a timely manner (Hedger et al.2008, Preston et al. 2011).

8
9 Despite the potential for change, evidence from the literature suggests that opportunities to mainstream climate
10 change into urban planning and development are so far largely missed (Sanchez-Rodriguez, 2009). Challenges
11 include lack of leadership, inadequate information, institutional compartmentalization and fragmentation, and
12 resource constraints (Sanchez-Rodriguez, 2009; Wilson, et al, 2011). It is difficult to introduce an additional layer of
13 climate change planning to already complex (and often fragmented) planning systems (Kithiia 2010, Roberts
14 2008a). The planning agenda can be already full, which in turn makes it difficult to find institutional space for
15 climate change adaptation (Measham et al. 2010). Climate change policies may also be seen merely as “add-ons to
16 the overall strategies driven by economic and spatial concerns” (Kithiia and Dowling 2010: 474). In all instances,
17 where progress on adaptation planning is observed, local leadership is a central factor (Carmin and Anguelovski
18 2009, Measham et al. 2010).

21 8.4.1.3. *Delivering Co-Benefits*

22
23 Co-benefits of adaptation and development for urban contexts include delivering safer, more comfortable and
24 healthier urban environments and reducing the vulnerability of low-income groups to wider concerns of
25 environmental and public health and local development capacity – livelihoods, skills training, leadership capacity
26 (Burch 2010, Clapp et al., 2010, Hallegatte et al., 2011, Kousky and Schneider 2003, Carmin and Anguelovski 2009,
27 Roberts 2010). Co-benefits also extend beyond the urban core where hazard is driven in part by local environmental
28 conditions such as land-use on hill-slopes or in wetlands – and also influenced by what is done in water-basin
29 management and coastal defence regimes.

30
31 Co-benefits may be particularly important to highlight and plan around in low and middle income countries, where
32 lack of policy buy-in is associated with limited local capacity to make changes to policy agendas capacity (UN-
33 Habitat 2011a) and where current climate change challenges appear marginal when compared with the deficits in
34 infrastructure and service provision outlined earlier and other socio-economic problems faced by authorities
35 responsible for urban development and security (Kithiia and Dowling 2010, Roberts 2008a).

36
37 Development and climate change adaptation are often seen as separate challenges in a sub-national, regional
38 planning context. A review in OECD countries revealed that only Japan and South Korea are championing climate
39 action as an integral part of sub-national development planning, however Finland and Sweden also have innovative
40 sub-national climate policies and action programmes that are incentivised and funded by the central government
41 (OECD 2010, Ch. 8). For most OECD countries, however, the two issues of urban development and adaptation are
42 tackled separately. Policy research argues that successful adaptation has to be rooted within development context of
43 the city or country and harmonised with its development priorities, such as poverty reduction, food security and
44 disaster management (Moser and Luers 2008, Satterthwaite et al. 2009, Lwasa, 2010, Measham et al. 2011).

47 8.4.1.4. *Urban Vulnerability and Risk Assessment Practices:* 48 *Understanding Science, Socio-Economics, and Policy Interactions*

49
50 Principles of good practice in public decision-making and urban climate risk governance include an important
51 component of science. This includes policy exchange and deliberation where good adaptation decisions will
52 necessarily be based on credible scientific and expert information to consider future predictions and uncertainty
53 around these (Bourque et al 2009, NRC 2009, Rosenzweig and Solecki 2010; Government of South Africa,2010).
54 Climate science shows that future changes will need to vary in some cases significantly from past trends, so the past

1 is no longer a sufficient basis for future planning. Understanding climate risks and vulnerabilities at the urban scale
2 demands a continuous re-assessment of the scientific knowledge about local climate conditions and translating this
3 into useable local knowledge. This will depend upon local capacity to access and use climate change information as
4 it becomes available and processes for local stakeholder engagement in science-policy exercises to understand and
5 assess climate change risk and uncertainties in national, regional and local contexts (Hallegatte et al. 2011; Carmin,
6 Dodman and Chu 2013 forthcoming).

7
8 Urban climate science refers to the ability to understand past climate conditions, monitor and attribute historical and
9 present climate change to anthropogenic forcings, and project future changes in temperature, sea level and
10 precipitation sufficiently well that urbanites and urban governments can plan for and adapt to these changes
11 (McCarthy et al. 2010). The paths by which climate change alters local climatic conditions and who is exposed to
12 risk and impacted, will vary with local contextual factors such as local physical and socio-economic conditions (e.g.
13 the size of the local population and its distribution across the land; age structure, the quality, thermal characteristics
14 and location of the built environment; and altitude, soil and vegetation conditions, proximity to the sea or river
15 basins of the area). Urban climate science requires the integration of different kinds of detailed information and
16 projections from physical science and socio-economic domains (Hallegatte et al. 2011, McCarthy et al. 2010).
17 Attention to credibility, legitimacy and salience increase the usability of science and other expert knowledge in
18 policy assessments (from local to global) (e.g. NRC 2007, Preston et al. 2011).

19
20 On science-policy issues, such as climate adaptation, research demonstrates the key role of boundary organisations
21 to interpret and shape scientific inputs such that they become more useable in a political context (Cash 2001,
22 Jasanoff 1990, Gieryn 1999, Guston 2001, Driessen et al 2010). In urban adaptation planning, local or regional
23 boundary organisations have also been shown to have influence and support policy decisions (Bourque et al 2009,
24 Corfee-Morlot et al. 2011, Horton et al. 2011). Boundary activities designed to support urban decision-making can
25 take a variety of institutional forms (NRC 2009) and receive funding and support from different sources (e.g.
26 national or sub-national public sources, and in some cases private funding) (Corfee-Morlot et al. 2011). In many
27 instances, key boundary functions are carried out by nearby academic or research communities; local scholars in
28 these institutions can also be a source of leadership for urban adaptation efforts (Molnar et al., 2012; Sanchez-
29 Rodriguez 2009; Government of South Africa 2010).

30
31 Even where detailed quantitative and technical urban climate vulnerability or risk assessments exist, the influence of
32 these may be limited if the timing is mis-matched with major policy decisions or if decision-makers do not access
33 and use this information. For example, urban master plans or strategic plans with a time horizon of ten or more years
34 into the future have the potential to incorporate climate risks and vulnerabilities, but timely assessments need to be
35 made available to influence such plans. Beyond timeliness, Moser and Tribbia (2006) explore how decision makers
36 access or use scientific information and the sources they rely upon. Resource managers are more likely to rely upon
37 informal sources, such as maps or in-house experts, media and internet, thanon scientific journals. This emphasises
38 the need to work closely with decision makers in the production and communication of scientific information (ibid,
39 Moser 2006, Cash et al. 2003 and 2006). This demonstrates a need for two-way communication between producers
40 and consumers of scientific and expert information early in any urban climate change assessment and adaptation
41 planning process (Carmin et al. 2012, Horton et al. 2011, McCarthy et al. 2010).

42 43 44 *8.4.1.5. Assessment Tools: Risk Screening, Vulnerability Mapping, and Urban Integrated Assessment*

45
46 Assessments of risk and vulnerability to climate change's direct and indirect impacts are often the first step in
47 getting the attention of governments, especially where these are assessed in the context of general development
48 policy objectives (Hallegatte et al. 2011; see also 8.2). Including risk management information in infrastructure
49 design at the planning or early design phase including that associated with climate change, can avoid higher costs of
50 retrofit at a later date (Baker, 2012, Dickson et al. 2012). This can be assisted through a variety of planning and
51 assessment tools including environmental impact assessment, vulnerability mapping and urban integrated
52 assessment as part of public investment planning and as used by community organisations (UN-Habitat 2007).
53 Governments can ensure that up to date climate information is available to the private sector to support adaptation
54 (Agrawala et al. 2011; see also section below).

1
2 A wide range of tools have been developed and used to assess the environmental performance of urban areas
3 including environmental impact assessment tools, environmental audits, strategic environmental assessments and
4 local agenda 21s (Haughton 1999) as well as disaster risk assessment and management tools (Baker 2012). These
5 have potential to support adaptation planning, as they provide useful entry points for adaptation and a means for
6 participatory engagement; however in practice they often give little or no consideration to adaptation (Gurran et al
7 2012). More reliable, specific and downscaled projections of climate change and tools for risk screening and
8 management can help engage not only relevant public sector actors but also the interest of businesses and consumers
9 (AGF 2010a, UNEP-FI 2011).

10
11 Local climate change risk assessments, vulnerability and risk mapping can identify vulnerable populations and
12 locations at risk and provide a tool for urban adaptation decision makers (Ranger et al 2009, Hallegatte et al. 2010,
13 Livengood and Kunte 2012). One example is the LOCATE methodology (Local Options for Communities to Adapt
14 and Technologies to Enhance Capacity) that is being tested in eight African countries; in each, a non-governmental
15 organisation is working with one or more communities on project design and implementation, as well as monitoring,
16 evaluation and learning phases. It integrates hazard and vulnerability mapping to inform choices about which
17 populations, infrastructure and areas to prioritise for action (Annecke 2010). Elsewhere, Halsnaes and Traerup
18 (2009) recommend the use of a limited set of indicators, engagement with representatives of local development
19 policy objectives, and a stepwise approach to address climate change impacts, development linkages, and the
20 economic, social and environmental dimensions. There is also a need for assessment tools that go beyond spatial and
21 multi-criteria assessment in order to consider the urban environment as a system; this will allow better
22 understanding of the inter-connections between root causes and risk production, cascading impacts and
23 vulnerabilities (da Silva et al, 2012, UN-ISDR, 2011).

24
25 Tools that organize and rank information on vulnerability in different locations often aim to identify relative and
26 absolute differences in risk and resilience capacity (Manuel-Navarrete et al. 2011, Hahna et al. 2009, Posey 2009,
27 Milman and Short 2008). A review of risk screening and assessment tools, and of experience with their use by
28 different donors and their partner countries (Hammil and Tanner 2011) show how these vary from a quick screening
29 to identify risks to a fuller risk analysis and evaluation of adaptation options. In another review, Preston et al. (2011)
30 consider 45 vulnerability mapping studies highlighting two broad functions: problem orientation (i.e. assessing and
31 understanding the problem) and decision support. Noting the wide variety of functions and methods in the mapping
32 exercises, the review suggests that effectiveness is guided by: identifying clear goals; framing vulnerability in a way
33 that is meaningful to users; choice of robust technical methods; and ensuring engagement of the appropriate
34 stakeholder (user) communities.

35
36 Downscaling of climate scenarios, systems models and urban integrated assessment modelling at local scales
37 integrate different types of information in a forward-looking framework to support policy assessment in an urban
38 context (e.g. Dawson et al. 2009, Hall et al. 2010, Hallegatte et al. 2011, Van Vuuren 2007, Viguie and Hallegatte
39 2012, Walsh et al., 2011). Integrated assessment modelling considers the driving forces of urban vulnerability and
40 climate change impacts alongside possible policy responses and their outcomes. By integrating knowledge, this
41 modelling provides a tool for use in urban areas by policy-makers to examine and better understand synergies and
42 trade-offs across policy strategies. From this, policies can be identified that will deliver benefits across multiple
43 criteria (Viguie and Hallegatte 2012, Dawson et al. 2009). These modelling frameworks take time to build and to be
44 integrated into decision maker processes but early results are promising (e.g. Viguie and Hallegatte 2012, Dawson et
45 al. 2009, Walsh et al., 2011).

46
47 Despite growing attention, useful information and assessment of climate change at urban spatial scales is generally
48 still lacking (Hunt and Watkiss 2011; Kehew 2009). Only a small number of cities, largely in high-income countries,
49 have quantified risks in local contexts and even fewer have quantified possible costs of climate change risks under
50 different climate, adaptation and/or socio-economic scenarios. Some exceptions exist – as in the case of Durban and
51 the development of a benefit-cost model for climate change adaptation options (Cartwright et al 2013). Other
52 exceptions include urban climate risk assessments carried out in low- or middle-income countries as part of targeted
53 development cooperation programmes and thus supported by external partners (World Bank 2011). Sea level rise
54 and coastal flood risk, health and water resources are among the most studied sectors, while energy, transport and

1 built infrastructure receive far less attention (ibid, Hunt and Watkiss 2011, Roy et al. 2012). While science and
2 climate change information is increasingly available, socio-economic drivers of vulnerability and impacts, as well as
3 opportunities and barriers to adaptation, are less well studied or understood (Romero-Lankao and Qin 2011;
4 Measham et al. 2011).

7 **8.4.2. *Engaging Citizens, Civil Society, the Private Sector, and Other Actors and Partners***

9 **8.4.2.1. *Engaging Stakeholders in Urban Planning and Building Decision Processes for Learning***

10
11 If the goal is a resilient, safe and healthy city, having a common understanding or vision of what such a future might
12 comprise at urban scale is a first step to achieving it (Corfee-Morlot et al. 2011, Moser 2006, Moser and Dilling
13 2006, UN-Habitat 2011a). Participatory processes figure prominently across cities that have demonstrated leadership
14 on urban adaptation (Carmin et al. 2012, Brown et al. 2012, Rosenzweig and Solecki 2010; see also below). This
15 experience is consistent with the conceptual literature that suggests that participatory decision-making is essential
16 where uncertainty and complexity characterise scientific understanding of the policy problem (Funtowicz and
17 Ravetz 1993, Liberatore and Funtowicz 2003). Further, many have argued that, the institutional features of the risk
18 management decision-making process -- notably participatory inclusiveness, equity, awareness raising, deliberation,
19 argument, and persuasion -- will determine the legitimacy and effectiveness of action (Dietz 2003, Corfee-Morlot et
20 al. 2011, Lim et al. 2005, Mukheibir and Ziervogel 2007). Yet a recent review of 45 vulnerability mapping exercises
21 found that only 40 percent included stakeholder participation; this raises questions about procedural justice,
22 legitimacy and salience of contemporary approaches to support adaptation investments and other adaptation
23 decisions (Preston et al. 2011). It also highlights the challenge that local governments face to garner resources,
24 including technical expertise and institutional capacity, to organise and effectively use participatory processes to
25 strengthen rather than delay adaptation decision-making (Carmin, Dodman and Chu, 2013).

26
27 In many urban settings, civil society and the private sector already have significant and positive roles in support of
28 adaptation planning and decisions. For example, some studies show that despite limited information, some action is
29 moving ahead on adaptation at urban scale particularly through initial planning and awareness raising (Hunt,
30 Watkiss 2011, Anguelovski, Carmin 2011, Lowe et al 2009, Carmin, Anguelovski 2009). Experience in a handful of
31 cities – e.g. Cape Town, Durban, London, New York -- demonstrate that engaging a wide number and variety of
32 stakeholders at early stages in the risk assessment helps to create political support and momentum for follow-on
33 research and ultimately adaptation planning (Hunt and Watkiss 2011, Anguelovski and Carmin 2011; Rosenzweig
34 and Solecki 2010). In informal settlements where there is little or no formal infrastructure and services, stakeholder
35 engagement provides a means for participatory community risk assessment, where local capacity to adapt is built in
36 part through accessing local knowledge (Livengood and Kunte 2012, Kiunsi 2013). Overtime, it is possible to
37 establish institutional mechanisms that support innovation, collaboration and learning within and across sectors to
38 advance urban adaptation action but this takes time and resources (Mukheibir, Ziervogel 2007, Burch 2010,
39 Anguelovski and Carmin 2011, Roberts 2010).

42 **8.4.2.2. *Supporting Household and Community-Based Adaptation***

43
44 In well governed cities, community groups and municipal governments are mutually supportive providing
45 information, capacity and resources in maintaining local environmental and public safety. Where local government
46 has not yet formulated adaptation strategy, community groups can be important in raising political visibility for
47 climate risks and in providing front-line coping (Wilson, 2006; Granberg and Elander, 2007) including highlighting
48 gender disparities in urban risks (Björnberg and Hansson, 2013). Where cities are less well managed and governed,
49 community organizations may be discouraged and seen as a threat to formal urban planning. They may have to
50 lobby an under-resourced municipality in the hope of getting some provision for infrastructure. Or they may have to
51 address the deficit in roads, drains, good quality buildings and other infrastructure and services themselves (and thus
52 it also falls to them to build local resilience to climate change impacts). This has been observed in rapidly urbanizing
53 middle-income (Redclift, et al 2011) and low-income countries (Pelling, 2011a). But it is generally only in middle

1 and upper income residential developments that the full range of infrastructure and services needed for resilience
2 can be afforded.

3
4 However, in many cities, community organizations formed by lower-income groups offer a rich resource of flexible
5 capacity that can adapt to take on local priorities for development under climate change (Mitlin and Satterthwaite
6 2013). They are active in coping that better uses current resources to live with risk and at adaptation that seeks to
7 realign resource options to prepare for future risks. But shifting the burden of adaptation to the community level is
8 unlikely to bring success. Work from the Caribbean and Latin America has indicated the necessity of supportive
9 linkages to wide community networks and/or local government for community level adaptation to be sustainable
10 (Pelling 2011b)

11
12 Individuals and households in informal settlements are well used to coping with environmental hazards and the
13 human vulnerabilities that generate risk; they have been shown to take multiple measures to mitigate the impact of
14 extreme weather, especially where there is a history of floods, heat waves or high winds (Wamsler 2007, Adelekan
15 2010, Jabeen et al. 2010, Livengood and Kunte 2012, Kiunsi 2013). Some seek to modify the hazard itself e.g.
16 ventilation and roof covering to reduce high temperatures during heat waves or barriers built to prevent floodwater
17 entering homes) or reduce their exposure e.g. by sleeping and keeping food stores on top of high furniture and
18 moving temporarily to safer locations. Exposure reduction measures are the most common (Douglas et al 2008).

19
20 There is an important distinction to be made between coping and adapting. SREX (IPCC 2012) distinguishes
21 between coping as acts that bring together existing resources and entitlements to protect against a current threat, and
22 adaptation, which seeks to adjust entitlements and future resource portfolios in the expectation of future risk. Many
23 studies show the importance of coping mechanisms for low-income households because they lack the resources or
24 capacities for adaption. A study in Korail, one of the largest informal settlements in Dhaka, showed that diverse
25 household responses to flood risk (see Figure 8-2 for one example of this). Measures include barriers across door
26 fronts, increasing the height of furniture, making floors or shelves to store goods above the flood line. Provision for
27 ventilation, creepers or other material on roofs and false ceilings helped to keep down temperatures. Households
28 also used portable cookers that can be used on shelves or furniture (Jabeen et al. 2010). These are important coping
29 responses (and comparable responses are found in many informal settlements – see for instance Adelekan 2010 and
30 Kiunsi 2013) but they do not articulate capacity to adapt – to influence future coping.

31
32 [INSERT FIGURE 8-2 HERE

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

35
36 There are also constraints on the capacity of low-income households to act. For instance, in Korail, many inhabitants
37 did not move to safer locations when floods are anticipated because this risked loss of assets from theft and
38 disrupting livelihoods (Jabeen et al. 2010). They also worried whether they would be allowed to return to their
39 original location. Similar concerns were expressed by the inhabitants of informal settlements during flooding in
40 Santa Fe, Argentina (Hardoy et al. 2011). There is some recognition that strengthening and supporting the asset base
41 of low-income households helps increase their resilience to stresses and shocks, including those related to climate
42 change (Moser and Satterthwaite 2008.).

43
44 Community-based adaptation arises when a group of residents in a particular settlement agree to work together to
45 address a perceived risk they face that the city government is not addressing (Boyd et al. 2009, Dodman and Mitlin
46 2011). These responses to climate change can be autonomous of, or engage with, local governments, sometimes via
47 networks of community organization or with brokerage from NGOs (Mitlin, 2012). There is typically far less need
48 for comprehensive community action in well governed cities, as shown in Table 8-2. In low and most middle-
49 income nations where capacity and resources are most stretched as well as cities in high-income countries with
50 inadequate governance and resource base, enabling community based adaptation and building resilience is more
51 relevant. This is because of the limited capacity of governments to provide much needed risk-reducing infrastructure
52 and services or their unwillingness to work in informal settlements. A range of studies documents how local
53 populations have a depth of knowledge and capacities to mitigate their vulnerabilities (Dodman and Mitlin 2011,
54 Anguelovski and Carmin 2011, Livengood and Kunte 2012). Close to a billion people live in informal settlements in

1 urban areas across the world and for a high proportion of these, community-based adaptation is their only means of
2 response.

3
4 Community-based responses are often reactive – also more coping than adaptation facing - as residents within a
5 particular settlement work together to install or repair infrastructure or provide services or action to engage local
6 government and if possible work with it. There are many precedents for this engagement with local governments,
7 including many upgrading programmes in informal settlements that have improved housing quality and
8 infrastructure provision. Most upgrading programmes also mean that those living in these settlements became
9 incorporated into ‘the formal’ city and this often means other measures by the state to reduce their risks – for
10 instance though access to schools, health care and safety nets (Almansi 2009, Boonyabanha 2005, Fernandes 2007,
11 Ferguson and Navarrete 2003, Imparato and Ruster 2003, Some et al , 2009, UN Millennium Project 2005). In many
12 informal settlements, the issue of land tenure is difficult to resolve and this impedes upgrading programmes and
13 local level adaptation action (Boonyabanha 2005, 2009, Almansi 2009). Where upgrading is able to deliver basic
14 needs and services including security of tenure this can act as a foundation for coping and potentially adaptive
15 capacity. Where adapting to or coping with climate change dovetails with the meeting of existing priorities and
16 reducing existing risks, considerable local scope can exist. But where climate change or disaster risk are seen as
17 distant or low probability then the immediate pressures of poverty tend to dominate local agendas (Banks et al.
18 2011). The studies noted above highlight how the willingness of individuals to invest in collective action is
19 influenced by their tenure status. Tenants and those with the least secure tenure are often amongst the most
20 vulnerable and exposed to hazards but also are usually unwilling to invest in improving the housing they live in and
21 less willing to invest in community initiatives. But the contribution of community-level organization, DRR and
22 climate change adaptation can be greatly enhanced where local governments and other agencies like civil defence
23 organizations recognize the potential role of community organization and action and support them.

24
25 It has become more common for local governments to work with community-based organizations not only in
26 upgrading but also in disaster risk reduction (Pelling 2011b, United Nations 2009, 2011, IFRC 2010). Community-
27 based adaptation will probably be preceded by community-based actions to reduce risks and vulnerabilities to
28 flooding, storms and heat waves in the past (Archer and Boonyabanha 2011, Carcellar et al 2011). But there are
29 limits to what community action can do in urban areas. For instance it may be able to build and maintain community
30 water sources, toilets and washing facilities or construct or improve drainage (see for instance the large community-
31 driven sewers and drains programmes in cities in Pakistan Hasan 2006) but it cannot provide the network
32 infrastructure on which these depend (e.g. the water, sewer and drainage mains and water treatment) or city-region
33 management (Satterthwaite et al. 2009). Most informal settlements are embedded in a larger built up area so there is
34 no space in their periphery to which to channel flood waters or dispose of household wastes. But here, supportive
35 local governments or utilities can help – for instance in Karachi, the water and sanitation utility supported the
36 community-driven provision mentioned above by providing the trunk infrastructure into which it could integrate.
37 There are also many examples of where community organizations in informal settlements negotiated inclusion into
38 formal water and sanitation systems (Boonyabanha 2005), such as in in Penjaringan, a low-income informal
39 settlement in North Jakarta, where community groups organized to gain connection to the city piped water network
40 (Prabahyaka and Pooroe 2010).

41
42 Urban resilience to climate change impacts requires actions, investments and governance frameworks that only local
43 governments can provide, even though private sector and community-based action may support this. A focus on
44 community-action may mean a lack of attention to the structural and institutional inequalities or failures that
45 underpin local vulnerabilities and the failure of local governments and agencies to address these (Dodman and
46 Mitlin 2011). Table 8-3 illustrates the contemporary limits of community based action across key sites of coping and
47 adaptation – highlighting where strategic partnerships, especially with a supportive municipal government have key
48 advantages.

49
50 [INSERT TABLE 8-3 HERE

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

52
53 The IFRC (2011) identify three broad requirements for successful urban community based disaster risk reduction,
54 work that can be extended to assess coping and adaptive capacity. These requirements are: (1) the motivation and

1 partnerships of stakeholders; (2) the levels of community ownership, wider integration and flexibility in project
2 design, and (3) having sufficient time, funding and management capacity.]

3
4 The effectiveness of community-based action is also dependent on how representative and inclusive the community
5 leaders and organizations are. There are examples of its effectiveness where there are representative organizations
6 formed by those living in informal settlements (Appadurai 2004, Mitlin 2012) but also examples of local political
7 structures that inhibit this (Banks 2008 and Houtzager and Acharya 2011). There are also wider constraints on the
8 capacity of community organizations to act. For instance, discussions in El Salvador with the inhabitants of 15
9 disaster-prone “slum” communities and with local organizations showed many making individual and household
10 responses – but difficulties in getting community action as there were no representative community organizations
11 through which to design and implement settlement-measures. In addition, there was a lack of support from
12 government agencies and from civil society organizations (Wamsler 2007).

13
14 The effectiveness of community-based adaptation in urban areas depends on the extent to which community
15 organization (and the larger networks or federations they form) can generate pressure for larger changes within
16 government and for relations between community organizations and government (Boonyabanha and Mitlin 2012).
17 Community-based adaptation can engage with key development agendas that reduce poverty and vulnerability
18 (Sabates-Wheeler et al. 2008) and potentially be effective in light of local inequalities and adverse power relations at
19 district, city, national and transnational levels (Mohan and Stokke 2000). But urban governance regimes are often
20 resistant to challenge and civil society organizations can be marginalized or co-opted reducing scope for adaptive
21 action at the level of governance (Pelling and Manuel-Navarrete, 2011).

22
23 There are new methods of documenting and mapping risks and vulnerabilities in informal settlements that serve and
24 support community based adaptation. Even though it is common for a third or more of the inhabitants of cities in
25 low- and middle-income nations to live in informal settlements, these are often not included in official government
26 records and maps. In a growing number of cities, the mapping and enumeration of informal settlements has been
27 undertaken by residents organizations supported by grassroots leaders and local NGOs – with city governments
28 coming to support these and recognizing the validity of the data and maps produced (Patel and Baptist 2012). These
29 provide the household and settlement data and maps needed to plan the installation or upgrading of infrastructure
30 and services that reduce risks from extreme weather. Some of these community-driven enumerations also collect
31 data for each informal settlement on risks and vulnerabilities to extreme weather and other hazards (Pelling 2011b,
32 Carcellar et al. 2011, Livengood and Kunte 2012, UNHABITAT 2007). For instance, community surveys in the
33 Philippines identified at risk communities under bridges, near cliffs and other landslide-prone areas, on coastal
34 shorelines and river banks, in public cemeteries near open dumpsites, and on those in flood-prone locations
35 (Carcellar et al. 2011). This mapping also helps raise awareness among the inhabitants of informal settlements of the
36 risks they face, as well as getting their engagement in planning risk reduction and making early warning systems and
37 when needed emergency evacuation effective (Pelling 2011b).

38 39 40 8.4.2.3. *Private Sector Engagement and the Insurance Sector*

41
42 Cities represent a particular interest for companies because much business activity, private investment and demand
43 is concentrated there and because of their dependence on the functioning of infrastructure and usually a wide range
44 of services. Brugmann (2012) notes how cities concentrate a high proportion of global investment and value added
45 in global supply chains of production, and therefore a high proportion of what requires adaptation (and the funding
46 needed to realize it). He argues that the costs of effective adaptation reaches far beyond what governments or
47 international agencies can provide and depends on catalysing market-based investments in adaptation and financial
48 instruments that reward investors who contribute to resilience. There is also a large number of private service
49 providers and professional associations -- including architects, engineers and urban planners – positioned to
50 influence the pace and quality of adaptation efforts (McBain et al. 2010).

51
52 Others argue that most of the investment required for sound adaptation will come from a multitude of private
53 decisions spanning individuals, households and firms (Bowen, Fankhauser et al. 2008, OECD 2008). In contrast,
54 international discussions often assume that the public goods nature of adaptation will require a major public

1 investment to cover the principal adaptation needs in low- and middle-income countries (AGF 2010b and c). Even
2 when considering this more political set of questions around how to support adaptation efforts internationally, it is
3 clear that the need for adaptation investments will far exceed available funds from public budgets (Hedger 2011,
4 OECD 2008, World Bank 2010e). This underscores the need for both public and private engagement to address
5 adaptation.
6

7 For markets to work in favour of urban adaptation, the private sector will need to see financial value in getting
8 involved. In a survey of the most serious risks that companies face (Aon 2011), the top ranked risks were economic
9 slowdown, regulatory/legislative change, increasing competition and damage to reputation. Weather and natural
10 disasters came 16th and climate change 44th – even if some risks that were ranked higher may be associated with
11 climate change impacts (business interruption was 5th, commodity price risk 8th and distribution or supply chain
12 failure 12th). It is not clear that private sector actors are well positioned to consider the big questions of urban
13 development that climate change adaptation requires (Redclift et al. 2011). For example, in Cancun, Mexico close
14 relationships between government and the corporate private sector, and the push for lucrative urban development,
15 have led to a failure to reflect on the urban development model and generates climate change risk through hazard
16 exposure of capital intensive and large-scale coastal development. Private sector investments in adaptation in this
17 context are limited to superficial changes, for example in building design to withstand hurricanes; most investment
18 in risk management comes from the state sector through for example beach replenishment and a focus on policies
19 for rapid disaster recovery (Manuel-Navarrete et al. 2011).
20

21 The Private Sector Initiative of the UNFCCC Nairobi Work Programme offers support for businesses to integrate
22 climate change science into their business planning, including urban infrastructure and high technology
23 developments (see http://unfccc.int/adaptation/nairobi_work_programme/private_sector_initiative/items/6547.php).
24 This experience has shown that both public and private (including civil society) actors can have a role in providing
25 regional and local climate predictions and hazard mapping e.g. data and projections on socio-economic trends,
26 climate change, urban water supply and management practices and land use and building trends (UNEP-FI, 2011). A
27 recent review of private sector engagement in adaptation shows anecdotal evidence of some large businesses
28 beginning to invest in vulnerability assessments, yet few have begun to invest in adaptation; these include business
29 with assets at risk to climate change, or with dependence on natural resources that are particularly exposed to
30 climate change e.g. freshwater resources (Agrawala et al. 2011). While some private sector actors may be pro-active
31 in taking action against climate change risks, many more will postpone upfront investments for longer-term benefits
32 against uncertain risks. Eakin et al. (2010) and Chu and Schroeder (2010) suggest that the private sector may
33 become more prominent when local governments and civil society action is limited but this raises the issue of what
34 incentives private sector enterprises require to do so and whether they will do so for the public good.
35

36 Insurance markets can play a unique role in urban adaptation by sharing and spreading financial risk from climate
37 change, for example, to help limit damages and manage risks of climate change in urban flood prone areas
38 (Rosenzweig and Solecki 2010). Risk-differentiated property insurance premiums can incentivise individuals and
39 businesses to invest in adaption or to avoid being or building in high-risk areas (e.g. flood prone or fire hazard areas)
40 and retro-fit property to reduce risk (Fankhauser et al. 2008, Mills 2007). Relevant insurance instruments include
41 provision of health and life insurance to individuals; property and possessions insurance for home and commercial
42 property owners, and micro insurance or micro finance mechanisms to support those in low-income urban
43 communities that are not covered by commercial insurance (see Box 8-2) Catastrophe bonds may also be developed
44 to cover some urban climate risks, however experience to date suggests that they are written quite narrowly - for
45 specific events in specific locations - and thus may not provide the broad protection necessary to limit catastrophic
46 risk as warranted in a changing climate and urban context (Brugmann 2012, Keogh et al. 2010).
47

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

1 2010, Ranger et al. 2011, McFarlane 2008). The risk profile for this informal settlement population is set to increase
2 under most scenarios of climate change. This population will not be served by insurance mechanisms unless the
3 risks they face are greatly reduced (and thus insurance costs lowered). They will rely instead upon government
4 assistance and local solidarity, such as family and community support, to respond when disaster hits (Hallegatte et
5 al. 2010). So insurance while reducing net risk and loss potential in urban areas can increase inequality in security
6 across the city and within neighbourhoods or across regions (da Silva 2010).

7
8 In many informal settlements, informal savings groups are active and provide members with quick access to funds.
9 Most savers and most savings managers are women and these groups have particular importance for providing their
10 members with rapid access to emergency loans (Mitlin 2008). Where access to formal banking is limited by poverty,
11 but where social capital is high, slum dwellers have pooled their savings and used these for collective investments
12 that reduce risk within their existing settlement or reduce risk by allowing them to negotiate land and support where
13 they can build new homes (d’Cruz et al 2013, Manda 2007, Mitlin and Muller 2004).

14 _____ START BOX 8-2 HERE _____

15 **Box 8-2. Microfinance for Urban Adaptation**

16
17 Microfinance schemes may contribute to pro-poor, urban adaptation through a variety of different instruments
18 including micro-credit, micro-insurance and micro-savings to help households and small entrepreneurs that do not
19 have access to formal insurance or commercial credit markets. To date, these have been applied mostly in rural areas
20 generally benefitting those with some property status (and thus not the poorest of rural populations). As Hammill et
21 al. (2008: 117) state: “*The value of MFS holds for climate change adaptation is in its outreach to vulnerable*
22 *populations through a combination of direct and in-direct financial support, and through the long-term nature of its*
23 *services that help families build assets and coping mechanisms over time, especially through savings and*
24 *increasingly through micro insurance – products and sharing of knowledge and information to influence*
25 *behaviours.*” Although typically more costly than commercial bank loans, micro-finance can support entrepreneurial
26 undertakings by those unable to get bank loans, help diversify local economies and empower women in particular,
27 which can in turn contribute to adaptive capacity in a local context (World Bank 2010c, Agrawala and Carraro
28 2010). But micro-finance may focus on short-term gains by encouraging growth in risk-prone areas and sustaining
29 livelihoods with little resilience to climate change (Agrawala and Carraro 2010). This suggests a need for “climate-
30 proofing” microfinance practices and targeting its use to priority tasks that will deliver adaptation and development
31 benefits in the nearer term including disaster risk reduction and community based technical training and education
32 (ibid.). Microfinance also provides a means for donors to deliver support to low-income groups without creating an
33 ongoing dependence on aid (ibid., Hammill et al. 2008). But one limitation of micro-finance for adaptation is that it
34 typically provides credit to individuals for their use only, so it is not easily used to help finance collective
35 investments - for instance to improve drainage - and can be a route into indebtedness especially during disaster
36 recovery. There has been some experience of pooling savings, e.g. in low-income communities to set up City
37 Development Funds in Asia, from which they can draw loans for disaster rehabilitation among other things (Archer
38 2012).

39 _____ END BOX 8-2 HERE _____

40
41
42 For the private sector to fulfil its potential to facilitate adaptation, public policy needs to establish enabling
43 conditions in markets (see 8.3). For example, urban policies can target payment for provision of ecosystem services
44 that will otherwise fall outside of the market system to provide adaptation benefits; such services include storm
45 buffering and flood protection through payments for mangrove protection in coastal zones or payment for protection
46 of urban green space along river-ways (Fankhauser et al., 2008, Roberts et al. 2012). In the buildings sector, well-
47 documented examples of market failure exist where optimal investment in weather proofing new construction and
48 retrofitting existing stock will not occur without regulatory intervention; this is also an area where municipal
49 governments often have authority to act. Public policy and funding is also needed to protect the poorest and most
50 vulnerable populations, who are least able to protect themselves through private action. More generally, where
51 information is highly uncertain or not consistent with past experience, as is the case for the prediction of extreme
52 weather events and potential losses, public policy has a role to help provide information about risks and to ensure
53
54

1 action e.g. to fill gaps in insurance markets where insurers are unable or unwilling to act (Fankhauser et al., 2008,
2 Mills 2007, SREX 2012, UN-Habitat 2011). For example, regulations can require pro-active engagement of the
3 private sector, as in the UK, where vulnerability assessment is required for infrastructure investments with
4 implications for urban planning and investments (Agrawala et al., 2011). Other examples exist where urban
5 governments lead by example by requiring the integration of adaptation considerations into public operations and
6 infrastructure investments through procurement requirements, which in turn affects private sector providers of
7 services and products in the supply chain of these operations. Thus even where markets exist and are well-
8 functioning, public intervention – spanning local to national level action - is warranted as a means to engage the
9 private sector in adaptation. There will also be a role for public-private initiatives to provide educational and skill
10 development resources to ensure that professional networks of private service providers (i.e. architects, engineers
11 and urban planners) are trained in the latest decision tools, assessment methods and practices (McBain et al., 2010,
12 da Silva, 2012)

15 8.4.2.4. *Civil Society Partnerships and Philanthropic Engagement*

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

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

28 One example of this is the Rockefeller Foundation's support for the Asian Cities Climate Change Resilience
29 Network (ACCCRN). This is supporting partner institutions in ten cities in India, Indonesia, Thailand and Vietnam
30 to build local knowledge, capacity and strategies to institutionalise climate change adaptation and resilience in local
31 planning and development. This includes prioritising support for interventions to guide future investments to build
32 resilience into the measures to meet the diverse needs of residents, businesses and the urban economy (Moench et al.
33 2011, Brown et al 2012). Others, such as the Bill and Melinda Gates Foundation approach urban adaptation
34 indirectly through interests in poverty and disaster response and emphasise capacity building through education
35 including programme support for universities in disaster-prone regions in Africa and Asia to establish a network of
36 education and development programs in disaster resilience and leadership organized from Tulane University, New
37 Orleans. The growth in philanthropic foundation spending has as yet largely unresearched implications for the
38 direction of knowledge and capacity building on urban adaptation (Buchner et al. 2011).

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

1 in a structured assessment of the local delivery for disaster risk reduction goals, as set out in the Hyogo Framework,
2 as a means of verifying claims made by national government submissions to the ISDR.
3

4 Where urban-based civil society is well coordinated and has high degrees of legitimacy, it can reach beyond this to
5 offer alternative models for urban governance and for adapting to climate change as part of the development struggle
6 (Mitlin 2012). These are alternatives that need not be in confrontation with local government. Evidence from Santo
7 Domingo, the Dominican Republic has shown the importance of partnerships between local urban government and
8 local civil society actors in achieving longevity, in options for upscaling local disaster risk reduction initiatives and
9 for building on trust generated by such projects to deliver other gains, in this case improved policing and reduction
10 in gang related violence (Pelling 2011b). In the Philippines, many local governments now work with the Philippines
11 Homeless People's Federation in identifying those most at risk to natural disasters and acting to address this
12 (Carcellar et al., 2011)
13

14 The coming together of grassroots civil society organisations to form international collaborations strengthens the
15 framing role of civil society while retaining its local accountability and focus. The local situatedness of adaptation
16 and the need to both address local conditions and structural root causes of vulnerability makes such organisations
17 well placed. Amongst the most active with a dedicated urban focus is Shack/Slum Dwellers International (SDI), a
18 network of community-based organizations and federations of the urban poor in 33 countries in Africa, Asia, and
19 Latin America and their local support NGOs. Its member federations share experiences, lobby and undertake
20 practical upgrading and risk reduction initiatives as well as seeking to influence the policies of development
21 assistance agencies. Regional networks of organisations also contribute to the emerging international architecture of
22 civil society movements working on risk reduction - for example, the Asian Coalition for Community Action
23 Program managed by the Asian Coalition for Housing Rights is supporting community-driven upgrading initiatives
24 in 150 cities in 18 different nations and supporting improved relations between community organizations and local
25 governments (REF). Other civil society networks have broader interests but include urban risk reduction, for
26 example the Asian Disaster Reduction and Response Network (ADRRN), which aims to strengthen local civil
27 society groups in the region.
28
29

30 *8.4.2.5. University Partnerships and Research Initiatives* 31

32 Since AR4, interest in urban aspects of adaptation has grown amongst researchers and universities and some
33 associated national research funding agencies. This is also evident in the number of conferences on this topic and in
34 the number of professional societies (including architects, urban planners and engineers) that are considering their
35 roles and responsibilities. Parallel agendas from social and behavioural sciences and policy on one hand and
36 engineering and city planning sciences on the other are beginning to integrate. Examples of this include the Urban
37 Climate Change Research Network (UCCRN), which brings together researchers and city planners to exchange
38 knowledge and build a coalition of awareness and policy – particularly important when national level policymaking
39 on adaptation is slow (Rosenzweig et al, 2010).
40

41 The Urban Global Environmental Change Programme (UGEC) of the International Human Dimensions Programme
42 of the Earth Systems Science Partnership (ESSP) was a pioneer in promoting social science and knowledge
43 exchange and has built international networks in adaptation, mitigation and relationships between these two.
44 Urbanization and adaptation has become a thematic issue dealt with by the Land-Ocean Interface at the Coastal
45 Zone (LOICZ) programme through its interest on megacities and coastal urban regions. The role of adaptation and its
46 interaction with disaster risk reduction is also highlighted by the International Scientific Union project, Integrated
47 Research on Disaster Risk (IRDR). There is also the IDRC funded research on urban adaptation in Africa and the
48 START programme supporting research on global environmental change in Africa and Asia-Pacific.
49

50 Individual academic institutes have also begun to champion and support urban adaptation efforts. For example the
51 Urban Observatory in Manila has become a regional hub for climate change science and urban adaptation, though
52 interests in mitigation and rural adaptation are much more developed. In Malaysia the Universiti Kebangsaan
53 Malaysia hosts a Malaysian Network for Research on Climate, Environment and Development (MyCLIMATE) and
54 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, Angelovski 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 Governments that represents local governments within the United Nations have a growing interest in climate change adaptation. The Asian Cities Climate Change Resilience Network (ACCCRN) mentioned above also encourages inter-city learning for officials and local researchers (Brown et al. 2012). 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

1 governance structures or where administration is manifestly lacking in capability. One key issue here is 'unfunded
2 mandates.' In many nations, local governments have been assigned responsibilities without the needed increase in
3 funding and capacity (UCLG 2011) – and this may now also happen in relation to new responsibilities for adapting
4 to (or mitigating) climate change (Kehew et al. 2012). The implication is that the funding regime and supportive
5 legal frameworks need to integrate climate change risk management and adaptation into development.
6
7

8 8.4.3.1. Domestic Financing: Tapping into National or Sub-national Regional Sources of Funding and Support 9

10 Domestic public funding is one of the most significant and sustainable source of funding for adaptation in many
11 countries. In recent years, initiatives to green local fiscal policies have spread. These include congestion charges on
12 automobiles and value-capture land taxes that make visible the cost of environmental externalities and/or the
13 benefits of infrastructure and services provided to property owners (e.g. transport, water and wastewater services).
14 Such measures can promote private investment in risk management while mobilising local revenue sources (where a
15 portion could be targeted to support urban adaptation). Local fiscal incentives for mal-adaptation may also exist, e.g.
16 in China and parts of Québec, urban government budgets and actions are financed by land sales, which in turn
17 promote urban sprawl or development in areas at risk (Merk, 2012; Drejza et al. 2012). Greening local fiscal policies
18 will need to identify and address pre-existing policies that incentivise mal-adaptation.
19

20 Another important source of funding for local adaptation is grants, loans or other forms of revenue transfers from
21 national or regional (sub-national) governments (OECD 2010: Ch 9, Hedger and Bird 2011). OECD (2010:239)
22 states: “*In cases where environmental policies with large spillovers are assigned to local governments,*
23 *intergovernmental grants could make sense in order to compensate local governments for the external benefits of its*
24 *expenditures.*” One example of this is municipal funding in Brazil that is influenced by ecosystem management
25 quality; in this case the allocation of tax revenues is performance based (see Box 8-3).
26

27 _____ START BOX 8-3 HERE _____
28

29 **Box 8-3. Environmental Indicators in Allocating Tax Shares to Local Governments in Brazil** 30

31 In Brazil, part of the revenues from a value-added tax (ICMS) collected by state governments must be redistributed
32 among municipalities. Three-quarters of this is defined by the federal constitution, but the remaining 25% is
33 allocated by each state government. The state of Paraná introduced the ecological ICMS (ICMS-E) in 1992,
34 followed by several other states. It was introduced against the background of state-induced land-use restrictions
35 (protected areas) for several municipalities, which prevented them from developing land but provided no
36 compensation. For example, 90 percent of the municipality of Piraquara is designated as a protected area for
37 conserving a watershed to supply the Curitiba metropolitan region with water (May et al. 2002).
38

39 Although the states have different systems in place, there are many commonalities in the allocation mechanism.
40 Revenues are allocated according to an ecological index based on the proportion of a municipality’s area set aside
41 for protection. Protected areas are weighted according to different categories of conservation management ranging
42 from 1.0 (for ecological research centres and biological reserves) to 0.1 (for special local areas of tourist interest,
43 and buffer zones). Paraná and some other states include an evaluation of the quality of the protected areas in the
44 calculation of the index based on physical quality, biological quality (fauna and flora), quality of water resources,
45 physical representativeness and quality of planning, implementation and maintenance.
46

47 Evaluations in Paraná and Minas Gerais show that the introduction of the ICMS-E has been associated with
48 improved environmental management and the creation of new protected areas (May et al. 2002). The ICMS-E has
49 also improved relations between protected areas and the surrounding inhabitants, as they start to see these as an
50 opportunity to generate revenue, rather than an obstacle to development. The ICMS-E has built on existing
51 institutions and administrative procedures, and thus has had very low transaction costs (Ring 2008).
52

53 _____ END BOX 8-3 HERE _____
54

1 A number of other innovative financial mechanisms may be used to support urban adaptation. These include
2 revolving funds and the energy services company (or the “ESCO”) model (OECD 2010:Ch. 8 and Ch 9). Revolving
3 funds can be developed from a variety of different revenue streams, say from a Clean Development Mechanism
4 project (Puppim de Oliveira 2009) or financial savings from energy efficiency investments in municipal buildings,
5 to feed a public fund that can support public investments that yield adaptation benefits. Local governments in high
6 and some middle income countries may also have direct access to debt instruments such as bond markets or loans
7 from national (or regional) development banks or financial institutions (OECD 2010, EIB 2011). Local access to
8 capital markets to fund adaptation investments can also be facilitated through risk-sharing mechanisms or financial
9 guarantees provided by external or domestic development banks e.g. Kfw provides low-interest loans to local banks
10 which in turn finance energy efficiency renovations in residential and commercial building (OECD 2010, Kfw
11 2011). Funding for climate change adaptation in cities is usually oriented towards technological investment and
12 capital projects, rather than to integrating economic and social approaches. A key challenge is to determine how far
13 adaptation funding should be recalibrated to better take advantage of inputs from social, economic and behavioural
14 sciences and target associated policy realms. For example, the very high costs brought by extreme weather events in
15 urban areas, described in earlier sections, and the fact that climate change increases these risk indicates the need for
16 increased funding and attention from national budgets for disaster risk reduction, early warning and evacuation
17 procedures within urban areas, alongside other adaptation measures (World Bank 2010a, 2010f, Hallegatte and
18 Corfee-Morlot 2011). The urban funding gap may be particularly wide for “soft” rather than “hard” infrastructure
19 investments yet they can be a motor for resilience.
20

21 22 8.4.3.2. *Multilateral Humanitarian and Disaster Management Assistance* 23

24 The international humanitarian community is increasingly active in urban contexts. The scale and scope of action is
25 often impressive, particularly when large disasters unfold in major urban areas. There is opportunity for
26 humanitarians to learn from non-climate related disasters (earthquakes, tsunamis and technological or military
27 events), and the sector is beginning to review experience and develop appropriate tools and guidelines for urban
28 contexts (eg ALNAP, 2012). In 2009 the Inter-agency Standing Committee, an umbrella group of humanitarian
29 groups that sets policy for the aid community, formed a reference group on meeting humanitarian challenges in
30 urban areas, setting a two-year action plan in 2010. It has developed a database of urban specific aid tools, the Urban
31 Humanitarian Response Portal (<http://www.urban-response.org/>). The complexity faced by humanitarians working
32 in urban areas makes it difficult to target aid to risk reduction or response. One report concludes that the
33 humanitarian sector needs to make better use of social sciences and urban planning in humanitarian teams to better
34 understand urban settings (Grünwald et al, 2011). Amongst the biggest challenges facing the sector working in
35 urban contexts is to develop policies sensitive to the needs of internally displaced urban populations, and how this
36 can be managed in contexts where the resident population is chronically poor (Zetter and Deikun, 2010); also how
37 international agencies can respond appropriately to the prospect of a significant increase in urban food insecurity
38 (see IRIN, 2013).
39

40 The systematic programming of climate change adaptation into multilateral humanitarian, disaster response and
41 management funding is in its infancy and urban dimensions are largely under-developed although this is changing
42 (see United Nations 2009, 2011, IFRC 2010). The World Bank’s Global Facility for Disaster Reduction and
43 Recovery (GFDRR) explicitly includes adaptation to climate change and its Country Programmes for Disaster Risk
44 Management and Climate Change Adaptation 2009-2011 also seek to deepen engagement in selected priority
45 countries (GFDRR 2009). The GFDRR has also worked with UNISDR to advocate for more joined up policy and
46 advisory services at the technical level (see Mitchell et al. 2010). A survey of 2009-2011 reports from 82
47 governments on how they were advancing disaster risk reduction and the treatment of urban and climate change
48 issues within this, found that some progress has been made in both areas, across different types of countries (i.e.
49 from low to high income) (Figure 8-3, United Nations 2011).
50

51 [INSERT FIGURE 8-3 HERE

52 Figure 8-3: Progress reported by 82 governments in addressing some key aspects of disaster risk reduction by
53 countries’ per capita income.]
54

1 Despite such progress, many urban governments lack the capacity to address disaster risk reduction and
2 management. Almost 60 percent of the countries surveyed by the UN and almost 80 percent of lower-middle income
3 countries reported that local governments have legal responsibility for disaster risk management, but only about a
4 third confirmed dedicated budget allocations and these were mostly in upper middle and high income countries
5 (United Nations 2011). Figure 8-3 highlights a relative lack of attention to urban and land-use planning and greater
6 attention to investments in drainage infrastructure. As a whole, attention to these linkages is lower in low and lower-
7 middle income nations, yet in more than half the high to lower middle-income nations, governments reported
8 progress to integrate climate change policies into disaster risk reduction.
9

10 11 8.4.3.3. *International Financing and Donor Assistance for Urban Adaptation* 12

13 To date international adaptation financing has largely overlooked urban areas (UN HABITAT 2011) and most of the
14 most vulnerable cities and municipalities are not well positioned to access available funding (ICLEI, 2010, Paulais
15 and Pigey 2010). This generates a double funding gap – low availability of funds for adaptation and often very large
16 deficits in risk-reducing infrastructure and services.
17

18 While more international funding for adaptation and mitigation is being committed (see for instance the Cancun
19 Agreements) and there are some indications that governments are broadly on track to deliver on these (Clapp et al.
20 2012, Buchner et al. 2011), there is less in evidence is the institutional arrangements by which such support is
21 available to urban governments for adaptation – and thus to support work that can build adaptive systems for urban
22 management, systems that evolve with changing social and environmental dynamics as indicated in the IPCC SREX
23 report (IPCC, 2012). The failure to explicitly recognise urban adaptation needs is also the case for new dedicated
24 climate change funds. In addition, international public funding for adaptation may be difficult to discern from
25 development finance (Tirpak et al. 2010, Buchner et al. 2011).
26

27 Recent data suggest that a notable yet still minor share of development finance targets climate adaptation (UNEP
28 2010, OECD 2012). The extent to which urban adaptation is explicitly or even indirectly covered in donor portfolios
29 is largely unknown, although many bilateral agencies choose to have a very limited engagement with urban
30 initiatives (Satterthwaite and Mitlin, 2013). OECD estimates that between 23-38% of reported ODA commitments
31 from bilateral donors for climate change target adaptation (OECD 2012). In an in-depth assessment of five major
32 donors, with coverage of concessional (ODA) and non-concessional finance, adaptation was estimated to be 30% of
33 the climate change portfolio, most of it targeted to water and sanitation (about 75%) while the remainder targeted
34 urban relevant sectors (i.e. transport, policy loans, disaster risk reduction) with energy and health seemingly largely
35 overlooked (UNEP 2010, see also Atteridge et al. 2007). Conventional multilateral and bilateral channels for
36 development finance appear to have the biggest role in adaptation financing, though several new vertical funds are
37 also emerging. The proliferation of multiple, single purpose funding mechanisms runs contrary to long-standing
38 principles of sound development cooperation notably harmonisation and alignment (McKenzie Hedger 2011). This
39 also creates a more complex funding architecture, making it difficult for smaller actors, such as local authorities, to
40 access available sources for timely adaptation investments.
41

42 Reconciling external resources with bottom-up, locally based planning and project preparation could provide a
43 means to better target development assistance (i.e. to urban planning processes that take climate risks into account),
44 while also ensuring that limited funding is directed to programmes that aim to be mainstreamed into urban
45 development over time (Brugmann 2012). Yet research shows that partner countries typically lack defined priorities
46 for the use of funds; when combined with a donor tendency to “control” funds to ensure short-term results, and a
47 large variety of different funding instruments, the result is highly fragmented delivery systems that lead to unclear
48 outcomes (Peskett and Brown 2011). Even where national leadership and climate strategies exist to guide action – as
49 in the case of Bangladesh, an “early mover” on adaptation planning – the plan is not yet costed nor is it sequenced.
50 This makes it difficult to use as a framework for delivery of international climate finance (McKenzie Hedger 2011).
51 A key to improving effectiveness of international public finance will be building the capacity for country-led
52 planning processes that identify priority projects and programmes for the targeting of adaptation funds that include
53 urban adaptation.
54

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

9
10 A growing consensus among authors concludes that international development finance is failing to tackle urban
11 adaptation financing needs (Parry et al 2009, Paulais and Pigeay 2010, UN-Habitat 2011c, ICLEI 2011a). In some
12 middle income countries, such as Indonesia, rather than focusing on large amounts of new external funding to
13 support climate action, a more effective and sustainable strategy may be national fiscal policy reforms and
14 incentives to steer investment to priority needs (Peskett and Brown, 2011). Beyond better delivery and use of
15 development finance, there is also a need to mobilise domestic public and private investment to ensure delivery of
16 adaptation at national and urban levels (Hedger 2011a & b, Hedger and Bird 2011, OECD 2012). Accessing
17 international development finance for urban adaptation will require building routine institutional mechanisms for
18 supporting multilevel planning and risk governance (Corfee-Morlot et al. 2011, Carmin et al, 2013).

19 20 21 *8.4.3.4. Institutional Capacity and Leadership, Staffing, and Skill Development*

22
23 A critical factor of generating interest in urban adaptation is leadership, for example from the Mayor's office or from
24 entrepreneurial staff that understand the challenge and champion awareness raising and institutional change to bring
25 action (Anguelovski, Carmin 2011, Carmin et al. 2012). Creation of a climate change and environmental focal point
26 or office in a city can help to champion and coordinate climate action across government departments or line
27 management agencies (Roberts 2008a, 2010, Anguelovski, Carmin 2011, Hunt and Watkiss 2011, OECD 2011,
28 Brown et al. 2012). Yet there may be downsides when the urban climate change function is housed by the
29 environmental line department (e.g. Durban - Roberts, 2008 :523, Boston see Boston 2010, Sydney see Measham et
30 al. 2010). Roberts (2010) notes that urban environment line managers or departments are typically among the
31 weakest parts of city government. This in turn can marginalise the climate change coordination function to the low
32 or lower priority and limited resources are usually assigned to environmental departments within government
33 structures, which results in limited institutional influence.

34
35 Although there is growing evidence of adaptation leadership in urban contexts (Anguelovski and Carmin 2011,
36 Lowe et al 2009, Carmin and Anguelovski 2009, Foster et al., 2011b), there are also important political constraints
37 to making adaptation decisions at the local level. Local government decisions are often driven by short term
38 priorities and nearer term concerns about economic growth and competitiveness, making it difficult for them to
39 focus on the more distant implications of climate change (OECD 2009, Romero Lankao and Qin 2011, Pelling
40 2011A). Powerful vested interests may oppose attention to adaptation and can promote development on sites at risk
41 (e.g. coastal or river-side real estate developments). A key step forward is to work towards institutionalising
42 different types of behaviour and norms to recognise and act upon climate and disaster risk (Figure 8-4).

43
44 [INSERT FIGURE 8-4 HERE]

45 Figure 8-4: The basic challenge of effective climate change communication to change behavior and norms.]

46
47 Beyond goal setting and planning for adaptation and disaster risk management, governments also need a regulatory
48 framework that ensures relevant behaviour and investment, creates job descriptions that require actions and provide
49 incentives to act in new ways (e.g. for line managers and sector policymakers); they also need to provide training for
50 staff and clear guidance on what to do (Moser 2006). Establishing budgetary transparency and metrics to measure
51 progress on adaptation will also help to institutionalised changes in planning and policy practice (OECD 2012).

1 8.4.3.5. *Monitoring and Evaluation to Assess Progress*

2
3 Tools for monitoring and evaluation of urban adaptation actions are needed to assist adaptation leaders and funding
4 institutions to justify investments. Monitoring urban adaptation activities and their effectiveness requires indicators
5 that show if adaptation is taking place, at what pace, and in what locations. Among the relevant evaluation criteria to
6 track are: cost, feasibility, efficacy, co-benefits (direct and indirect), and institutional considerations (Jacob et al.
7 2010). Assessment methods can capture outcomes of adaptation decisions, or the decision-making processes
8 themselves, and ideally both. Monitoring is particularly challenging for urban adaptation given that there are no
9 standard metrics to assess progress (Lamhauge et al. 2011, GIZ et al. 2012).

10
11 City authorities, NGOs and researchers have begun to design adaptation monitoring and evaluation frameworks.
12 Coordinated development of tools offers scope for international benchmarking and comparison and coordination
13 across scales of assessment, for example by associating local indicators of resilience with international ones
14 attributed to the Hyogo Framework for Action and post-2015 agenda (IFRC, 2011). Box 8-4 presents the experience
15 of monitoring from New York City.

16 _____ START BOX 8-4 HERE _____

17
18
19 **Box 8-4. Adaptation Monitoring: Experience from New York City**

20
21 Jacob et al. (2010) describe an adaptation monitoring approach developed for New York City. This has four
22 indicator elements: (1) physical climate change variables; (2) risk exposure, vulnerability and impacts; (3)
23 adaptation measures; and (4) new research within each of these categories. Examples of climate change adaptation
24 indicators arising from these four categories include: the percentage of building permits issued in any given year in
25 current FEMA coastal flood zones, and in projected 2080 coastal flood zones; an exact tally of building permits that
26 have measures to reduce precipitation runoff; an index based on insurance data that measures the insurer's
27 perception of New York City's infrastructure-coping capacity; an index that measures the rating of bonds issued by
28 the City or infrastructure operators for capital projects with climate change risk exposure; the detailed trend of
29 weather-related emergency/disaster losses (whether insured or uninsured, relative to the total asset volume); and the
30 number of days with major telecommunication outages (wireless versus wired), correlated with weather-related
31 power outages.

32
33 _____ END BOX 8-4 HERE _____

34
35 The New York experience has demonstrated that once monitoring is in place new demands for data can refine
36 existing data collection systems including a preference for long-term data sets that span a range of disciplines. This
37 has additional benefits for adaptive planning. In the New York case this need was resolved through data criteria
38 decided through a scientist-stakeholder consensus with designated groups used to evaluate prospective indicators
39 and their values. With its focus on data and processes required to monitor progress on urban adaptation, this case
40 study shows the need for interdisciplinary and longitudinal data collection and analysis systems along with an
41 inclusive and transparent process for stakeholder engagement to interpret the data as part of new monitoring
42 programmes.

43
44 A more established aspect of monitoring and evaluation focuses on the effectiveness of donor aid on climate
45 adaptation (Chaum et al. 2011). Recent work shows that consistent and internationally harmonised data collection is
46 urgently needed to support monitoring, this is a concern for adaptation and wider disaster risk reduction spending
47 suggesting a systemic challenge to the architecture of international finance (Kellett and Sparks, 2012). Steps are
48 being made in this direction through multi-site assessment programmes and in some instances this includes
49 treatment of urban issues. For example, the World Bank has recently included an adaptive capacity index as part of
50 an analysis of risk and adaptation options for five cities in Latin America and the Caribbean; the methodology was
51 applied before this to Guyana where it demonstrated a gap between national and city level adaptive capacity (Pelling
52 and Zaidi, 2013).

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

8
9 Thus, in reviewing the development of urban adaptation interventions and strategies, do or will they:

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

21 22 23 **8.5. Conclusions**

24 25 **8.5.1. Introduction**

26
27 *Urban areas are and increasingly need to be at the forefront of climate change adaptation and mitigation agendas.*
28 They house more than half the world's population and concentrate most of its assets and economic activities. Urban-
29 based activities generate a high proportion of global greenhouse gas emissions so urban policies are key to
30 addressing mitigation. Urban centres also concentrate a high proportion of the population and economic activities
31 most at risk from climate change and most in need of adaptation. Most of the increase in the world's population and
32 much of the increment in capital formation, economic activity, infrastructure development, ecosystem degradation
33 and emissions is projected to take place in urban areas in low- and middle income countries. Urban centres are thus
34 places where the present and future well-being and safety of humanity must be secured in the face of the increasing
35 uncertainty generated by climate change and other socio-ecological challenges (da Silva et al 2012).

36
37 *The key role of urban governments in climate change adaptation has become more widely recognized.* One example
38 of this is the signing of the Durban Adaptation Charter in December 2011 by 107 mayors representing over 950
39 local governments at COP17. This signalled their intention to begin addressing climate change adaptation in a more
40 concerted and structured way and is indicative of the climate change leadership being shown by local governments
41 around the world (Rosenzweig et al 2010). But as this chapter has described, the way forward is not simple, with
42 both climate change and climate change adaptation being acknowledged as highly complex and difficult to resolve in
43 most urban contexts (Martins and Ferreira 2011, Fünfgeld and McEvoy 2011). As yet, only a small proportion of
44 urban governments have begun to act on adaptation, often with variable levels of national support.

45
46 *Because of the complexities and uncertainties involved, action has been limited and focused mostly 'no-risk' and*
47 *'low cost' interventions that have adaptation as a co-benefit of existing work streams, rather than a new, stand*
48 *alone work area* (Roberts 2008a, Toronto Environment Office 2008, Runhaar et al 2012). This 'business-as-usual
49 with climate benefits' approach has resulted in a focus on interventionist and reactive infrastructure or asset-oriented
50 adaptation (e.g. LCCP 2006, Awuor, et al., 2008, Mehrotra et al. 2011a, Mees and Driessen 2011) rather than on the
51 'soft' or process (i.e. human, institutional and ecological) elements of adaptation, such as resilient development,
52 good governance, poverty reduction, livelihood security, social cohesion and ecosystem based adaptation (Lwasa
53 2010, Jones et al. 2010). A focus on adaptation measures rather than on building adaptive capacity or resilience is
54 especially problematic in urban areas of the global South where it is "limited by resources, weak institutions,

1 poor/inadequate infrastructure and poor governance” (Kithiia 2009:19). This suggests a need to shift from looking at
2 “what a system *has* that enables it to adapt, to recognising what a system *does* to enable it to adapt” (Jones, et
3 al2010:1). This in turn implies a need for more open-ended and flexible concepts such as adapting well, climate
4 smart, sustainable adaptation and resilience (Eriksen and Brown 2011, Wilson and Termeer 2011, Brown et al.
5 2012).

6
7 *This socio-institutionalempphasis also encourages a more transformative view of adaptation.* It shifts from being a
8 tool of last resort, or an ‘end-of-the-pipe’ and incremental intervention (Roberts, et al. 2012:2; Foster et al. 2011)
9 that supports the prioritisation of existing coping strategies (Heindrichs et al, 2011:216) to one that underscores the
10 need for “bouncing forward” (Shaw and Theobald, 2011; Manyena et al 2012) and a departure from the norm. This
11 is characterised in Table 8-2 as a shift from adaptation to resilience and then transformation (Pelling 2011a). This
12 ‘business-unusual’ approach is especially important in a world where transgressions of key planetary boundaries
13 such as climate change and biodiversity will take humanity out of the globe’s “safe operating” space (Rockström et
14 al. 2009: 1) into an unsafe and unpredictable future. If effective adaptation in urban centres is good development
15 conceived and implemented with adaptation in mind, transformation is adaptation that helps achieve the needed
16 global reductions in greenhouse gas emissions and other drivers of anthropogenic climate change. This requires
17 changes to the “fundamental attributes” of existing technological, governance, planning, economic, cultural and
18 value systems(IPCC 2011; Costanza et al 2012, O’Brien, 2011, Pelling 2011a).

21 8.5.2. *What Hinders Adaptation Progress in Urban Areas?*

22
23 *Lack of mandate:* There is a need to clarify which sphere (national, provincial, metropolitan and urban) of
24 government has a legal mandate to act on climate change through the promulgation and assignment of appropriate
25 constitutional and legal powers. Without these formal mandates, adaptation becomes an optional and discretionary
26 extra, dependent on local level interest and resources and particularly vulnerable to leadership change. Although
27 much of the innovation in adaptation and mitigation has come from particular local governments, for these to
28 become effective at a national scale and to ensure coherence and widespread implementation, support from higher
29 levels of government is required (Kazmierczak and Carter 2010, also Carter 2011, Brown 2011, Martins and Ferreira
30 2011). Where mandates exist, they have been important in driving local level action (Kazmierczak and Carter 2010)
31 but they need increased co-ordination and co-operation if they are shared between the different spheres of
32 government (Martins and Ferreira 2011, Carter 2011) or cross jurisdictional boundaries. New mandates (formal or
33 informal) may also require institutional changes(Lowe *et al.* 2009, Roberts 2008a, Kazmierczak and Carter 2010).

34
35 *Political obstacles:* Decisions in urban centres including those related to climate change adaptation, are affected by
36 political interests and competition for support (Mees and Driessen, 2011, Brown et al, 2012). Those who are most at
37 risk from climate change are often those with the least voice and influence on these decisions. Addressing
38 constraints such as information and resources alone will not ensure transformation if there is political resistance,
39 particularly as politicians control local level resources (Roberts 2008a). A further complication is the disjuncture
40 between political and climate time lines (Mees and Driessen, 2011). This sets short-term (often personal
41 advancement) priorities against the inter-generational and public good impacts of climate change adaptation, making
42 communicating and negotiating climate change related objectives in the political space often very difficult to
43 achieve (UN-Habitat 2010).

44
45 *The weakness of climate change focal points within local government:* These are often housed in or championed by
46 environmental line department which usually leads to marginalisation (Roberts 2010, Hardoy and Romero Lankao
47 2011) and limited institutional influence and access to resources given the low priority usually assigned to
48 environmental departments. There is also a concern that in the current recession, that local authorities(with already
49 limited resources) will prioritise conventional economic and development goals over ‘environmental’ issues
50 including climate change adaptation(Shaw and Theobald 2011, Solecki 2012).

51
52 *Undervaluing community resources and social capital:* Although 8.4 gives examples of the effectiveness of
53 household and community based adaptation in urban contexts, there is still limited work and limited understanding
54 of the potentials and limitations (Jones et al. 2010). This is a critical gap given that social capital and community

1 based adaptation may provide opportunities to achieve the “bouncing forward” required by adaptation, as
2 community collaboration, relationships and trust can provide a platform to generate material interventions directed
3 at reducing vulnerability (Kithiia 2009). The issue of social capacity has been identified as important to urban
4 resilience in a number of urban areas (TARU 2011, Roberts 2010) but there is also a need to determine the limits of
5 community based intervention; for example, communities cannot install, maintain and fund trunk infrastructure and
6 the scale and scope of needed service provision at city and city-region scales.

7
8 *The complexities of developing locally relevant adaptation plans:* Mitigation-focused interventions provided the first
9 experiential training for most local governments engaging with climate change. These were often based on step-wise
10 guidebooks or programmes (e.g. ICLEI’s Cities for Climate Protection Programme, UN-Habitat’s Planning for
11 climate change manual) (Anguelovski and Carmin 2011, Martins and Ferreira 2011). Experience with adaptation
12 programmes show they are less open to a standard set of requirements, given that actions are oftencross-sectoral,
13 cross-institutional, complex, operating across a range of scales and timelines, rooted in local contexts, involve more
14 stakeholders and include high levels of uncertainty (Roberts et. al. 2012, Roberts and O’Donoghue 2013). More than
15 standardised guidelines, urban adaptation practitioners need clarity, creativity, and courage (ICLEI Oceania 2008).

16
17 *Dealing with uncertainty:* Adaptation costs are immediate, a fact which contrasts with the uncertainty associated with
18 climate change projections (see 8.2.5.1.) and the possible delay in the benefits (OECD 2010). A pragmatic approach
19 is therefore to focus on existing vulnerabilities and to use those to identify ‘no-regrets’ options with near and long-
20 term co-benefits such as enhanced competitiveness, improved service delivery, economic resilience (and success),
21 job creation and risk management as these help get the attention of politicians and decision makers (e.g. Durban,
22 London, New York and Copenhagen) (Foster et al. 2011, Roberts 2010, GLA 2011, City of New York 2011, City of
23 Copenhagen 2011, Runhaar et al., 2011). The use of scenario planning as a possible alternative to scaled down
24 projections, the undertaking of further studies to develop better local data and understand the costs of inaction,
25 avoiding maladaptation and increasing awareness also contribute to increased adaptive capacity (Tyler et al. 2010,
26 OECD 2010, TARU 2010, Neimi 2009). Facilitating networking and learning between adaptation practitioners also
27 assists in improving the capacity to deal with uncertainty (Mees and Driessen, 2011).

28
29 *The issue of thresholds and conflicting agendas:* Most local governments acknowledge the value of mitigation and
30 adaptation, but to lead with one or the other depending on circumstances, priorities, resources and institutional
31 affiliations (Roberts 2010, Carmin et al. 2012, Hamin 2011, Moser 2012). The result is that little progress has been
32 made in ensuring that adaptation and mitigation policy goals are not in conflict (Hamin and Gurrán 2009, Moser
33 2012). Section 8.3.3.7 discussed what Hamin and Gurrán, 2009 described as the “density conundrum” where the
34 densities that serve mitigation can prevent or limit the possibilities of ecosystem based adaptation and may also
35 exacerbate the urban heat island and limit the possibility of utilizing solar energy. There is therefore an urgent need
36 for research to determine the thresholds for unacceptable biodiversity change and to derive from these locally
37 specific limits to urban densification and ensure that climate actions do not undermine other global environmental
38 change agendas such as biodiversity protection (Moser 2012). The issue of thresholds is also relevant beyond
39 biodiversity concerns, for example, determining when and where adaptation is no longer possible in urban areas, due
40 to technical difficulties or cost (or both) resulting in residual damage (UN-Habitat 2011c, Parry et al. 2009). This
41 knowledge about limits within existing systems will be vital in developing appropriate planning responses to future
42 climate challenges, especially as there is increasing concern that the current state of global inaction and lack of
43 ambition on mitigation could result in 4 degrees or more of global warming, necessitating a “more substantial,
44 continuous and transformative process” of adaptation (Smith et. al. 2011:196). This also raises the possibility of
45 abrupt, non-linear and unpredictable global environmental change (Rockström et al. 2009) that will stretch the
46 adaptive capacity not only of existing urban systems, but of the whole global system.

47 48 49 **8.5.3. What Contributes to the Development of Effective Transformative Adaptation Plans?**

50
51 *Building on future urbanization opportunities:* United Nations projections suggest that in the next 40 years, the
52 world’s urban population will nearly double (United Nations 2012) requiring the same scale of urban infrastructure
53 be built in 40 years as in the past 4000 years (ICLEI, 2011b). This provides a transformative opportunity at a global
54 level, especially in the global South with its large infrastructural deficits, to break away from unsustainable lifestyles

1 and patterns of development and ensure that urban areas develop in ways that acknowledge that “natural capital and
2 ecosystem services are not infinitely substitutable, and real limits exist” (Costanza et al 2013). This represents a
3 significant opportunity to urbanise the adaptation agenda, and converge climate mitigation and adaptation actions
4 within an understanding of a “full-world” context (Costanza et al 2013).

5
6 *Prioritising poverty reduction within climate change responses:* While cities like Boston and London consider low-
7 income groups among the vulnerable groups in their planning (Boston 2011, GLA 2011) for most cities and smaller
8 urban centres in low and middle-income nations, poverty reduction needs more attention because of its greater scale
9 and depth and because of the strong association between poverty and poor environmental health (Hardoy et al.
10 2001), disaster risk (United Nations 2009) and climate change risks (Hardoy and Pandiella 2009). Given this and the
11 pressing development needs in these urban centres (e.g. infrastructure, health care and emergency services,
12 education, housing and energy), climate change adaptation needs are often viewed as marginal in comparison. There
13 is therefore a need to work within the development context of each country and urban area (Kithiia and Dowling
14 2010, Roberts 2008a) and to demonstrate how adaptation can support development that is safe and cost effective
15 (Kazmierczak and Carter 2010) and prioritises poverty reduction, disaster risk reduction and resilient service
16 provision (Kithiia 2010, da Silva et al 2012).

17
18 *Reducing risk can provide a compelling vehicle for adaptation action (see 8.3.2.2).* This can occur by responding to
19 existing challenges (for instance extreme weather events) and opportunities (for instance disaster risk reduction after
20 a disaster that ‘builds back better’ - see Lyons 2009) in ways that enhance adaptive capacity (Kazmierczak and
21 Carter, 2010, Solecki 2012). Experience to date on this is mixed. It is influenced by differences in risk perception
22 and how successfully disaster risk reduction and adaptation become embedded within local development processes
23 and the extent to which they address the structural causes of vulnerability (UN-Habitat 2010, Pelling 2011a, Roberts
24 and O’Donoghue 2013). There is also a widespread assumption that sound urban development and the provision of
25 basic services is sufficient to reduce risk to climate change, but there is a need to interrogate the effectiveness and
26 limitations of current models of infrastructure and service provision. Adaptation can benefit from disaster risk
27 reduction’s more detailed, locally rooted analyses of risk and vulnerability and its recognition that most disasters are
28 the result of a failure to identify problems and act. It can also benefit from multi-level government responses to
29 disaster risk reduction that recognize the central role of local government and other local institutions but also the
30 importance of supportive policies, institutions and legislation at higher levels of government. But disaster risk
31 reduction is informed by analyses of past disasters, while adaptation also has to be informed by knowledge of new
32 risks, vulnerabilities and uncertainties.

33
34 *Incorporating ecosystem based adaptation:* 8.3 noted how a growing number of cities are recognizing that
35 biodiversity and ecological integrity can be used to protect people and the resources on which they depend.
36 Ecosystem-based adaptation is regarded as one of the more cost effective and sustainable approaches to adaptation
37 given what needs to be spent to manage and preserve ecosystems and the climate adaptation value derived from that
38 spend (Nature Conservancy TNC 2009, Mees and Driessen, 2011, da Silva et al 2012, Brown et al 2012). But there
39 are considerable knowledge gaps in determining the limits or thresholds to adaptation of various ecosystems and
40 where and how ecosystem based adaptation is best integrated with other adaptation measures. There is also some
41 indication that the costs of ecosystem based adaptation in urban contexts might be higher than expected, in large part
42 because costs are higher for land acquisition and ecosystem management (Roberts et al 2012, Cartwright et al 2013).

43
44 *Engaging all stakeholders and awareness raising:* There is a need for dialogue and opportunities to advance the
45 adaptation agenda through internal and external collaboration. These range from cross-cutting technical advisory
46 groups often with sectoral or task group focal areas (Lowe et al. 2009, Parzen 2008, Boston 2011, City of New York
47 2011, Mees and Driessen, 2011, Solecki, 2012) to more broadly representative multi-stakeholder or multi-
48 departmental groups with a core working group (Tyler et al. 2010, Roberts 2010, Brown et al. 2012, Boston 2010,
49 Kazmierczak and Carter 2010, Anguelovski and Carmin 2011). Equally important is building public awareness and
50 support for adaptation as transformation “neighborhood by neighborhood” (Foster et al. 2011, also Kazmierczak and
51 Carter 2010). This is especially important where large sections of the population live and work in informal
52 settlements and include a high proportion of those most at risk from climate change.

1 *Institutional and social learning*: For all urban centres, successful adaptation requires a learning organization that
2 adapts to changing environmental factors and incorporates new data on a regular and flexible basis – producing an
3 iterative process of learning about changing risks and opportunities and drawing in different stakeholders (Brown et
4 al 2012). This is difficult to achieve with weak governmental structures, lack of funding and trained staff, where
5 “decisions are delayed, correspondences lost in bureaucratic black-holes and ascription of responsibility is
6 obfuscated” (Kithiia 2009, also Brown 2011). Social learning is also critical to ensure new ideas are popularized and
7 commonly articulated in society (Pelling 2011a), translating stakeholder engagement into adaptation action.
8

9 *The importance of mainstreaming climate change adaptation requirements into municipal planning and land-use*
10 *management systems*: This chapter opened with an acknowledgement that local governments must provide the
11 planning, management and regulatory frameworks to ensure that investments and actions by businesses and
12 households contribute to adaptation (Kazmierczak and Carter 2010, Brown 2011, Mees and Driessen, 2011,
13 Sussman et al., 2010). But this must avoid overloading already complex and inadequate planning systems (Kithiia
14 2010, Roberts 2008a) stressed by lack of information, institutional constraints and resource limitations with
15 unrealistic new requirements. Mainstreaming adaptation ensures that limited financial resources are spent “with
16 adaptation needs in mind” (Lowe et al. 2009) and fosters a move to a risk-based design for a range of future
17 projected climate conditions. This can be enhanced by encouraging each sector to consider its need for and role in
18 adaptation action. A sectoral approach makes the climate message easier for local governments and other
19 stakeholders to understand and the associated responsibilities and actions clearer and simpler to identify and assign
20 (Roberts 2010, UN-Habitat 2011a, Roberts and O’Donoghue 2013). As each sector in local government comes to
21 understand its roles and responsibilities, so the basis for integration and cross-sectoral coordination is formed.
22

23 *The importance of champions*. Champions, regardless of their location or affiliation are important in driving
24 successful adaptation action (Kazmierczak and Carter 2010). The role of local government champions has often
25 proved critical in providing initial leadership (e.g. Sydney, Chicago, New York, Durban, London) and promoting
26 and sustaining the adaptation agenda both at a sectoral level (e.g. Durban) and in building broader institutional
27 memory and purpose (e.g. Chicago, Toronto)(Lowe et al. 2009, Roberts 2008a, Parzen 2008, Rosenzweig and
28 Solecki 2010, Shaw and Theobald 2011, Anguelovski and Carmin 2011, Carmin et. al. 2012, Mees and Driessen,
29 2011, Martins and Ferreira 2011, Roberts and O’Donoghue 2013). This may face a lack of continuity as champions
30 change position or leave office. It is important to plan for this so that progress is not stalled or undermined. This can
31 be helped by developing a broad base of support for adaptation across many sectors - within and outside government
32 and other local stakeholders such as civil society groups or universities can help ensure continuity (Hardoy 2013).
33

34 *The need for scientific support and an evidence base for adaptation action* (Lowe et al, 2009, Roberts 2008a,
35 Kazmierczak and Carter 2010, Horton et al 2011, Blake et. al, 2011, Moffet et al 2011): Despite growing attention,
36 useful information and assessment of climate change at urban spatial scales is still lacking (Hunt and Watkiss 2011;
37 Kehew 2009). Local governments need to access reliable, accurate, useable scientific data. Even where these are
38 available, their staff often cannot utilize them because of the language gap between information producers
39 (scientists) and information users (local decision makers) (Lowe et al. 2009, Opitz-Stapleton 2010). Practitioners
40 often rely more on informal information sources and formats such as colleagues and the internet (Corfee-Morlot et al.
41 2011). Here, local risk assessments of existing hazards, challenges and vulnerabilities that could be exacerbated by
42 climate change offer a useful alternative starting point and facilitate the creation of an appropriate evidence base
43 (Tyler et al. 2010, Kazmierczak and Carter 2010). Collaboration and partnership with researchers and research
44 institutes (especially those with local knowledge) (e.g. Durban, Chicago, Seattle, Manchester) can help each urban
45 centre gain knowledge about climate impacts (Lowe et al. 2009, Kazmierczak and Carter 2010).
46

47 *Catalytic role of multilateral and bilateral funding*: While conventional multilateral development banks and bilateral
48 agencies appear have the biggest role in adaptation financing (Ayers 2009), there is an emerging argument that
49 finance for urban resilience and adaptation needs to respond to local demands, contexts and possibilities. This poses
50 a challenge to conventional global finance mechanisms that work through national governments to determine which
51 local actions are eligible for funding (ICLEI 2011a, Brugmann 2012). There is also evidence of substantial spend on
52 adaptation from local and national governments in some nations (Kazmierczak and Carter 2010).
53

1 *Phased approaches:* A phased approach is more likely to attract local government attention (Foster et al. 2011, City
2 of Copenhagen 2011, Boston 2011, Wajih et al. 2010, Solecki 2012). In each urban centre, this prioritizes the most
3 urgent matters (usually rapid onset disasters) or near term climate impacts, leaving a longer time period to plan for
4 those impacts that may occur in the future and be associated with greater uncertainty (including slow onset
5 disasters). For slow-onset impacts, strategic forward planning is critical, and existing planning instruments such as
6 land use planning may need to be altered to take changes in climatic stressors into account. Often the initial phases
7 of action are made possible by the existence of previous or current environmental initiatives, or strong
8 environmental traditions at the local level (Kazmierczak and Carter 2010).
9

10 *Poorly developed Monitoring and Evaluation systems:* Monitoring and evaluating the development and
11 implementation of adaptation plans is still evolving (Jacob et al 2010) and not well developed or widely
12 implemented in urban areas (Kazmierczak and Carter 2010). Work is required in this regard, but it is likely to be
13 challenging given the localized nature of adaptation and hence the difficulty of standardizing performance
14 requirements and measurements (Anguelovski and Carmin 2011).
15

16 *Role of international institutions:* The lack of skills and resources in local governments gives international
17 institutions an important role in initiating and shaping the adaptation agenda. These international programmes are
18 often the main form of institutional and financial support to mitigation and adaptation work at local level, although
19 in some local governments internal motivations (e.g. perception of threat, city agendas, leadership, improving city
20 image) (Anguelovski and Carmin, 2011, Carmin et. al. 2012, Kazmierczak and Carter 2010) appear equally
21 influential. The danger of the donor driven model is that the funding agency's agenda may not coincide with local
22 priorities, resulting in little lasting local ownership once support is withdrawn.
23

24 Local action involving all local stakeholders, addressing local issues, tapping local knowledge and other resources
25 and respecting local limits is the key to transformative adaptation. Urban areas, because of their size, number,
26 economic importance and social and environmental characteristics, are the geography where this has to happen. So
27 they will have a critical role in the success or failure of the global adaptation project. Mobilising this local level
28 capacity is challenging for international agencies. But if done in ways that are equitable and co-operative and that
29 respect the limits of natural ecosystems, it has the potential to improve human well-being, maximize innovation and
30 help define and implement development paths that converge in a more sustainable and low carbon future.
31
32

33 **Frequently Asked Questions**

34

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

36 There is a long experience with urban governments implementing disaster risk reduction that is underpinned by
37 locally-driven identification of key hazards, risks and vulnerabilities to disasters and that identifies what should be
38 done to reduce or remove disaster risk. Its importance is that it encourages local governments to act before a disaster
39 – for instance for risks from flooding, to reduce exposure and risk as well as being prepared for emergency
40 responses prior to the flood (eg temporary evacuation from places at risk of flooding) and rapid response and
41 building back afterwards. In some nations, national governments have set up legislative frameworks to strengthen
42 and support local government capacities for this (see 8.3.2.2). This is a valuable foundation for assessing and acting
43 on climate-change related hazards, risks and vulnerabilities, especially those linked to extreme weather. So urban
44 governments with effective capacities for disaster risk reduction (with the needed integration of different sectors)
45 provides an important component of adaptive capacity. But climate change adaptation needs to take account of how
46 hazards, risks and vulnerabilities will or might change over time. Disaster risk reduction also covers disasters
47 resulting from hazards not linked to climate or to climate change such as earthquakes.
48

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

50 Adaptation is well served by good quality infrastructure and services that reach all of an urban centre's population
51 and the institutional capacity to provide, and manage these and expand them when needed. Poverty reduction can
52 also support adaptation by increasing individual and household resilience to stresses and shocks and enhancing their
53 capacities to adapt. These provides a foundation for building climate change resilience but additional knowledge,

1 resources, capacity and skills are generally required, especially to build resilience to changes beyond the ranges of
2 what have been experienced in the past.

3
4 **FAQ 8.3: Wouldn't urban problems be lessened by rural development?**

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

14
15 **FAQ 8.4: Shouldn't urban adaptation plans wait until there is more certainty about local climate change
16 impacts?**

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

25
26
27 **References**

- 28
29 Aall, C., K. Groven, and G. Lindseth, 2007: The scope of action for local climate policy: the case of Norway. *Global
30 Environmental Politics*, **7(2)**, 83-101.
- 31 Adachi, S.A., F. Kimura, H. Kusaka, T. Inoue, and H. Ueda, 2012: Comparison of the Impact of Global Climate
32 Changes and Urbanization on Summertime Future Climate in the Tokyo Metropolitan Area. *Journal of Applied
33 Meteorology and Climatology*, **51(8)**, 1441-1454.
- 34 Adamo, S.B., 2010: Environmental migration and cities in the context of global environmental change. *Current
35 Opinion in Environmental Sustainability*, **2(3)**, 161-165.
- 36 Adelekan, I.O., 2010: Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment
37 and Urbanization*, **22(2)**, 433-450.
- 38 Adelekan, I.O., 2012: Vulnerability to wind hazards in the traditional city of Ibadan, Nigeria. *Environment and
39 Urbanization*, **24(2)**, 597-617.
- 40 Adger, N.W., N.W. Arnell, and E.L. Tompkins, 2005: Successful adaptation to climate change across scales. *Global
41 Environmental Change*, **15(2)**, 77-86.
- 42 Adger, W. N., O'Brien K L, Lorenzoni I 2009: Adaptation now. In: Adger W N *et al.* ed Living with climate
43 change: Are there limits to adaptation? Cambridge University Press, Cambridge, pp. 1-22
- 44 Adger W.N., Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi K 2007:
45 Assessment of adaptation practices, options, constraints and capacity. In Parry ML *et al.* eds Climate Change
46 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment
47 Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge
- 48 AGF 2010a: Report of the Secretary-General's High-level Advisory Group on Climate Change Financing,
49 November 2010. Available at [http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/
50 AGF_reports/AGF%20Report.pdf](http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/AGF%20Report.pdf)
- 51 AGF 2010b: Work Stream 7: Public Interventions to Stimulate Private Investment in Adaptation and Mitigation.
52 Available at [http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/
53 Work_Stream_7%20Public_Private.pdf](http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/Work_Stream_7%20Public_Private.pdf)

- 1 AGF 2010c: Work Stream 4: Contributions from International Financial Institutions. Available at
2 http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/Work_Stream_4_International%20Finacial%20Institutions.pdf
3
- 4 Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy*, **8(2)**, 183-193.
- 5
6 Agrawala, S. & Carraro, M. 2010: *Assessing the Role of Microfinance in Fostering Adaptation to Climate Change*, Organisation for Economic Co-operation and Development.
- 7
8 Agrawala, S., M. Carraro, N. Kingsmill, E. Lanzi, M. Mullan, and G. Prudent-Richard, 2011: Private Sector Engagement in Adaptation to Climate Change: Approaches to Managing Climate Risks. *OECD Environment Working Papers*, .
- 9
10
11 Alam, M. and M.D.G. Rabbani, 2007: Vulnerabilities and responses to climate change for Dhaka. *Environment and Urbanization*, **19(1)**, 81-97.
- 12
13 Allen, L., F. Lindberg, and C. Grimmond, 2011: Global to city scale urban anthropogenic heat flux: model and variability. *International Journal of Climatology*, **31(13)**, 1990-2005.
- 14
15 Almansi, F., 2009: Regularizing land tenure within upgrading programmes in Argentina; the cases of Promeba and Rosario Hábitat. *Environment and Urbanization*, **21(2)**, 389-413.
- 16
17 Anguelovski, I. and J. Carmin, 2011: Something borrowed, everything new: innovation and institutionalization in urban climate governance. *Current Opinion in Environmental Sustainability*, **3(3)**, 169-175.
- 18
19 Aon 2011: *Global Risk Management Survey 2011*, Chicago,
- 20 Aragón-Durand, F., 2007: Urbanisation and flood vulnerability in the peri-urban interface of Mexico City. *Disasters*, **31(4)**, 477-494.
- 21
22 Aragón-Durand, Fernando 2011: Regional workshop on disaster risk reduction and climate change adaptation in urban settings: from theory to practice. SERNA, COPECO, PNUD-Honduras. Tegucigalpa, Honduras, 33pp.
- 23
24 Aragón-Durand, Fernando, 2008: Estrategias de Protección Civil y Gestión del Riesgo Hidro-meteorológico ante el cambio climático Instituto Nacional de Ecología- SEMARNAT, México.
- 25
26 Archer, D. and S. Boonyabanha, 2011: Seeing a disaster as an opportunity – harnessing the energy of disaster survivors for change. *Environment and Urbanization*, **23(2)**, 351-364.
- 27
28 Archer, D., 2012: Finance as the key to unlocking community potential: savings, funds and the ACCA programme. *Environment and Urbanization*, **24(2)**, 423-440.
- 29
30 Arnell, Nigel 2009: in Parry, Martin, Nigel Arnell, Pam Berry, David Dodman, Samuel Fankhauser, Chris Hope, Sari Kovats, Robert Nicholls, David Satterthwaite, Richard Tiffin and Tim Wheeler 2009, *Assessing the Costs of Adaptation to Climate Change; A Review of the UNFCCC and other Recent Estimates*, IIED and Grantham Institute, London, 111 pp.
- 31
32
33 ARUP/C40 2012: Climate Action in Megacities: C40 Cities Baseline and Opportunities. Version 1.0. June 2011
34 http://www.arup.com/Publications/Climate_Action_in_Megacities.aspx [last accessed: 18 May 2012]
- 35
36 Åström, Daniel Oudin, Forsberg Bertil, Rocklöv Joacim (2011), “Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies”, *Maturitas*, Volume 69, Issue 2, June 2011, Pages 99-105
- 37
38 Athanassiadou, M., J. Baker, D. Carruthers, W. Collins, S. Girnary, D. Hassell, M. Hort, C. Johnson, K. Johnson, and R. Jones, 2010: An assessment of the impact of climate change on air quality at two UK sites. *Atmospheric Environment*, **44(15)**, 1877-1886.
- 39
40
41 Atteridge, A., C.K. Siebert, R.J. Klein, C. Butler, and P. Tella, 2007: *Bilateral finance institutions and climate change: A mapping of climate portfolios*. Stockholm Environment Institute (SEI), .
- 42
43 Awuor, C.B. V.A. Orindi and A. Adwerah 2008: Climate change and coastal cities: The case of Mombasa, Kenya. *EnvironUrb*, **20(1)**, 231-242.
- 44
45 Ayers, J., 2009: International funding to support urban adaptation to climate change. *Environment and Urbanization*, **21(1)**, 225-240.
- 46
47 Ayers, J.M. and S. Huq, 2009: The value of linking mitigation and adaptation: A case study of Bangladesh. *Environmental Management*, **43(5)**, 753-764.
- 48
49 Backus, G.A., T.S. Lowry, and D.E. Warren, 2012: The near-term risk of climate uncertainty among the US states. *Climatic Change*, , 1-28.
- 50
51 Bangay, C. and N. Blum, 2010: Education responses to climate change and quality: Two parts of the same agenda? *International Journal of Educational Development*, **30(4)**, 359-368.
- 52
53 Banks, N., 2008: A tale of two wards: political participation and the urban poor in Dhaka city. *Environment and Urbanization*, **20(2)**, 361-376.
- 54

- 1 Banks, N., M. Roy, and D. Hulme, 2011: Neglecting the urban poor in Bangladesh: research, policy and action in
2 the context of climate change. *Environment and Urbanization*, **23(2)**, 487-502.
- 3 Barata, M., E. Ligeti, G. De Simone, T. Dickinson, D. Jack, J. Penney, M. Rahman, R. Zimmerman, 2011: Climate
4 change and human health in cities. *Climate Change and Cities: First Assessment Report of the Urban Climate
5 Change Research Network*, C. Rosenzweig, W. D. Solecki, S. A. Hammer, S. Mehrotra, Eds., Cambridge
6 University Press, Cambridge, UK, 179–213
- 7 Barnett, J. and W.N. Adger, 2007: Climate change, human security and violent conflict. *Political Geography*, **26(6)**,
8 639-655.
- 9 Bartlett, S., 2008: Climate change and urban children: impacts and implications for adaptation in low- and middle-
10 income countries. *Environment and Urbanization*, **20(2)**, 501-519.
- 11 Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2012: Climate change impacts on international seaports:
12 knowledge, perceptions, and planning efforts among port administrators. *Climatic Change*, **110(1)**, 5-29.
- 13 Bedsworth, L., 2009: Preparing for Climate Change: A Perspective from Local Public Health Officers in California.
14 *Environmental Health Perspectives*, **117(4)**, 617-623.
- 15 Bedsworth, L.W. and E. Hanak, 2010: Adaptation to Climate Change. *Journal of the American Planning
16 Association*, **76(4)**, 477-495.
- 17 Beggs, P.J., 2010: Adaptation to Impacts of Climate Change on Aeroallergens and Allergic Respiratory Diseases.
18 *International Journal of Environmental Research and Public Health*, **7(8)**, 3006-21.
- 19 Benson, C. and E.J. Clay, 2004: *Understanding the economic and financial impacts of natural disasters*. World
20 Bank Publications, .
- 21 Benvenuti, S. and D. Bacci, 2010: Initial agronomic performances of Mediterranean xerophytes in simulated dry
22 green roofs. *Urban Ecosystems*, **13(3)**, 349-363.
- 23 Berger F 2003: Crise et reconversion dans la sidérurgie: étude comparée des bassins charbonniers de la Ruhr et du
24 Nord-Pas-de-Calais ”, *Mitteilungsblatt (Zeitschrift des Bochumer Instituts für soziale Bewegungen)*, Nr.
25 29/2003
- 26 Bicknell, J, D. Dodman and D. Satterthwaite, 2009: *Adapting Cities to Climate Change: Understanding and
27 addressing the development challenges* Earthscan/Routledge.
- 28 Biesbroek, G.R., R.J. Swart, and W.G.M. van der Knaap, 2009: The mitigation–adaptation dichotomy and the role
29 of spatial planning. *Habitat International*, **33(3)**, 230-237.
- 30 Birkmann, J., M. Garschagen, F. Kraas, and N. Quang, 2010: Adaptive urban governance: new challenges for the
31 second generation of urban adaptation strategies to climate change. *Sustainability Science*, **5(2)**, 185-206.
- 32 Bishop, J. and S. Pagiola, 2012: *Selling forest environmental services: market-based mechanisms for conservation
33 and development*. Routledge.
- 34 Björnberg, K E and Hansson, S O 2013: Gendering local climate adaptation, *Local Environment: The International
35 Journal of Justice and Sustainability*, **18 (2)**, 217-232
- 36 Blackburn, Sophie and Jo da Silva 2013. *Mega-urbanisation on the coast: Global context and key trends in the
37 twenty-first century* in Mark Pelling (editor), Earthscan Publications, London.
- 38 Blake, R., A. Grimm, T. Ichinose, R. Horton, S. Gaffin, S. Jiong, D. Bader, L. D. Cecil, 2011: Urban climate:
39 Processes, trends, and projections. *Climate Change and Cities: First Assessment Report of the Urban Climate
40 Change Research Network*, C. Rosenzweig, W. D. Solecki, S. A. Hammer, S. Mehrotra, Eds., Cambridge
41 University Press, Cambridge, UK, 43–81.
- 42 Blanco A., 2007: Local initiatives and adaptation to climate change. *Disasters*, 301, 140-147.
- 43 Bloomberg, M.R. and R.T. Aggarwala, 2008: Think Locally, Act Globally: How Curbing Global Warming
44 Emissions Can Improve Local Public Health. *American Journal of Preventive Medicine*, **35(5)**, 414-423.
- 45 Bloomberg, Michael R. and Cas Holloway (2010), *NYC Green Infrastructure Plan; A Sustainable Strategy for Clean
46 Waterways*,. PLANYC and NYC Environmental Protection, New York.
- 47 BMA and UNEP 2009: *Bangkok Assessment Report on Climate Change*. Bangkok: BMA, GLF and UNEP
- 48 BMU 2011, *Harnessing the Potential of Ecosystems for Climate Change Adaptation*, May
- 49 Bohle, H.G., T.E. Downing, and M.J. Watts, 1994: Climate change and social vulnerability: Toward a sociology and
50 geography of food insecurity. *Global Environmental Change*, **4(1)**, 37-48.
- 51 Bolin, B., M. Seetharam, and B. Pompeii, 2010: Water resources, climate change, and urban vulnerability: a case
52 study of Phoenix, Arizona. *Local Environment*, **15(3)**, 261-279.

- 1 Bollin, Christina and Friedegund Mascher 2005: Honduras: Community – based disaster risk management and
2 intermunicipal cooperation. A review of experience gathered by the special intermunicipal association
3 MAMUCA. GTZ
- 4 Bonazza, A., P. Messina, C. Sabbioni, C.M. Grossi, and P. Brimblecombe, 2009: Mapping the impact of climate
5 change on surface recession of carbonate buildings in Europe. *Science of the Total Environment*, **407(6)**, 2039-
6 2050.
- 7 Boonyabancha, S., 2005: Baan Mankong: going to scale with “slum” and squatter upgrading in Thailand.
8 *Environment and Urbanization*, **17(1)**, 21-46.
- 9 Boonyabancha, S., 2009: Land for housing the poor — by the poor: experiences from the Baan Mankong nationwide
10 slum upgrading programme in Thailand. *Environment and Urbanization*, **21(2)**, 309-329.
- 11 Boonyabancha, S. and D. Mitlin, 2012: Urban poverty reduction: learning by doing in Asia. *Environment and*
12 *Urbanization*, **24(2)**, 403-421.
- 13 Bose, R.K., 2010: *Energy efficient cities: Assessment tools and benchmarking practices*. World Bank Publications, .
14 Boston 2010: Sparking Boston’s Climate Revolution: Recommendations of the Climate Action Leadership
15 Committee and Community Advisory Committee. Full Report. City of Boston, Boston.
- 16 Boston 2011: A climate of progress. City of Boston Climate Action Plan update 2011. City of Boston, Boston.
- 17 Botzen, W.J., J.C. van den Bergh, and L. Bouwer, 2010: Climate change and increased risk for the insurance sector:
18 A global perspective and an assessment for the Netherlands. *Natural Hazards*, **52(3)**, 577-598.
- 19 Bowler, D.E., L. Buyung-Ali, T.M. Knight, and A.S. Pullin, 2010: Urban greening to cool towns and cities: A
20 systematic review of the empirical evidence. *Landscape and Urban Planning*, **97(3)**, 147-155.
- 21 Boyd, E., Grist, N., Juhola, S. and Nelson, V. 2009. Exploring development futures in a changing climate: Frontiers
22 for development policy and practice. *Development Policy Review* 27:659-674.
- 23 Brody, S., H. Grover, E. Lindquist, and A. Vedlitz, 2010: Examining climate change mitigation and adaptation
24 behaviours among public sector organisations in the USA. *Local Environment*, **15(6)**, 591-603.
- 25 Brown, A., A. Dayal, and C.R. Del Rio, 2012: From practice to theory: emerging lessons from Asia for building
26 urban climate change resilience. *Environment and Urbanization*, **24(2)**, 531-556.
- 27 Brown, D., 2011: Making the linkages between climate change adaptation and spatial planning in Malawi.
28 *Environmental Science & Policy*, **14(8)**, 940-949.
- 29 Brown, S. and G. Walker, 2008: Understanding heat wave vulnerability in nursing and residential homes. *Building*
30 *Research & Information*, **36(4)**, 363-372.
- 31 Brugmann, J., 2012: Financing the resilient city. *Environment and Urbanization*, **24(1)**, 215-232.
- 32 Brunner, R.D., 1996: Policy and global change research. *Climatic Change*, **32(2)**, 121-147.
- 33 Brunner R, Steelman T, Coe-Juell L, Cromley C, Edwards C, Tucker D, Ronald D 2005: *Adaptive Governance:*
34 *Integrating Science, Policy, and Decision-Making*. Columbia University Press, New York
- 35 Buchner, B., A. Falconer, M. Hervé-Mignucci, C. Trabacchi, and M. Brinkman, 2011: The Landscape of Climate
36 Finance. *Climate Policy Initiative: Venice*, **27**.
- 37 Bulkeley, H., 2010: Cities and the governing of climate change. *Annual Review of Environment and Resources*, **35**,
38 229-253.
- 39 Bulkeley, H. and K. Kern, 2006: Local Government and the Governing of Climate Change in Germany and the UK.
40 *Urban Studies*, **43(12)**, 2237-2259.
- 41 Bulkeley, H., Schroeder, H., Janda, K., Zhao, Z., Armstrong, A. Chi, S.Y. and S. Ghosh 2011: The Role of
42 Institutions, Governance, and Urban Planning for Mitigation and Adaptation in *Cities and Climate Change:*
43 *Responding to an Urgent Agenda*, D. Hoornweg, M. Friere, M.J. Lee, P. Bhada-Tata and B. Yuen eds The
44 World Bank, Washington DC, USA.
- 45 Burch, S., 2010: Transforming barriers into enablers of action on climate change: Insights from three municipal case
46 studies in British Columbia, Canada. *Global Environmental Change*, **20(2)**, 287-297.
- 47 Burkart K, Schneider A, Breitner S, Khan MH, Krämer A, Endlicher W. (2011), “The effect of atmospheric thermal
48 conditions and urban thermal pollution on all-cause and cardiovascular mortality in Bangladesh”, *Environ*
49 *Pollut.* 2011 Aug-Sep;159(8-9):2035-43.
- 50 Burley, J.G., R.R. McAllister, K.A. Collins, and C.E. Lovelock, 2012: Integration, synthesis and climate change
51 adaptation: a narrative based on coastal wetlands at the regional scale. *Regional Environmental Change*, , 1-13.
- 52 Cabannes, Y., 2004: Participatory budgeting: a significant contribution to participatory democracy. *Environment*
53 *and Urbanization*, **16(1)**, 27-46.

- 1 Campbell, T., 2003: *Quiet Revolution: Decentralization and the Rise of Political Participation in Latin American*
2 *Cities*. University of Pittsburgh Press, .
- 3 Cantos, J., M. Hernandez, A. Amoros, and E. Ibarra, 2010: Increased risk of flooding on the coast of
4 Alicante (Region of Valencia, Spain). *Natural Hazards and Earth System Sciences*, **10(11)**, 2229-2234.
- 5 Cape Town 2006: Framework for Adaptation to Climate Change in the City of Cape Town
- 6 Carbognin, L., P. Teatini, A. Tomasin, and L. Tosi, 2010: Global change and relative sea level rise at Venice: what
7 impact in term of flooding. *Climate Dynamics*, **35(6)**, 1039-1047.
- 8 Carcellar, N., J.C.R. Co, and Z.O. Hipolito, 2011: Addressing disaster risk reduction through community-rooted
9 interventions in the Philippines: experience of the Homeless People's Federation of the Philippines.
10 *Environment and Urbanization*, **23(2)**, 365-381.
- 11 Carmin, J., I. Anguelovski, and D. Roberts, 2012: Urban Climate Adaptation in the Global South Planning in an
12 Emerging Policy Domain. *Journal of Planning Education and Research*, **32(1)**, 18-32.
- 13 Carmin J. and D Dodman 2012: Urban Climate Adaptation and Leadership: From Conceptual to Practical
14 Understanding. OECD Working Paper forthcoming.
- 15 Carmin, Joann, D Roberts and I Anguelovski (2011), Planning Climate Resilient Cities: Early Lessons from Early
16 Adapters., Chapter 17 in Daniel Hoornweg, Mila Freire, Marcus J. Lee, Perinaz Bhada-Tata, and Belinda Yuen,
17 editors Cities and Climate Change; Responding to an Urgent Agenda, Volume 2, The World Bank, Washington
18 DC, pages 462-497.
- 19 Carolini G 2007: Organizations of the urban poor and equitable urban development: process and product. In The
20 New Global Frontier. Urbanization, Poverty and Environment in the 21st Century. Edited by Martine G,
21 McGranahan G, Montgomery M, Fernandez-Castilla R. Earthscan:133-150.
- 22 Carter, J.G., 2011: Climate change adaptation in European cities. *Current Opinion in Environmental Sustainability*,
23 **3(3)**, 193-198.
- 24 Carter, T. and L. Fowler, 2008: Establishing green roof infrastructure through environmental policy instruments.
25 *Environmental Management*, **42(1)**, 151-164.
- 26 Cartwright, A; Roberts, D , Blignaut, J; De Wit, M; Goldberg, K; Mander, M; and O'Donoghue, S (2013)
27 Economics of climate change adaptation at the local scale under conditions of uncertainty and resource
28 constraints: the case of Durban, South Africa. *Environment and Urbanization*. Vol 25(1):
- 29 Cartwright, A., S. Parnell, G. Oelofse, and S. Ward, 2012: *Climate Change at the City Scale: Impacts, Mitigation*
30 *and Adaptation in Cape Town*. Routledge, .
- 31 Cartwright, A., J. Blignaut, M. De Wit, K. Goldberg, M. Mander, S. O'Donoghue, and D. Roberts, 2013: Economics
32 of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case
33 of Durban, South Africa. *Environment and Urbanization*, .
- 34 Carvalho, A. and J. Burgess, 2005: Cultural circuits of climate change in UK broadsheet newspapers, 1985–2003.
35 *Risk Analysis*, **25(6)**, 1457-1469.
- 36 Cash, D.W. and S.C. Moser, 2000: Linking global and local scales: designing dynamic assessment and management
37 processes. *Global Environmental Change*, **10(2)**, 109-120.
- 38 Cash, D.W., W.N. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, and O. Young, 2006: Scale and
39 cross-scale dynamics: governance and information in a multilevel world. *Ecology and Society*, **11(2)**, 8.
- 40 Cashman, A., L. Nurse, and C. John, 2010: Climate change in the Caribbean: the water management implications.
41 *The Journal of Environment & Development*, **19(1)**, 42-67.
- 42 Castán Broto, Vanesa et al. 2013. "Climate change adaptation, local governance and poverty alleviation in Maputo.
43 Local Environment: The International Journal of Justice and Sustainability". Forthcoming
- 44 Castleton, H.F., V. Stovin, S.B.M. Beck, and J.B. Davison, 2010: Green roofs; building energy savings and the
45 potential for retrofit. *Energy and Buildings*, **42(10)**, 1582-1591.
- 46 Center for Science in the Earth System, The Climate Impacts Group, King County, Washington and ICLEI – Local
47 Governments for Sustainability 2007: Preparing for Climate Change: A Guidebook for Local, Regional, and
48 State Governments. Center for Science in the Earth System The Climate Impacts Group, King County,
49 Washington and ICLEI – Local Governments for Sustainability, King County, Washington.
- 50 CEPAL 2008: Tabasco: Características e impacto socio-económico de las inundaciones provocadas a finales de
51 octubre y a comienzos de noviembre de 2007 por el frente frío N°4
- 52 Chance, T., 2009: Towards sustainable residential communities; the Beddington Zero Energy Development
53 (BedZED) and beyond. *Environment and Urbanization*, **21(2)**, 527-544.

- 1 Chang, H., M. Lafrenz, I. Jung, M. Figliozzi, D. Platman, and C. Pederson, 2010: Potential Impacts of Climate
2 Change on Flood-Induced Travel Disruptions: A Case Study of Portland, Oregon, USA. *Annals of the*
3 *Association of American Geographers*, **100(4)**, 938-952.
- 4 Chang, S., T.L. McDaniels, J. Mikawoz, and K. Peterson. 2007, Infrastructure failure dependencies in extreme
5 events: power outage consequences in the 1998 Ice Storm, *Nat Hazards* 41:337-358
- 6 Charlton, M.B. and N.W. Arnell, 2011: Adapting to climate change impacts on water resources in England—An
7 assessment of draft Water Resources Management Plans. *Global Environmental Change*, **21(1)**, 238-248.
- 8 Chaum, M., C. Faris, G. Wagner, B. Buchner, A. Falconer, C. Trabacchi, J. Brown, and K. Sierra, 2011: Improving
9 the effectiveness of climate finance: key lessons. *Climate Policy Initiative, Venice*, .
- 10 Chen, J., Q. Li, J. Niu, and L. Sun, 2011: Regional climate change and local urbanization effects on weather
11 variables in Southeast China. *Stochastic Environmental Research and Risk Assessment*, **25(4)**, 555-565.
- 12 Chicago 2008: Chicago Climate Action Plan 2008: Our City, Our Future, Chicago
- 13 Chicago 2010: Chicago Climate Change Action Plan 2010, Chicago Climate Action Plan Progress Report 2008-
- 14 Chu, S.Y. and H. Schroeder, 2010: Private Governance of Climate Change in Hong Kong: An Analysis of Drivers
15 and Barriers to Corporate Action. *Asian Studies Review*, **34(3)**, 287-308.
- 16 City of Copenhagen 2011: Copenhagen Climate Adaptation Plan. City of Copenhagen, Copenhagen.
- 17 City of New York 2011. PlaNYC. Update April 2011. City of New York, New York.
- 18 Clapp, C., A. Leseur, O. Sartor, and G. Briner, *J. Corfee-Morlot (2010), "Cities and Carbon Market Finance: Taking*
19 *Stock of Cities' Experience with CDM and JI,"*, .
- 20 Clapp, C., J. Ellis, J. Benn, and J. Corfee-Morlot, 2012: Tracking Climate Finance: What and How? .
- 21 Cohen, M.J. and J.L. Garrett, 2010: The food price crisis and urban food (in)security. *Environment and*
22 *Urbanization*, **22(2)**, 467-482.
- 23 Coombes, E.G. and A.P. Jones, 2010: Assessing the impact of climate change on visitor behaviour and habitat use at
24 the coast: A UK case study. *Global Environmental Change*, **20(2)**, 303-313.
- 25 Corburn, J., 2009: Cities, Climate Change and Urban Heat Island Mitigation: Localising Global Environmental
26 Science. *Urban Studies*, **46(2)**, 413-427.
- 27 Corfee-Morlot, J., M. Maslin, and J. Burgess, 2007: Global warming in the public sphere. *Philosophical*
28 *Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **365(1860)**, 2741-2776.
- 29 Corfee-Morlot, J., I. Cochran, S. Hallegatte, and P. Teasdale, 2011: Multilevel risk governance and urban adaptation
30 policy. *Climatic Change*, **104(1)**, 169-197.
- 31 Costanza, R., G. Alperovitz, H. Daly, J. Farley, C. Franco, T. Jackson, I. Kubiszewski, J. Schor, P. Victor, and R.
32 Colman, 2011: Building a Sustainable and Desirable Economy-in-Society-in-Nature. Proceedings of Report to
33 the United Nations for the 2012 Rio 20 Conference.
- 34 Costanza, R. G. Alperovitz, H.E Daly, J. Farley, C. Franco, T. Jackson, I. Kubiszewski, J. Schor and P. Victor
35 (2013). Building a Sustainable and Desirable Economy-in-Society-in-Nature. Chapter in State of the World
36 Report: 2013 in press.
- 37 Crawford, J. and S. Davoudi, 2012: *Planning for climate change: strategies for mitigation and adaptation for*
38 *spatial planners*. Routledge, .
- 39 Crichton, D., F. Nicol, and S. Roaf, 2012: *Adapting Buildings and Cities for Climate Change*. Routledge, .
- 40 Crush, J., B. Frayne and W. Pendleton 2012: The Crisis of Food Insecurity in African Cities *Journal of Hunger &*
41 *Environmental Nutrition* 7 (2-3) (2012):
- 42 Da Silva, J., 2010: *Lessons from Aceh: key considerations in post-disaster reconstruction*. Practical Action
43 Publishing Limited, .
- 44 da Silva, J., S. Kernaghan, and A. Luque, 2012: A systems approach to meeting the challenges of urban climate
45 change. *International Journal of Urban Sustainable Development*, **4(2)**, 125-145.
- 46 da Silva, J. (2012), Shifting agendas: response to resilience. The role of the engineer in disaster risk reduction., 9th
47 Brunel International Lecture Series, The Institution of Civil Engineers, London, 43 pages.
- 48 Darrel Jenerette, G. and L. Larsen, 2006: A global perspective on changing sustainable urban water supplies. *Global*
49 *and Planetary Change*, **50(3)**, 202-211.
- 50 Dávila, J.D., 2009: Being a mayor: the view from four Colombian cities. *Environment and Urbanization*, **21(1)**, 37-
51 57.
- 52 Dawson, R.J., Hall, J. W., Barr, S. L., Batty, M., Bristow, A. L., Carney, S., Dagoumas, A., Evans, S., Ford, A.C.,
53 Köhler, J., Tight, M. R., Walsh, C. L., Watters, H. and Zanni, A. M. 2009 A blueprint for the integrated

- 1 assessment of climate change in cities. In Tang, K. Ed. *Green CITYnomics. The urban war against climate*
2 *change*. Greenleaf Publishing, Sheffield, pp.32-52.
- 3 de Lucena, A.F.P., R. Schaeffer, and A.S. Szklo, 2010: Least-cost adaptation options for global climate change
4 impacts on the Brazilian electric power system. *Global Environmental Change*, **20(2)**, 342-350.
- 5 de Lucena, A.F.P., A.S. Szklo, R. Schaeffer, R.R. de Souza, B.S.M.C. Borba, I.V.L. da Costa, A.O.P. Júnior, and
6 S.H.F. da Cunha, 2009: The vulnerability of renewable energy to climate change in Brazil. *Energy Policy*,
7 **37(3)**, 879-889.
- 8 de Sherbinin, A., A. Schiller, and A. Pulsipher, 2007: The vulnerability of global cities to climate hazards.
9 *Environment and Urbanization*, **19(1)**, 39-64.
- 10 de Sherbinin, A., K. Warner, and C. Ehrhart, 2011: Casualties of climate change. *Scientific American*, **304(1)**, 64-71.
- 11 Deak, J. and E. Bucht, 2011: Planning for climate change: the role of indigenous blue infrastructure, with a case
12 study in Sweden. *Town Planning Review*, **82(6)**, 669-685.
- 13 Depietri, Y., F.G. Renaud, and G. Kallis, 2011: Heat waves and floods in urban areas: a policy-oriented review of
14 ecosystem services. *Sustainability Science*, , 1-13.
- 15 Diagne, K., 2007: Governance and natural disasters: addressing flooding in Saint Louis, Senegal. *Environment and*
16 *Urbanization*, **19(2)**, 552-562.
- 17 Dietz, T., E. Ostrom, and P.C. Stern, 2003: The Struggle to Govern the Commons. *Science*, **302(5652)**, 1907-1912.
- 18 Dietz, T., 2005: The Darwinian trope in the drama of the commons: variations on some themes by the Ostroms.
19 *Journal of Economic Behavior & Organization*, **57(2)**, 205-225.
- 20 DiMento, J.F. and P.M. Doughman, 2007: *Climate change: what it means for us, our children, and our*
21 *grandchildren*. MIT Press, .
- 22 Dimitriou, H.T. and R.A. Gakenheimer, 2011: *Urban transport in the developing world: a handbook of policy and*
23 *practice*. Edward Elgar Publishing, .
- 24 Dobney, K., C. Baker, A. Quinn, and L. Chapman, 2008: Quantifying the effects of high summer temperatures due
25 to climate change on buckling and rail related delays in south-east United Kingdom. *Meteorological*
26 *Applications*, **16(2)**, 245-251.
- 27 Dodman, D. and D. Mitlin, 2011: Challenges for community-based adaptation: discovering the potential for
28 transformation. *Journal of International Development*, .
- 29 Dodman, D. and D. Satterthwaite (2009), 'The Costs of Adapting Infrastructure to Climate Change', in M Parry *et*
30 *al*, eds. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent*
31 *Estimates*, International Institute for Environment and Development (IIED) and Grantham Institute for Climate
32 Change, London.
- 33 Donald, A. and C. Seeger, 2010: Melbourne: responding to a changing climate. *Journal of Water and Climate*
34 *Change Vol*, **1(3)**, 220-226.
- 35 Dossou, K.M.R. and B. Gléhouenou-Dossou, 2007: The vulnerability to climate change of Cotonou (Benin): the rise
36 in sea level. *Environment and Urbanization*, **19(1)**, 65-79.
- 37 Douglas, I., 2009: Climate change, flooding and food security in south Asia. *Food Security*, **1(2)**, 127-136.
- 38 Douglas, I., K. Alam, M. Maghenda, Y. McDonnell, L. Mclean, and J. Campbell, 2008: Unjust waters: climate
39 change, flooding and the urban poor in Africa. *Environment and Urbanization*, **20(1)**, 187-205.
- 40 Douglass, M., 2002: From global intercity competition to cooperation for livable cities and economic resilience in
41 Pacific Asia. *Environment and Urbanization*, **14(1)**, 53-68.
- 42 Drejza, S., P. Bernatchez, and C. Dugas, 2011: Effectiveness of land management measures to reduce coastal
43 georisks, eastern Québec, Canada. *Ocean & Coastal Management*, **54(4)**, 290-301.
- 44 Dulal, H.B., G. Brodnig, and C.G. Onoriose, 2011: Climate change mitigation in the transport sector through urban
45 planning: A review. *Habitat International*, **35(3)**, 494-500.
- 46 Eakin, H., V. Magaña, J. Smith, J.L. Moreno, J.M. Martínez, and O. Landavazo, 2007: A stakeholder driven process
47 to reduce vulnerability to climate change in Hermosillo, Sonora, Mexico. *Mitigation and Adaptation Strategies*
48 *for Global Change*, **12(5)**, 935-955.
- 49 Eakin, H., A.M. Lerner, and F. Murtinho, 2010: Adaptive capacity in evolving peri-urban spaces: Responses to
50 flood risk in the Upper Lerma River Valley, Mexico. *Global Environmental Change*, **20(1)**, 14-22.
- 51 Ebi, K.L., J. Balbus, P.L. Kinney, E. Lipp, D. Mills, M.S. O'Neill, and M.L. Wilson, 2009: U.S. Funding Is
52 Insufficient to Address the Human Health Impacts of and Public Health Responses to Climate Variability and
53 Change. *Environmental Health Perspectives*, **117(6)**, 857-862.

- 1 Edvardsson Björnberg, K. and S.O. Hansson, 2013: Gendering local climate adaptation. *Local Environment*, **18(2)**,
2 217-232.
- 3 Egondi T, Kyobutungi C, Kovats S, Muindi K, Ettarh R, Rocklöv J. (2012), “Time-series analysis of weather and
4 mortality patterns in Nairobi's informal settlements”, *Glob Health Action*. 2012 Nov 23;5:23-32
- 5 Eichhorst, Urda (2009), Adapting Urban Transport to Climate Change, Module 5f Sustainable Transport: A
6 Sourcebook for Policy-makers in Developing Cities, Deutsche Gesellschaft für Technische Zusammenarbeit
7 (GTZ) GmbH, Eschborn, 62 pages.
- 8 El Banna, Mahmoud M. and Omran E. Frihy 2009: Natural and anthropogenic influences in the northeastern coast
9 of the Nile delta, Egypt, *Environmental Geology* 57(7), 1593-1602.
- 10 Eriksen, S. and K. Brown, 2011: Sustainable adaptation to climate change. *Climate and Development*, **3(1)**, 3-6.
- 11 Ernstson, H., S.E. van der Leeuw, C.L. Redman, D.J. Meffert, G. Davis, C. Alfsen, and T. Elmqvist, 2010: Urban
12 transitions: on urban resilience and human-dominated ecosystems. *AMBIO: A Journal of the Human
13 Environment*, **39(8)**, 531-545.
- 14 Eurocontrol. 2008. The Challenges of Growth, Air Traffic Statistics and Forecasts, The European Organisation for
15 the Safety of Air Navigation. Eurocontrol. Available at: <http://www.eurocontrol.int/statfor>.
- 16 Fane, S. and A. Turner, 2010: Integrated water resource planning in the context of climate uncertainty. *Water
17 Science and Technology: Water Supply*, **10(4)**, 487-494.
- 18 Fankhauser, S., 2010: The costs of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, **1(1)**, 23-30.
- 19 Fankhauser, S., Agrawala, S., Hanrahan, D., Pope, D., Skees, J., Stephens, C. & Yearley, S. 2008, Economic and
20 Policy Instruments to Promote Adaptation in *Economic Aspects of Adaptation to Climate Change: Costs,
21 Benefits and Policy Instruments*, eds. S. Agrawala & S. Fankhauser, OECD, Paris, pp. 85-133.
- 22 Farley, K.A., C. Tague, and G.E. Grant, 2011: Vulnerability of water supply from the Oregon Cascades to changing
23 climate: Linking science to users and policy. *Global Environmental Change*, **21(1)**, 110-122.
- 24 Fazey, I., M. Kesby, A. Evely, I. Latham, D. Wagatora, J. Hagasua, M.S. Reed, and M. Christie, 2010: A three-
25 tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environmental
26 Change*, **20(4)**, 713-728.
- 27 Ferguson, B. and J. Navarrete, 2003: A financial framework for reducing slums: lessons from experience in Latin
28 America. *Environment and Urbanization*, **15(2)**, 201-216.
- 29 Fernandes, E., 2007: Implementing the urban reform agenda in Brazil. *Environment and Urbanization*, **19(1)**, 177-
30 189.
- 31 Findland Safety Investigations Authority, 2011. S2/2010Y The storms of July-August 2010. Available at:
32 <http://www.turvallisuustutkinta.fi/en/1279614262854>
- 33 Firman, T., I.M. Surbakti, I.C. Idroes, and H.A. Simarmata, 2011: Potential climate-change related vulnerabilities in
34 Jakarta: Challenges and current status. *Habitat International*, **35(2)**, 372-378.
- 35 Flanner, M.G., 2009: Integrating anthropogenic heat flux with global climate models. *Geophysical Research Letters*,
36 **36(2)**, L02801.
- 37 Foster, J., A. Lowe, and S. Winkelman, 2011a: The value of green infrastructure for urban climate adaptation. *The
38 Center for Clean Air Policy, Washington*
- 39 Foster, J., Winkelman, S. & Lowe, A. 2011b, Lessons learned on Local Climate Adaptation from the Urban Leaders
40 Adaptation Initiative, Center for Clean Air Policy - Urban Leaders Adaptation Initiative, Washington.
- 41 Frumkin, H., J. Hess, G. Luber, J. Malilay, and M. McGeehin, 2008: Climate Change: The Public Health Response.
42 *American Journal of Public Health*, **98(3)**, 435-445.
- 43 Fujibe, F., 2008: Detection of urban warming in recent temperature trends in Japan. *International Journal of
44 Climatology*, **29(12)**, 1811-1822.
- 45 Fujibe, F., 2011: Urban warming in Japanese cities and its relation to climate change monitoring. *International
46 Journal of Climatology*, **31(2)**, 162-173.
- 47 Fünfgeld, H. and D. McEvoy, 2011: Framing climate change adaptation in policy and practice. *Climate Change
48 Adaptation Program: Global Cities Institute. Melbourne, .*
- 49 Funtowicz, S.O. and J.R. Ravetz, 1993: Science for the post-normal age. *Futures*, **25(7)**, 739-755.
- 50 Füssel, H., 2007: Vulnerability: A generally applicable conceptual framework for climate change research. *Global
51 Environmental Change*, **17(2)**, 155-167.
- 52 Gaffin, S., M. Imhoff, C. Rosenzweig, R. Khanbilvardi, A. Pasqualini, A.Y. Kong, D. Grillo, A. Freed, D. Hillel,
53 and E. Hartung, 2012: Bright is the new black — multi-year performance of high-albedo roofs in an urban
54 climate. *Environmental Research Letters*, **7(1)**, 014029.

- 1 Gasper, R., A. Blohm, and M. Ruth, 2011: Social and economic impacts of climate change on the urban
2 environment. *Current Opinion in Environmental Sustainability*, **3(3)**, 150-157.
- 3 Gavidia Jorge 2006: *Priority Goals in Central America. The development of sustainable mechanisms for*
4 *participation in local risk management*, in Milenio Ambiental, No 4, pp 56 -59. Journal of the Urban
5 Environment Programme UPE of the International Development Research Centre, IDRC Montevideo;
- 6 GDF, Gobierno del Distrito Federal 2006 Estrategia Local de Acción Climática del Distrito Federal.
- 7 GDF, Gobierno del Distrito Federal 2008 Programa de Acción Climática de la Ciudad de México 2008-2012.
- 8 Getter, K.L., D.B. Rowe, J.A. Andresen, and I.S. Wichman, 2011: Seasonal heat flux properties of an extensive
9 green roof in a Midwestern U.S. climate. *Energy and Buildings*, **43(12)**, 3548-3557.
- 10 Gibbons, Sheila J. Arenstam and Robert J. Nicholls 2006, Island abandonment and sea-level rise: An historical
11 analog from the Chesapeake Bay, USA, *Global Environmental Change* Vol 16, No 1, February, 40-47.
- 12 Gieryn, T.F., 1999: *Cultural boundaries of science: Credibility on the line*. University of Chicago Press, .
- 13 Giguère, M., 2010: *Mesures de lutte aux îlots de chaleur urbains: revue de littérature*. Direction des risques
14 biologiques, environnementaux et occupationnels, Institut national de santé publique Québec, .
- 15 Gill, S., J. Handley, A. Ennos, and S. Pauleit, 2007: Adapting cities for climate change: the role of the green
16 infrastructure. *Built Environment*, **33(1)**, 115-133.
- 17 Gillingham, K., R.G. Newell, and K. Palmer, 2009: Energy Efficiency Economics and Policy.
18 *Annu.Rev.Resour.Econ.*,**1(1)**, 597-620.
- 19 GLA 2008: The London climate change adaptation strategy,, Draft Report, Greater London Authority, London, 113
20 pages.
- 21 GLA 2010: The draft climate change adaptation strategy for London. *Public Consultation Draft, Greater London*
22 *Authority, London, Feb*
- 23 GLA - Greater London Authority 2011. The London climate change adaptation strategy for London. Greater London
24 Authority, London.
- 25 GFDRR Global Facility for Disaster Reduction and Recovery: 2009 *Integrating Disaster Risk Reduction into the*
26 *Fight Against Poverty*, Annual Report 2009, 71 pgs.
- 27 Gober, P., 2010: Desert urbanization and the challenges of water sustainability. *Current Opinion in Environmental*
28 *Sustainability*, **2(3)**, 144-150.
- 29 Gober, P., C.W. Kirkwood, R.C. Balling, A.W. Ellis, and S. Deitrick, 2010: Water Planning Under Climatic
30 Uncertainty in Phoenix: Why We Need a New Paradigm. *Annals of the Association of American Geographers*,
31 **100(2)**, 356-372.
- 32 Godfray, H.C.J., J.R. Beddington, I.R. Crute, L. Haddad, D. Lawrence, J.F. Muir, J. Pretty, S. Robinson, S.M.
33 Thomas, and C. Toulmin, 2010: Food Security: The Challenge of Feeding 9 Billion People. *Science*, **327(5967)**,
34 812-818.
- 35 Granberg, M. and I. Elander, 2007: Local Governance and Climate Change: Reflections on the Swedish Experience.
36 *Local Environment*, **12(5)**, 537-548.
- 37 Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, X. Bai, and J.M. Briggs, 2008: Global Change
38 and the Ecology of Cities. *Science*, **319(5864)**, 756-760.
- 39 Grimmond, S. 2011. Climate of Cities.In *The Routledge Handbook of Urban Ecology*. Edited by I. Douglas, David
40 Goode, Mike Houck, Rusong Wang. Routledge.
- 41 Grindle, M.S. and J.W. Thomas, 1991: *Public choices and policy change: the political economy of reform in*
42 *developing countries*. Johns Hopkins University Press Baltimore, .
- 43 Grossi, C.M., P. Brimblecombe, and I. Harris, 2007: Predicting long term freeze–thaw risks on Europe built heritage
44 and archaeological sites in a changing climate. *Science of the Total Environment*, **377(2–3)**, 273-281.
- 45 Güneralp, B. and K.C. Seto, 2008: Environmental impacts of urban growth from an integrated dynamic perspective:
46 A case study of Shenzhen, South China. *Global Environmental Change*, **18(4)**, 720-735.
- 47 Gupta, J., R. Lasage, and T. Stam, 2007: National efforts to enhance local climate policy in the Netherlands.
48 *Environmental Sciences*, **4(3)**, 171-182.
- 49 Gusdorf, F., S. Hallegatte, and A. Lahellec, 2008: Time and space matter: How urban transitions create inequality.
50 *Global Environmental Change*, **18(4)**, 708-719.
- 51 Habermas, J., 1996: *Between Facts and Norms: Contributions to a Discourse Theory of Law and Democracy*.
- 52 Hacker, J.N. and M.J. Holmes, 2007: Thermal comfort: climate change and the environmental design of buildings in
53 the United Kingdom. *Built Environment*, **33(1)**, 97-114.

- 1 Hahn, M.B., A.M. Riederer, and S.O. Foster, 2009: The Livelihood Vulnerability Index: A pragmatic approach to
2 assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental*
3 *Change*, **19(1)**, 74-88.
- 4 Haines, A., N. Bruce, S. Cairncross, M. Davies, K. Greenland, A. Hiscox, S. Lindsay, T. Lindsay, D. Satterthwaite,
5 and P. Wilkinson, 2012: Promoting Health and Advancing Development through Improved Housing in Low-
6 Income Settings. *Journal of Urban Health*, , 1-22.
- 7 Hajat, S., M. O'Connor, and T. Kosatsky, 2010: Health effects of hot weather: from awareness of risk factors to
8 effective health protection. *The Lancet*, **375(9717)**, 856-863.
- 9 Hall, J., J. Henriques, A. Hickford, and R. Nicholls, 2012: A fast track analysis of strategies for infrastructure
10 provision in Great Britain: executive summary, Environmental Change Institute, University of Oxford.
- 11 Hallegatte, S., J. Hourcade, and P. Ambrosi, 2007: Using climate analogues for assessing climate change economic
12 impacts in urban areas. *Climatic Change*, **82(1)**, 47-60.
- 13 Hallegatte, S., J. Hourcade, and P. Dumas, 2007: Why economic dynamics matter in assessing climate change
14 damages: illustration on extreme events. *Ecological Economics*, **62(2)**, 330-340.
- 15 Hallegatte, S. and P. Dumas, 2009: Can natural disasters have positive consequences? Investigating the role of
16 embodied technical change. *Ecological Economics*, **68(3)**, 777-786.
- 17 Hallegatte, S. and J. Corfee-Morlot, 2011: Understanding climate change impacts, vulnerability and adaptation at
18 city scale: an introduction. *Climatic Change*, **104(1)**, 1-12.
- 19 Hallegatte, S., F. Henriet, and J. Corfee-Morlot, 2011: The economics of climate change impacts and policy benefits
20 at city scale: a conceptual framework. *Climatic Change*, **104(1)**, 51-87.
- 21 Hallegatte, S., N. Ranger, O. Mestre, P. Dumas, J. Corfee-Morlot, C. Herweijer, and R.M. Wood, 2011: Assessing
22 climate change impacts, sea level rise and storm surge risk in port cities: a case study on Copenhagen. *Climatic*
23 *Change*, **104(1)**, 113-137.
- 24 Halsnæs, K. and A. Garg, 2011: Assessing the role of energy in development and climate policies—conceptual
25 approach and key indicators. *World Development*, **39(6)**, 987-1001.
- 26 Halsnæs, K. and S. Trærup, 2009: Development and climate change: a mainstreaming approach for assessing
27 economic, social, and environmental impacts of adaptation measures. *Environmental Management*, **43(5)**, 765-
28 778.
- 29 Hamdan, M.A., J. Yamin, and E.A. Abdelhafez, 2011: Passive cooling roof design under Jordanian climate.
30 *Sustainable Cities and Society*, .
- 31 Hamdi, R., P. Termonia, and P. Baguis, 2011: Effects of urbanization and climate change on surface runoff of the
32 Brussels Capital Region: a case study using an urban soil–vegetation–atmosphere–transfer model. *International*
33 *Journal of Climatology*, **31(13)**, 1959-1974.
- 34 Hamin, E.M. Integrating Adaptation and Mitigation In Local Climate Change Planning. Forthcoming 2011 in
35 Ingram and Hong, Eds., *The Environment, Climate Change, and Land Policies*. Lincoln Institute of Land
36 Policy, Cambridge.
- 37 Hamin, E.M. and N. Gurran, 2009: Urban form and climate change: Balancing adaptation and mitigation in the U.S.
38 and Australia. *Habitat International*, **33(3)**, 238-245.
- 39 Hammer, S. A., J. Keirstead, S. Dhakal, J. Mitchell, M. Colley, R. Connell, R. Gonzalez, M. Herve-Mignucci, L.
40 Parshall, N. Schulz, M. Hyams, 2011: Climate change and urban energy systems. *Climate Change and Cities:*
41 *First Assessment Report of the Urban Climate Change Research Network*, C. Rosenzweig, W. D. Solecki, S. A.
42 Hammer, S. Mehrotra, Eds., Cambridge University Press, Cambridge, UK, 85–111.
- 43 Hammill, A., Richard Matthew, R. & McCarter, E. 2008, Microfinance and Climate Change Adaptation, *IDS*
44 *Bulletin*, 39, no. 4, pp. 113-122.
- 45 Hanak, E. and J. Lund, 2008: *Adapting California's Water Management to Climate Change*. Public Policy Institute
46 of California San Francisco, CA, .
- 47 Hanson, S., R. Nicholls, N. Ranger, S. Hallegatte, J. Corfee-Morlot, C. Herweijer, and J. Chateau, 2011: A global
48 ranking of port cities with high exposure to climate extremes. *Climatic Change*, **104(1)**, 89-111.
- 49 Haque, A.N., S. Grafakos, and M. Huijsman, 2012: Participatory integrated assessment of flood protection measures
50 for climate adaptation in Dhaka. *Environment and Urbanization*, **24(1)**, 197-213.
- 51 Hardoy, J.E., D. Mitlin, and D. Satterthwaite, 2001: *Environmental problems in an urbanizing world*. Earthscan, .
- 52 Hardoy, J. (2013) Los desafíos de incorporar la adaptación al cambio climático en las agendas locales: algunas
53 experiencias de Latino América. *Medio Ambiente y Urbanización*, No 78.

- 1 Hardoy, J. and G. Pandiella, 2007: Adaptación de las ciudades argentinas a los efectos del cambio y la variabilidad
2 climática. *Medio Ambiente y Urbanización*, **67(1)**, 45-58.
- 3 Hardoy, J. and G. Pandiella, 2009: Urban poverty and vulnerability to climate change in Latin America.
4 *Environment and Urbanization*, **21(1)**, 203-224.
- 5 Hardoy, J., G. Pandiella, and L.S. Velásquez Barrero, 2011: Local disaster risk reduction in Latin American urban
6 areas. *Environment and Urbanization*, **23(2)**, 401-413.
- 7 Hardoy, J. and P. Romero Lankao, 2011: Latin American cities and climate change: challenges and options to
8 mitigation and adaptation responses. *Current Opinion in Environmental Sustainability*, **3(3)**, 158-163.
- 9 Hardoy, Jorgelina and Luz Stella Velásquez Barreto 2014: Re-thinking 'Biomanzales' to address climate change
10 adaptation in Manizales, Colombia. *EnvironUrb* 26(1).
- 11 Hardoy, Jorgelina and Regina Ruete 2013: Incorporating climate change adaptation into planning for a liveable city
12 in Rosario, Argentina. *EnvironUrb* 25(2).
- 13 Harlan, S.L. and D.M. Ruddell, 2011: Climate change and health in cities: impacts of heat and air pollution and
14 potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability*, **3(3)**,
15 126-134.
- 16 Hasan, A., M. Younus, and S.A. Zaidi, 2002: *Understanding Karachi: planning and reform for the future*. City
17 Press
- 18 Haughton, G., 1999: Information and participation within environmental management. *Environment and*
19 *Urbanization*, **11(2)**, 51-62.
- 20 Hayhoe, K., M. Robson, J. Rogula, M. Auffhammer, N. Miller, J. VanDorn, and D. Wuebbles, 2010: An integrated
21 framework for quantifying and valuing climate change impacts on urban energy and infrastructure: A Chicago
22 case study. *Journal of Great Lakes Research*, **36, Supplement 2(0)**, 94-105.
- 23 He, J., J. Liu, D. Zhuang, W. Zhang, and M. Liu, 2007: Assessing the effect of land use/land cover change on the
24 change of urban heat island intensity. *Theoretical and Applied Climatology*, **90(3)**, 217-226.
- 25 Healey, P., 1997: *Collaborative planning: shaping places in fragmented societies*. Ubc Press, .
- 26 Hebert, K. and R. Taplin, 2006: Climate change impacts and coastal planning in the Sydney greater metropolitan
27 region. *Australian Planner*, **43(3)**, 34-41.
- 28 Hedger, M., T. Mitchell, J. Leavy, M. Greeley, A. Downie, and L. Horrocks, 2008: Desk review: evaluation of
29 adaptation to climate change from a development perspective. *A Study Commissioned by GEF and Financed by*
30 *DFID*, .
- 31 Hedger, M.M., R. Connell, and P. Bramwell, 2006: Bridging the gap: empowering decision-making for adaptation
32 through the UK Climate Impacts Programme. *Climate Policy*, **6(2)**, 201-215.
- 33 Heinrichs, D., Aggarwal, R., Barton, J., Bharucha, E., Butsch, C., Fragkias, M., Johnston, P., Krass, F., Krellenberg,
34 K., Lampis, A., Ling, O.G. and J. Vogel 2011 Adapting Cities to Climate Change: Opportunities an Constraints
35 in *Cities and Climate Change: Responding to an Urgent Agenda*, D. Hoornweg, M. Friere, M.J. Lee, P. Bhada-
36 Tata and B. Yuen eds The World Bank, Washington DC, USA.
- 37 Herrfahrdt-Pahle, E., 2010: South African water governance between administrative and hydrological boundaries.
38 *Climate and Development*, **2(2)**, 111-127.
- 39 Hess, J.J., K.L. Heilpern, T.E. Davis, and H. Frumkin, 2009: Climate change and emergency medicine: impacts and
40 opportunities. *Academic Emergency Medicine*, **16(8)**, 782-794.
- 41 Hisschemöller, M., R. Hoppe, and W. Dunn, 2001: *Knowledge, power and participation in environmental policy*
42 *analysis*. Transaction Pub, .
- 43 Hodo-Abalo, S., M. Banna, and B. Zeghmami, 2012: Performance analysis of a planted roof as a passive cooling
44 technique in hot-humid tropics. *Renewable Energy*, **39(1)**, 140-148.
- 45 Holmes, P., J. Woods, and C. Dorse, 2008: City of Cape Town Biodiversity Report. *City of Cape Town*, .
- 46 Hoornweg, D. and P. Bhada-Tata, 2012: What a waste: a global review of solid waste management. *Urban*
47 *Development Series; Knowledge Papers no*, **15**.
- 48 Hoornweg, D., M. Freire, M.J. Lee, P. Bhada-Tata, and B. Yuen, 2011: *Cities and climate change: responding to an*
49 *urgent agenda*. World Bank Publications, .
- 50 Hoornweg, D., L. Sugar, and C.L. Trejos Gómez, 2011: Cities and greenhouse gas emissions: moving forward.
51 *Environment and Urbanization*, **23(1)**, 207-227.
- 52 Horton, R.M., V. Gornitz, D.A. Bader, A.C. Ruane, R. Goldberg, and C. Rosenzweig, 2011: Climate hazard
53 assessment for stakeholder adaptation planning in New York City. *Journal of Applied Meteorology and*
54 *Climatology*, **50(11)**, 2247-2266.

- 1 Howard, G., K. Charles, K. Pond, A. Brookshaw, R. Hossain, and J. Bartram, 2010: Securing 2020 vision for 2030:
2 climate change and ensuring resilience in water and sanitation services. *Journal of Water and Climate Change*
3 *Vol, 1(1)*, 2-16.
- 4 Huang, C., P. Vaneckova, X. Wang, G. FitzGerald, Y. Guo, and S. Tong, 2011: Constraints and Barriers to Public
5 Health Adaptation to Climate Change: A Review of the Literature. *American Journal of Preventive Medicine*,
6 **40(2)**, 183-190.
- 7 Huang, S. -L., Yeh, C. -T. and Chang, L. -F. 2010. The transition to an urbanizing world and the demand for natural
8 resources, *Current Opinion in Environmental Sustainability*, 2(3): 136-143
- 9 Hunt, A. and P. Watkiss, 2011: Climate change impacts and adaptation in cities: a review of the literature. *Climatic*
10 *Change*, **104(1)**, 13-49.
- 11 Iamarino, M., S. Beevers, and C. Grimmond, 2011: High-resolution (space, time) anthropogenic heat emissions:
12 London 1970–2025. *International Journal of Climatology*, .
- 13 ICLEI. 2010. Cities in a Post-2012 Climate Policy Framework. ICLEI, Bonn. Accessed from
14 http://www.preventionweb.net/files/13181_CitiesinaPost2012PolicyFrameworkCli.pdf
- 15 ICLEI, 2011a. Financing the Resilient City: A demand driven approach to development, disaster risk reduction and
16 climate adaptation - An ICLEI White Paper, ICLEI Global Report.
- 17 ICLEI 2011b. ICLEI submission for Rio+20: Contribution to the Zero Draft of the Rio+20 outcome document. 31
18 October 2011.
- 19 ICLEI Oceania 2008 Local Government Climate Change Adaptation Toolkit. Cities for Climate Protection Australia
20 Adaptation Initiative. ICLEI Oceania, Melbourne.
- 21 IFRC 2010, World Disasters Report 2010: Focus on Urban Risk, International Federation of Red Cross and Red
22 Crescent Societies, Geneva, 211 pp.
- 23 IFRC 2011 Key determinants of a successful CBDRR programme, IFRC, accessed from
24 http://www.ifrc.org/docs/Evaluations/Evaluations%202012/Global/GlobalKey_Determinants_12.pdf
- 25 Imparato, I. and J. Ruster, 2003: *Slum upgrading and participation: Lessons from Latin America*. World Bank
26 Publications, .
- 27 Institute for Sustainable Communities ISC Undated. Promising Practices in Adaptation & Resilience: A Resource
28 Guide for Local Leaders Version 1.0. Produced in partnership with the Centre for Clean Air Policy.
- 29 IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A
30 Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V.
31 Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K.
32 Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY,
33 USA, 582 pp.
- 34 IPCC, 2011: Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on
35 Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B.,
36 Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K.,
37 Allen, S. K., Tignor, M. and P. M. Midgley eds.]. Cambridge University Press, Cambridge, United Kingdom
38 and New York, NY, USA.
- 39 Iqbal, M.J. and J. Quamar, 2011: Measuring temperature variability of five major cities of Pakistan. *Arabian Journal*
40 *of Geosciences*, **4(3)**, 595-606.
- 41 Ismail, A., M.H.A. Samad, and A.M.A. Rahman, 2011: The Investigation of Green Roof and White Roof Cooling
42 Potential on Single Storey Residential Building in the Malaysian Climate. Proceedings of Proceedings of World
43 Academy of Science, Engineering and Technology, pp. 129-137.
- 44 Jabeen, H., C. Johnson, and A. Allen, 2010: Built-in resilience: learning from grassroots coping strategies for
45 climate variability. *Environment and Urbanization*, **22(2)**, 415-431.
- 46 Jacob, D.J. and D.A. Winner, 2009: Effect of climate change on air quality. *Atmospheric Environment*, **43(1)**, 51-63.
- 47 Jacob, K., R. Blake, R. Horton, D. Bader, and M. O'Grady, 2010: Chapter 7: Indicators and monitoring. *Annals of*
48 *the New York Academy of Sciences*, **1196(1)**, 127-142.
- 49 Jacob, Klaus, George Deodatis, John Atlas, Morgan Whitcomb, Madeleine Lopeman, Olga Markogiannaki, Zackary
50 Kennett, Aurelie Morla, Robin Leichenko and Peter Ventura 2011:—Transportation 2011. In Rosenzweig, C.,
51 W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn, eds. Responding to Climate Change in New
52 York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation. Technical
53 Report. New York State Energy Research and Development Authority (NYSERDA), Albany, New
54 York. Chapter 9.

- 1 Jacobs, K. and S. Williams, 2011: What to do now? Tensions and dilemmas in responding to natural disasters: a
2 study of three Australian state housing authorities. *International Journal of Housing Policy*, **11(2)**, 175-193.
- 3 Jaroszowski, D., L. Chapman, and J. Petts, 2010: Assessing the potential impact of climate change on transportation:
4 the need for an interdisciplinary approach. *Journal of Transport Geography*, **18(2)**, 331-335.
- 5 Jasanoff, S., 1994: *The fifth branch: Science advisers as policymakers*. Harvard University Press
- 6 Jenerette, G. Darrel and Larissa Larsen 2006, A global perspective on changing sustainable urban water supplies,
7 *Global and Planetary Change* Vol 50, Nos 3-4, April, 202-211.
- 8 Jha, A.K., R. Bloch, and J. Lamond, 2012: *Cities and flooding: a guide to integrated urban flood risk management*
9 *for the 21st century*. World Bank Publications,
- 10 Jim, C., 2012: Effect of vegetation biomass structure on thermal performance of tropical green roof. *Landscape and*
11 *Ecological Engineering*, , 1-15.
- 12 Jo, J.H., J. Carlson, J.S. Golden, and H. Bryan, 2010: Sustainable urban energy: Development of a mesoscale
13 assessment model for solar reflective roof technologies. *Energy Policy*, **38(12)**, 7951-7959.
- 14 Johansson, T.B. N. Nakicenovic, A. Patwardhan and L. Gomez-Echeverri (editors, 2012: *Global Energy*
15 *Assessment: Toward a Sustainable Future*, Cambridge: Cambridge University Press, 1865 pages.
- 16 Johnson, Cassidy (2011). Creating an enabling environment for reducing disaster risk: Recent experience of
17 regulatory frameworks for land, planning and building in low and middle-income countries. Background Paper
18 for the Global Assessment Report on Disaster Risk Reduction 2011: Revealing Risk, Redefining Development,
19 UNISDR, Geneva. Available from:
20 http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Johnson_2011.pdf (accessed 15 Mar 2013).
- 21 Johnson, C. and S. Blackburn 2013: The role of global campaigns in enhancing urban resilience, *Environment and*
22 *Urbanization* (forthcoming).
- 23 Jollands, N., M. Ruth, C. Bernier, and N. Golubiewski 2007: The climate's long-term impact on New Zealand
24 infrastructure CLINZI project—A case study of Hamilton City, New Zealand, *Journal of Environmental*
25 *Management* Vol 83, No 4, June, 460-477
- 26 Jones, L., Ludi E. and S. Levine 2010. Towards a characterisation of adaptive capacity: a framework for analysing
27 adaptive capacity at the local level. Overseas Development Institute: Background paper.*
- 28 Jung, S., 2008: Spatial variability in long-term changes of climate and oceanographic conditions in Korea. *Journal*
29 *of Environmental Biology*, **29(4)**.
- 30 Kabat, P., F. Ludwig, van der van der Valk, Michael, and H. van van Schaik, 2012: *Climate change adaptation in the*
31 *water sector*. Routledge, .
- 32 Kalnay, E., M. Cai, H. Li, and J. Tobin, 2006: Estimation of the impact of land-surface forcings on temperature
33 trends in eastern United States. *Journal of Geophysical Research*, **111(D6)**, D06106.
- 34 Kasperson, R.E., 2012: *Integrating science and policy: Vulnerability and resilience in global environmental change*.
35 Routledge, .
- 36 Kazmierczak, A. and J. Carter 2010. Adaptation to climate change using green and blue infrastructure. A database of
37 case studies. University of Manchester.
- 38 Kehew, R., M. Kolisa, C. Rollo, A. Callejas, and G. Alber, 2012: Urban Climate Governance in the Philippines,
39 Mexico and South Africa: National-and State-Level Laws and Policies in Otto-Zimmermann, Konrad, ed.
40 *Resilient Cities 2: Cities and Adaptation to Climate Change: Proceedings of the Global Forum 2011*.
41 Dordrecht: Springer, 305-316
- 42 Keim, M.E., 2008: Building Human Resilience: The Role of Public Health Preparedness and Response As an
43 Adaptation to Climate Change. *American Journal of Preventive Medicine*, **35(5)**, 508-516.
- 44 Keogh, B. O. Suess, J. Westbrook 2010. The Trouble with Catastrophe Bonds in *Bloomberg Businessweek*, 25 April
45 2011
- 46 Kern, K. and G. Alber, 2008: Governing climate change in cities: Modes of urban climate governance in multi-level
47 systems. *Competitive Cities and Climate Change*, , 171.
- 48 Kern, K. & Gotelind, A. 2009, Governing climate change in cities: modes of urban climate governance in multi-
49 level systems in *Competitive Cities and Climate Change*, OECD Conference Proceedings, Milan, Italy, 9-10
50 October 2008 OECD, Paris, pp. 171-196.
- 51 Kessler, R., 2011: Stormwater Strategies: Cities Prepare Aging Infrastructure for Climate Change. *Environmental*
52 *Health Perspectives*, **119(12)**, A514-9.
- 53 Kinney, P.L., 2008: Climate Change, Air Quality, and Human Health. *American Journal of Preventive Medicine*,
54 **35(5)**, 459-467.

- 1 Kirshen, P., M. Ruth, and W. Anderson, 2008: Interdependencies of urban climate change impacts and adaptation
2 strategies: a case study of Metropolitan Boston USA. *Climatic Change*, **86(1)**, 105-122.
- 3 Kithiia, J., 2010: Old notion–new relevance: setting the stage for the use of social capital resource in adapting East
4 African coastal cities to climate change. *International Journal of Urban Sustainable Development*, **1(1-2)**, 17-
5 32.
- 6 Kithiia, J., 2011: Climate change risk responses in East African cities: need, barriers and opportunities. *Current
7 Opinion in Environmental Sustainability*, **3(3)**, 176-180.
- 8 Kithiia, J. and R. Dowling, 2010: An integrated city-level planning process to address the impacts of climate change
9 in Kenya: The case of Mombasa. *Cities*, **27(6)**, 466-475.
- 10 Kithiia, J. and A. Lyth, 2011: Urban wildscapes and green spaces in Mombasa and their potential contribution to
11 climate change adaptation and mitigation. *Environment and Urbanization*, **23(1)**, 251-265.
- 12 Kiunsi, Robert 2013: The constraints on climate change adaptation in a city with large development deficits: the
13 case of Dar es Salaam City, *Environment and Urbanization*, Vol. 25, No. 2.
- 14 Koetse, M.J. and P. Rietveld, 2009: The impact of climate change and weather on transport: An overview of
15 empirical findings. *Transportation Research Part D: Transport and Environment*, **14(3)**, 205-221.
- 16 Kolokotroni, M., M. Davies, B. Croxford, S. Bhuiyan, and A. Mavrogianni, 2010: A validated methodology for the
17 prediction of heating and cooling energy demand for buildings within the Urban Heat Island: Case-study of
18 London. *Solar Energy*, **84(12)**, 2246-2255.
- 19 Kousky, C. and S.H. Schneider, 2003: Global climate policy: will cities lead the way? *Climate Policy*, **3(4)**, 359-
20 372.
- 21 Kovats, S 2009: ‘Adaptation costs for human health’ in M Parry *et al*, eds., *Assessing the Costs of Adaptation to
22 Climate Change: A Review of the UNFCCC and Other Recent Estimates*, International Institute for
23 Environment and Development (IIED) and Grantham Institute for Climate Change, London.
- 24 Kovats, S. and R. Akhtar, 2008: Climate, climate change and human health in Asian cities. *Environment and
25 Urbanization*, **20(1)**, 165-175.
- 26 Krishnamurthy, P.K., J.B. Fisher, and C. Johnson, 2011: Mainstreaming local perceptions of hurricane risk into
27 policymaking: A case study of community GIS in Mexico. *Global Environmental Change*, **21(1)**, 143-153.
- 28 Kumar, R., P. Jawale, and S. Tandon, 2008: Economic impact of climate change on Mumbai, India. Proceedings of
29 Regional Health Forum, pp. 39.
- 30 La Greca, P., D. La Rosa, F. Martinico, and R. Privitera, 2011: Agricultural and green infrastructures: The role of
31 non-urbanised areas for eco-sustainable planning in a metropolitan region. *Environmental Pollution*, **159(8)**,
32 2193-2202.
- 33 Larsen, P.H., S. Goldsmith, O. Smith, M.L. Wilson, K. Strzeppek, P. Chinowsky, and B. Saylor, 2008: Estimating
34 future costs for Alaska public infrastructure at risk from climate change. *Global Environmental Change*, **18(3)**,
35 442-457.
- 36 Laurent, S. 2010, Xynthia : une communication qui passe mal, April 19 edn, Paris.
- 37 Le Roux, J. and G. Alexander, 2002: *The Biodiversity of South Africa 2002: Indicators, trends and human impacts*.
38 Struik, .
- 39 Lee-Smith, D., 2010: Cities feeding people: an update on urban agriculture in equatorial Africa. *Environment and
40 Urbanization*, **22(2)**, 483-499.
- 41 Leichenko, R., 2011: Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, **3(3)**,
42 164-168.
- 43 Leichenko, Robin M., O'Brien, Karen L. and Solecki, William D. 2010: 'Climate Change and the Global Financial
44 Crisis: A Case of Double Exposure', *Annals of the Association of American Geographers* Vol 100, No 4,
45 December, 963-972
- 46 Leichenko, R.M. and W.D. Solecki, 2005: Exporting the American dream: the globalization of suburban
47 consumption landscapes. *Regional Studies*, **39(2)**, 241-253.
- 48 Leiserowitz, A., 2006: Climate change risk perception and policy preferences: The role of affect, imagery, and
49 values. *Climatic Change*, **77(1)**, 45-72.
- 50 Levina, E., J. Jacob, L.E.R. Bustillos, and I. Ortiz, 2007: Policy frameworks for Adaptation to Climate Change in
51 Coastal Zones: The Case of the Gulf of Mexico. *OECD Papers*, **7(1)**.
- 52 Levy, C., 2013: Travel choice reframed: “deep distribution” and gender in urban transport. *Environment and
53 Urbanization*, .
- 54 Levy, D.L. and P.J. Newell, 2004: *The business of global environmental governance*. MIT press, .

- 1 Liberatore, A. and S. Funtowicz, 2003: ‘Democratising’expertise, ‘expertising’democracy: What does this mean, and
2 why bother? *Science and Public Policy*, **30(3)**, 146-150.
- 3 Lim, B., E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq, 2005: *Adaptation policy frameworks for climate*
4 *change: developing strategies, policies, and measures*. Cambridge University Press Cambridge, .
- 5 Lindgren, J., D.K. Jonsson, and A. Carlsson-Kanyama, 2009: Climate adaptation of railways: lessons from Sweden.
6 *Ejtir*, **9(2)**, 164-181.
- 7 Linnekamp, F., A. Koedam, and I.S.A. Baud, 2011: Household vulnerability to climate change: Examining
8 perceptions of households of flood risks in Georgetown and Paramaribo. *Habitat International*, **35(3)**, 447-456.
- 9 Liu, J. and X. Deng, 2011: Impacts and mitigation of climate change on Chinese cities. *Current Opinion in*
10 *Environmental Sustainability*, **3(3)**, 188-192.
- 11 Livengood, A. and K. Kunte, 2012: Enabling participatory planning with GIS: a case study of settlement mapping in
12 Cuttack, India. *Environment and Urbanization*, **24(1)**, 77-97.
- 13 Logan, J.R., 2006: The impact of Katrina: Race and class in storm-damaged neighborhoods. *Brown University*, **16**.
- 14 Love, G., A. Soares, and H. Püempel, 2010: Climate Change, Climate Variability and Transportation. *Procedia*
15 *Environmental Sciences*, **1(0)**, 130-145.
- 16 Lowe, A., J. Foster, and S. Winkelmand, 2009: *Ask the climate question: adapting to climate change impacts in*
17 *urban regions*. Center for Clean Air Policy Washington, DC., USA, .
- 18 Lucena, A.F.P de.et al. 2009: The vulnerability of renewable energy to climate change in Brazil. *Energy Policy*.
19 **37(3)**: 879-889.
- 20 Lucena, A.F.P. de. 2010. Least-cost adaptation options for global climate change impacts on the Brazilian electric
21 power system. *Global Environmental Change*. **20(2)**: 342-350
- 22 Luque, Andres, Gareth Edwards, Christophe Lalande 2013. "Climate change governance at the local level: new tools
23 to respond to old deficiencies in Esmeraldas, Ecuador." *Local Environment: The International Journal of Justice*
24 *and Sustainability*". Forthcoming
- 25 Lwasa, S., 2010: Adapting urban areas in Africa to climate change: the case of Kampala. *Current Opinion in*
26 *Environmental Sustainability*, **2(3)**, 166-171.
- 27 Lwasa, S. 2013. Bridging adaptation to climate change across city scales in Kampala". *Local Environment: The*
28 *International Journal of Justice and Sustainability*. Forthcoming.
- 29 Lyons, M., 2009: Building back better: the large-scale impact of small-scale approaches to reconstruction. *World*
30 *Development*, **37(2)**, 385-398.
- 31 Major, D. C., A. Omojola, M. Dettinger, R. T. Hanson, R. Sanchez-Rodriguez, 2011: Climate change, water, and
32 wastewater in cities. *Climate Change and Cities: First Assessment Report of the Urban Climate Change*
33 *Research Network*, C. Rosenzweig, W. D. Solecki, S. A. Hammer, S. Mehrotra, Eds., Cambridge University
34 Press, Cambridge, UK, 113–143.
- 35 Maller, C.J. and Y. Strengers, 2011: Housing, heat stress and health in a changing climate: promoting the adaptive
36 capacity of vulnerable households, a suggested way forward. *Health Promotion International*, **26(4)**, 492-498.
- 37 Manda, Mtafu A Zeleza 2007, Mchenga - urban poor housing fund in Malawi, *EnvironUrb*, **19(2)**, 337-359.
- 38 Mansilla, Elizabeth with Brenes, Alice and Icaza Julio (2008), “Centroamérica a 10 años de Mitch. Reflexiones en
39 torno a la reducción del riesgo”, CEPREDENAC and the World Bank, Washington DC, 81 pages.
- 40 Manton, M.J., 2010: Trends in climate extremes affecting human settlements. *Current Opinion in Environmental*
41 *Sustainability*, **2(3)**, 151-155.
- 42 Manuel-Navarrete, D., M. Pelling, and M. Redclift, 2011: Critical adaptation to hurricanes in the Mexican
43 Caribbean: Development visions, governance structures, and coping strategies. *Global Environmental Change*,
44 **21(1)**, 249-258.
- 45 Manyena, S., G. O’Brien, P. O’Keefe, and J. Rose, 2011: Disaster resilience: a bounce back or bounce forward
46 ability? *Local Environment*, **16(5)**, 417-424.
- 47 Marcotullio, P. and G. McGranahan, 2007: *Scaling Urban Environmental Challenges: from local to global and*
48 *back*. Earthscan/James & James.
- 49 Martine, G., G. McGranahan, M. Montgomery, and R. Fernandez-Castilla, 2012: *The new global frontier:*
50 *urbanization, poverty and environment in the 21st century*. Routledge, .
- 51 Martins, R.D. and L. da Costa Ferreira, 2011: Climate change action at the city level: tales from two megacities in
52 Brazil. *Management of Environmental Quality: An International Journal*, **22(3)**, 344-357.
- 53 Massetti, E., S. Pinton, and D. Zanoni, 2007: National through to local climate policy in Italy. *Environmental*
54 *Sciences*, **4(3)**, 149-158.

- 1 Mather, A.A., G.G. Garland and DD Stretch (2009), Southern African sea levels: corrections, influences and trends,
2 African Journal of Marine Science, 31(2), pages 145-156.
- 3 MATTHIAS, R. and D. Coelho, 2007: Understanding and managing the complexity of urban systems under climate
4 change. *Climate Policy*, **7(4)**, 317-336.
- 5 Matzarakis, A. and C. Endler, 2010: Climate change and thermal bioclimate in cities: impacts and options for
6 adaptation in Freiburg, Germany. *International Journal of Biometeorology*, **54(4)**, 479-483.
- 7 May, P. et al. 2002, Using Fiscal Instruments to Encourage Conservation: Municipal Responses to the ‘Ecological’
8 Value Added Tax in Paraná and Minas Gerais, Brazil, in S. Pagiola, J. Bishop and N. Landell-Mills eds., *Selling*
9 *Forest Environmental Services: Market-based Mechanisms for Conservation and Development*, Earthscan,
10 London
- 11 McBain, W., D. Wilkes, and M. Retter, 2010: Flood resilience and resistance for critical infrastructure. *CIRIA C688*,
12 *CIRIA, London*, .
- 13 McCarthy, M.P., M.J. Best, and R.A. Betts, 2010: Climate change in cities due to global warming and urban effects.
14 *Geophysical Research Letters*, **37(9)**, L09705.
- 15 McCarthy, M., C. Harpham, C. Goodess, and P. Jones, 2011: Simulating climate change in UK cities using a
16 regional climate model, HadRM3. *International Journal of Climatology*, .
- 17 McDonald, R.I., P. Green, D. Balk, B.M. Fekete, C. Revenga, M. Todd, and M. Montgomery, 2011: Urban growth,
18 climate change, and freshwater availability. *Proceedings of the National Academy of Sciences*, **108(15)**, 6312-
19 6317.
- 20 McGranahan, G., 2007: *Urban environments, wealth and health: shifting burdens and possible responses in low and*
21 *middle-income nations*. Iied, .
- 22 McGranahan, G., D. Balk, and B. Anderson, 2007: The rising tide: assessing the risks of climate change and human
23 settlements in low elevation coastal zones. *Environment and Urbanization*, **19(1)**, 17-37.
- 24 McKenzie Hedger M, Connell R, Bramwell P 2006. Bridging the gap: empowering decision-making for adaptation
25 through the UK Climate Impacts Programme. *Climate Policy* 6:201–215
- 26 McMichael, A., S. Friel, A. Nyong, and C. Corvalan, 2008: Global environmental change and health: impacts,
27 inequalities, and the health sector. *BMJ: British Medical Journal*, **336(7637)**, 191.
- 28 Mdluli, T.N. and C.H. Vogel, 2010: Challenges to achieving a successful transition to a low carbon economy in
29 South Africa: examples from poor urban communities. *Mitigation and Adaptation Strategies for Global*
30 *Change*, **15(3)**, 205-222.
- 31 Measham, T.G., B.L. Preston, C. Brooke, T.F. Smith, C. Morrison, G. Withycombe, and R. Gorddard, 2010:
32 *Adapting to Climate Change through Local Municipal Planning: Barriers and Opportunities*, .
- 33 Mees, H.P. and P.P.J. Driessen, 2011: Adaptation to climate change in urban areas: Climate-greening London,
34 Rotterdam, and Toronto. *Climate Law*, **2(2)**, 251-280.
- 35 Mehrotra, S., C.E. Natenzon, A. Omojola, R. Folorunsho, J. Gilbride, and C. Rosenzweig, 2009: Framework for city
36 climate risk assessment. Proceedings of Fifth Urban Research Symposium, Marseille, France, .
- 37 Mehrotra, S., B. Lefevre, R. Zimmerman, H. Gerçek, K. Jacob, S. Srinivasan, 2011b. Climate change and urban
38 transportation systems. Climate Change and Cities: First Assessment Report of the Urban Climate Change
39 Research Network, C. Rosenzweig, W. D. Solecki, S. A. Hammer, S. Mehrotra, Eds., Cambridge University
40 Press, Cambridge, UK, 145–177.
- 41 Mehrotra, S., Rosenzweig, C., Solecki, W.D., Natenzon, C.E., Omojola, A., Folorunsho, R., and J. Gillbride 2011a.
42 Cities, disasters and climate risk in *Climate change and cities: First Assessment Report or the Urban Climate*
43 *Change Research Network*, C. Rosenzweig, W.D. Solecki, S.A. Hammer, S. Mehrotra eds, Cambridge
44 University Press, Cambridge, UK.
- 45 Melbourne ,City of 2009: *City of Melbourne: Climate Change Adaptation Strategy*, 128 pages.
- 46 Merk, O. 2012. “Financing Green Growth in Cities” OECD Working Paper on on Regional Development. OECD,
47 Paris, forthcoming.
- 48 Mideksa, T.K. and S. Kallbekken, 2010: The impact of climate change on the electricity market: A review. *Energy*
49 *Policy*, **38(7)**, 3579-3585.
- 50 Mills, E., 2007: Synergisms between climate change mitigation and adaptation: an insurance perspective. *Mitigation*
51 *and Adaptation Strategies for Global Change*, **12(5)**, 809-842.
- 52 Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer,
53 2008: Stationarity Is Dead: Whither Water Management? *Science*, **319(5863)**, 573-574.

- 1 Milman, A. and A. Short, 2008: Incorporating resilience into sustainability indicators: An example for the urban
2 water sector. *Global Environmental Change*, **18(4)**, 758-767.
- 3 Mirasgedis, S., Y. Sarafidis, E. Georgopoulou, V. Kotroni, K. Lagouvardos, and D. Lalas, 2007: Modeling
4 framework for estimating impacts of climate change on electricity demand at regional level: Case of Greece.
5 *Energy Conversion and Management*, **48(5)**, 1737-1750.
- 6 Mitchell, T., M. Van Aalst, and P.S. Villanueva, 2010: *Assessing Progress on Integrating Disaster Risk Reduction
7 and Climate Change Adaptation in Development Processes*. University of Sussex Institute, Development
8 Studies, Strengthening Climate Resilience, .
- 9 Mitlin, D., 2008: With and beyond the state — co-production as a route to political influence, power and
10 transformation for grassroots organizations. *Environment and Urbanization*, **20(2)**, 339-360.
- 11 Mitlin D 2012 Lessons from the urban poor: collective action and the rethinking of development. In Pelling, M., D.
12 Manuel-Navarrete, and M. Redclift, 2012: *Climate Change and the Crisis of Capitalism: A Chance to Reclaim,
13 Self, Society and Nature*. Routledge, London.
- 14 Mitlin, D. and A. Muller, 2004: Windhoek, Namibia: towards progressive urban land policies in Southern Africa.
15 *International Development Planning Review*, **26(2)**, 167-186.
- 16 Mitlin, D. and D. Satterthwaite, 2013: *Urban poverty in the global south: scale and nature*. Routledge, .
- 17 Moench, M., S. Tyler, and J. Lage, 2011: Catalyzing urban climate resilience: applying resilience concepts to
18 planning practice in the ACCCRN program (2009–2011). *Bangkok (Thailand): ISET-Boulder*, .
- 19 Moffet, V., M. Alibert, and C. Larrivée, 2011: Interdisciplinary and Multi-institutional Approaches to Climate
20 Change Adaptation. *Resilient Cities*, , 213-221.
- 21 Mohan, G. and K. Stokke, 2000: Participatory development and empowerment: the dangers of localism. *Third
22 World Quarterly*, **21(2)**, 247-268.
- 23 Mohan, M., A. Kandya, and A. Battiprolu, 2011b: Urban Heat Island Effect over National Capital Region of India:
24 A Study using the Temperature Trends. *Journal of Environmental Protection*, **2(4)**, 465-472.
- 25 Mohan, M., S.K. Pathan, K. Narendrareddy, A. Kandya, and S. Pandey, 2011a: Dynamics of Urbanization and Its
26 Impact on Land-Use/Land-Cover: A Case Study of Megacity Delhi. *Journal of Environmental Protection*, **2(9)**,
27 1274-1283.
- 28 Mohan, M., Y. Kikegawa, B. Gurjar, S. Bhati, A. Kandya, and K. Ogawa, 2012: Urban Heat Island Assessment for a
29 Tropical Urban Airshed in India. *Atmospheric and Climate Sciences*, **2(2)**, 127-138.
- 30 Moser, C., A. Norton, A. Stein, and S. Georgieva, 2010: Pro-Poor adaptation to climate change in urban centers:
31 case studies of vulnerability and resilience in Kenya and Nicaragua.
- 32 Moser, C. and D. Satterthwaite, 2010: Towards pro-poor adaptation to climate change in the urban centres of low-
33 and middle-income countries. *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming
34 World*, , 231-258.
- 35 Moser, S.C., 2006: Talk of the city: engaging urbanites on climate change. *Environmental Research Letters*, **1(1)**,
36 014006.
- 37 Moser, S.C., 2009: Good morning, America! The explosive US awakening to the need for adaptation.
- 38 Moser, S.C., 2012: Adaptation, mitigation, and their disharmonious discontents: an essay. *Climatic Change*, , 1-11.
- 39 Moser, S.C. and L. Dilling, 2007: *Creating a climate for change: communicating climate change and facilitating
40 social change*. Cambridge University Press, .
- 41 Moser, S.C. and A.L. Luers, 2008: Managing climate risks in California: the need to engage resource managers for
42 successful adaptation to change. *Climatic Change*, **87**, 309-322.
- 43 Moser, S.C. and J. Tribbia, 2006: Vulnerability to inundation and climate change impacts in California: coastal
44 managers' attitudes and perceptions. *Marine Technology Society Journal*, **40(4)**, 35-44.
- 45 Mukheibir, P. and G. Ziervogel, 2007: Developing a Municipal Adaptation Plan (MAP) for climate change: the city
46 of Cape Town. *Environment and Urbanization*, **19(1)**, 143-158.
- 47 Mukheibir, P., 2008: Water resources management strategies for adaptation to climate-induced impacts in South
48 Africa. *Water Resources Management*, **22(9)**, 1259-1276.
- 49 Muller, M., 2007: Adapting to climate change: water management for urban resilience. *Environment and
50 Urbanization*, **19(1)**, 99-113.
- 51 Munich Re Group 2004: *Megacities; Megarisks; Trends and Challenges for Insurance and Risk Management*,
52 Munich Reinsurance, Munich, 79 pp.
- 53 Nagendra, H. and D. Gopal, 2011: Tree diversity, distribution, history and change in urban parks: studies in
54 Bangalore, India. *Urban Ecosystems*, **14(2)**, 211-223.

- 1 Nagy, G., M.G. Erache, and V. Fernández, 2007: El aumento del nivel del mar en la costa uruguaya del Río de la
2 Plata. Tendencias, vulnerabilidades y medidas para la adaptación. *Medio Ambiente y Urbanización*, **67(1)**, 77-
3 93.
- 4 Nature Conservancy TNC 2009. Adapting to climate change: ecosystem-based approaches for people and nature. The
5 Nature Conservancy, Arlington VA.
- 6 Nelson, K.C., M.A. Palmer, J.E. Pizzuto, G.E. Moglen, P.L. Angermeier, R.H. Hilderbrand, M. Dettinger, and K.
7 Hayhoe, 2008: Forecasting the combined effects of urbanization and climate change on stream ecosystems:
8 from impacts to management options. *Journal of Applied Ecology*, **46(1)**, 154-163.
- 9 Newman, P., 2010: Green Urbanism and its Application to Singapore. *Environment and Urbanization Asia*, **1(2)**,
10 149-170.
- 11 Nicholls, R.J., 2004: Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and
12 socio-economic scenarios. *Global Environmental Change*, **14(1)**, 69-86.
- 13 Nie, Linmei, Oddvar Lindholm, Geir Lindholm, and Elisabeth Syversen 2009, Impacts of climate change on urban
14 drainage systems - a case study in Fredrikstad, Norway, *Urban Water Journal* Vol 6, No 4, August, 323-332
- 15 Niemi E., M. Buckley, C. Neculae and S. Reich (2009a). An Overview of Potential Economic Costs to Washington
16 of a Business-As-Usual Approach to Climate Change. The Program on Climate Economics, Climate Leadership
17 Initiative, Institute for a Sustainable Environment, Eugene, OR: University of Oregon.
- 18 Niemi E., M. Buckley, C. Neculae and S. Reich (2009b). An Overview of Potential Economic Costs to Oregon of a
19 Business-As-Usual Approach to Climate Change. The Program on Climate Economics, Climate Leadership
20 Initiative, Institute for a Sustainable Environment, Eugene, OR: University of Oregon.
- 21 Niemi E., M. Buckley, C. Neculae and S. Reich (2009c). An Overview of Potential Economic Costs to New Mexico
22 of a Business-As-Usual Approach to Climate Change. The Program on Climate Economics, Climate Leadership
23 Initiative, Institute for a Sustainable Environment, Eugene, OR: University of Oregon
- 24 Nobre, C.A., A. Young, P. Saldiva, J.A. Marengo, A.D. Nobre, S. Alves Jr, G.C.M. Silva and M. Lombardo 2010:
25 Vulnerabilidade das Megacidades Brasileiras às mudanças climáticas: Região Metropolitana de São Paulo.
26 Sumário Executivo. Brasil, CCST/INPE, NEPO/UNICAMP, FM/USP, IPT, UNESP-Rio Claro, São Paulo.
- 27 O'Brien, K., 2012: Global environmental change II From adaptation to deliberate transformation. *Progress in*
28 *Human Geography*, **36(5)**, 667-676.
- 29 O'Hara, J.K. and K.P. Georgakakos, 2008: Quantifying the urban water supply impacts of climate change. *Water*
30 *Resources Management*, **22(10)**, 1477-1497.
- 31 O'Neill M.S. and K. Ebi 2009: Temperature extremes and health: impacts of climate variability and change in the
32 United States. *J Occup Environ Med* 51(1):13-25
- 33 Oberndorfer, E., J. Lundholm, B. Bass, R.R. Coffman, H. Doshi, N. Dunnett, S. Gaffin, M. Köhler, K.K. Liu, and
34 B. Rowe, 2007: Green roofs as urban ecosystems: ecological structures, functions, and services. *Bioscience*,
35 **57(10)**, 823-833.
- 36 OECD 2008: *Economic Aspects of Adaptation to Climate Change*, Paris: OECD
- 37 OECD 2009, Integrating Climate Change Adaptation into Development Cooperation: Policy Guidance, OECD,
38 Paris.
- 39 OECD 2010a, Cities and Climate Change, OECD, Paris.
- 40 OECD 2010b, Strategic Environmental Assessment and Adaptation to Climate Change, OECD, Paris.
- 41 OECD 2012. *Enhancing Capacity: a Basis for Greening Development*. OECD, Paris.
- 42 O'Hara, Jeffrey and Konstantine Georgakakos 2008: Quantifying the Urban Water Supply Impacts of Climate
43 Change, *Water Resources Management* Vol 22, No 10, October, 1477-1497.
- 44 Ohashi, Y. and H. Kida, 2002: Local circulations developed in the vicinity of both coastal and inland urban areas: A
45 numerical study with a mesoscale atmospheric model. *Journal of Applied Meteorology*, **41(1)**, 30-45.
- 46 Ojima, Ricardo 2009: Perspectivas para a adaptação frente às mudanças ambientais globais no contexto da
47 urbanização brasileira: cenários para os estudos de população. In Hogan, Daniel and Eduardo Marandola Ed.
48 *População e mudança climática*. United Nations Population Fund, UNICAMP, São Paulo
- 49 Oke, T.R., 1982: The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological*
50 *Society*, **108(455)**, 1-24.
- 51 Oleson, K., 2012: Contrasts between urban and rural climate in CCSM4 CMIP5 climate change scenarios. *Journal*
52 *of Climate*, **25(5)**, 1390-1412.
- 53 Oliveira, S., H. Andrade, and T. Vaz, 2011: The cooling effect of green spaces as a contribution to the mitigation of
54 urban heat: A case study in Lisbon. *Building and Environment*, **46(11)**, 2186-2194.

- 1 Olsson, J., K. Berggren, M. Olofsson, and M. Viklander, 2009: Applying climate model precipitation scenarios for
2 urban hydrological assessment: A case study in Kalmar City, Sweden. *Atmospheric Research*, **92(3)**, 364-375.
- 3 Onof, C. and K. Arnbjerg-Nielsen, 2009: Quantification of anticipated future changes in high resolution design
4 rainfall for urban areas. *Atmospheric Research*, **92(3)**, 350-363.
- 5 OPITZ-STAPLETON, S., G. GUIBERT, K. MACCLUNE, K. MACCLUNE, L. SABBAG, and S. TYLER, 2010:
6 Only Death is Certain, Yet You Still Get Out of Bed in the Morning: : observations on the use of climate
7 information in adaptation and resilience practice. Climate Resilience in Concept and Practice Working Paper
8 Series. Boulder, Colorado.
- 9 Ostrom, E., 2009: A polycentric approach for coping with climate change. *Available at SSRN 1934353*, .
- 10 Oven, K.J., S.E. Curtis, S. Reaney, M. Riva, M.G. Stewart, R. Ohlemüller, C.E. Dunn, S. Nodwell, L. Dominelli,
11 and R. Holden, 2012: Climate change and health and social care: Defining future hazard, vulnerability and risk
12 for infrastructure systems supporting older people's health care in England. *Applied Geography*, **33(0)**, 16-24.
- 13 Paavola, J. and W.N. Adger, 2006: Fair adaptation to climate change. *Ecological Economics*, **56(4)**, 594-609.
- 14 Palla, A., J. Sansalone, I. Gnecco, and L. Lanza, 2011: Storm water infiltration in a monitored green roof for
15 hydrologic restoration. *Water Science and Technology*, **64(3)**, 766.
- 16 Palutikof, J.P., 2010: The view from the front line: Adapting Australia to climate change. *Global Environmental*
17 *Change*, **20(2)**, 218-219.
- 18 Parizotto, S. and R. Lamberts, 2011: Investigation of green roof thermal performance in temperate climate: A case
19 study of an experimental building in Florianópolis city, Southern Brazil. *Energy and Buildings*, **43(7)**, 1712-
20 1722.
- 21 Parry, M., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., Hope, C., Kovats, S., Nicholls, R., Satterthwaite, D.,
22 Tiffin, R. and T. Wheeler 2009. *Assessing the Costs of Adaptation to Climate Change: A Review of the*
23 *UNFCCC and Other Recent Estimates*, International Institute for Environment and Development IIED and
24 Grantham Institute for Climate Change, London
- 25 Parzen, J., 2008: Lessons learned: Creating the Chicago climate action plan. *Report to the Mayor of Chicago by the*
26 *Global Philanthropy Partnership*. Accessed June, **28**, 2009.
- 27 Patel, S. and C. Baptist, 2012: Editorial: Documenting by the undocumented. *Environment and Urbanization*, **24(1)**,
28 3-12.
- 29 Paulais, T. and J. Pigey (2010), "Adaptation and Mitigation: What Financing is Available for Local Government
30 Investments in Developing Countries?" Chapter 23 in in Hoornweg, Daniel; Freire, Mila; Lee, Marcus J.;
31 Bhada-Tata, Perinaz; Yuen, Belinda. 2012. *Cities and the urgent challenges of climate change : introduction*.
32 Vol. 2 of *Cities and climate change : responding to an urgent agenda*. Urban development series. Washington
33 D.C. - The Worldbank. <http://documents.worldbank.org/curated/en/2012/01/16494244/cities-climate-change-responding-urgent-agenda-vol-2-2-main-report>
- 34
- 35 Pavri, F., 2010: Urban Expansion and Sea-Level Rise Related Flood Vulnerability for Mumbai (Bombay), India
36 Using Remotely Sensed Data. *Geospatial Techniques in Urban Hazard and Disaster Analysis*, , 31-49.
- 37 Pelling, M., 2003: *The vulnerability of cities: natural disasters and social resilience*. Earthscan, .
- 38 Pelling, M. 2006: Measuring vulnerability to urban natural disaster risk, *Open House International*, special edition
39 on managing urban disasters 31 (1) 125-132
- 40 Pelling, M. 2011a: *Adaptation to climate change: from resilience to transformation*. Routledge, London
- 41 Pelling, M. 2011b: Urban governance and disaster risk reduction in the Caribbean: the experiences of Oxfam GB.
42 *Environment and Urbanization*, **23(2)**, 383-400.
- 43 Pelling, M. and C. Dill 2010: Disaster politics: Tipping points for change in the adaptation of
44 socio-political regimes, *Progress in Human Geography* 34, 21-37
- 45 Pelling, M. and D. Manuel-Navarrete, 2011: From resilience to transformation: the adaptive cycle in two Mexican
46 urban centers. *Ecology and Society*, **16(2)**, 11.
- 47 Pelling, M., D. Manuel-Navarrete, and M. Redclift, 2012: *Climate Change and the Crisis of Capitalism: A Chance*
48 *to Reclaim, Self, Society and Nature*. Routledge, London .
- 49 Pelling, M. and B. Wisner, 2009: *Disaster risk reduction: Cases from urban Africa*. Earthscan, London.
- 50 Pelling M and Zaidi Z 2013 *Measuring adaptive capacity: application of an indexing*
51 *methodology in Guyana*, Working Paper #47, Environment, Development and Politics Research Group, King's
52 College London. Accessed from
53 <http://www.kcl.ac.uk/sspp/departments/geography/research/epd/PellingZaidiWP47.pdf>

- 1 Peterson, N.D., 2012: Developing Climate Adaptation: The Intersection of Climate Research and Development
2 Programmes in Index Insurance. *Development and Change*, **43(2)**, 557-584.
- 3 PlaNYC 2011: *A Greener, Greater New York*, April 2011 update
4 http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_planyc_full_report.pdf
- 5 Posey, J., 2009: The determinants of vulnerability and adaptive capacity at the municipal level: Evidence from
6 floodplain management programs in the United States. *Global Environmental Change*, **19(4)**, 482-493.
- 7 Prabaharyaka I and Pooroe V. 2010. Participatory Urban Water Supply in Jakarta Slum Area in K. Irvine, T.
8 Murphy, V. Vanchan, and S. Vermette (eds.) *Water Resources and Development in Southeast Asia*, Learning
9 Solutions, Pearson Learning Solutions
- 10 Praskievicz, S. and H. Chang, 2009: A review of hydrological modelling of basin-scale climate change and urban
11 development impacts. *Progress in Physical Geography*, **33(5)**, 650-671.
- 12 Preston, B.L., R.M. Westaway, and E.J. Yuen, 2011: Climate adaptation planning in practice: an evaluation of
13 adaptation plans from three developed nations. *Mitigation and Adaptation Strategies for Global Change*, **16(4)**,
14 407-438.
- 15 Preston, B.L., E.J. Yuen, and R.M. Westaway, 2011: Putting vulnerability to climate change on the map: a review of
16 approaches, benefits, and risks. *Sustainability Science*, **6(2)**, 177-202.
- 17 Prowse, T.D., C. Furgal, R. Chouinard, H. Melling, D. Milburn, and S.L. Smith, 2009: Implications of climate
18 change for economic development in northern Canada: energy, resource, and transportation sectors. *AMBIO: A*
19 *Journal of the Human Environment*, **38(5)**, 272-281.
- 20 Puppim de Oliveira, J.A., 2009: The implementation of climate change related policies at the subnational level: An
21 analysis of three countries. *Habitat International*, **33(3)**, 253-259.
- 22 Quah, A.K. and M. Roth, 2011: Diurnal and weekly variation of anthropogenic heat emissions in a tropical city,
23 Singapore Anthropogenic heat emissions. *Atmospheric Environment*, .
- 24 Rahman, M. Maksudur, Graham Haughton, and Andrew E G Jonas 2010: The challenges of local environmental
25 problems facing the urban poor in Chittagong, Bangladesh: a scale-sensitive analysis. *EnvironUrb* 22(2), 561-
26 578.
- 27 Ramachandraiah, C., 2011: Coping with urban flooding: a study of the 2009 Kurnool floods, India. *Environment and*
28 *Urbanization*, **23(2)**, 431-446.
- 29 Ramin, B. and T. Svoboda, 2009: Health of the homeless and climate change. *Journal of Urban Health*, **86(4)**, 654-
30 664.
- 31 Ranger, N., Muir-Wood, R. & Priya, S. 2009, *Assessing extreme climate hazards and options for risk mitigation and*
32 *adaptation in the developing world. Development and Climate Change Background note.*, World Bank,
33 Washington, DC.
- 34 Ranger, N., S. Hallegatte, S. Bhattacharya, M. Bachu, S. Priya, K. Dhore, F. Rafique, P. Mathur, N. Naville, F.
35 Henriet, C. Herweijer-S. Pohit, J. Corfee-Morlot 2011: An assessment of the potential impact of climate change
36 on flood risk in Mumbai. *Climatic Change*, **104(1)**, 139-167.
- 37 Redclift, M.R., D.M. Navarrete, and M. Pelling, 2011: *Climate Change and Human Security: The Challenge to*
38 *Local Governance Under Rapid Coastal Urbanization*. Edward Elgar Publishing, .
- 39 Rees, W.E., 1992: Ecological footprints and appropriated carrying capacity: what urban economics leaves
40 out. *Environment and Urbanization*, **4(2)**, 121-130.
- 41 Rees, W.E., 2009: The ecological crisis and self-delusion: implications for the building sector. *Building Research &*
42 *Information*, **37(3)**, 300-311.
- 43 Regmi, M.B. and S. Hanaoka, 2011: A survey on impacts of climate change on road transport infrastructure and
44 adaptation strategies in Asia. *Environmental Economics and Policy Studies*, **13(1)**, 21-41.
- 45 Reid, C.E., M.S. O'Neill, C.J. Gronlund, S.J. Brines, D.G. Brown, A.V. Diez-Roux, and J. Schwartz, 2009: Mapping
46 Community Determinants of Heat Vulnerability. *Environmental Health Perspectives*, **117(11)**, 1730-6.
- 47 Ren, C., E.Y. Ng, and L. Katzschner, 2011: Urban climatic map studies: a review. *International Journal of*
48 *Climatology*, **31(15)**, 2213-2233.
- 49 Ren, G., Z. Chu, Z. Chen, and Y. Ren, 2007: Implications of temporal change in urban heat island intensity observed
50 at Beijing and Wuhan stations. *Geophysical Research Letters*, **34(5)**, L05711.
- 51 Renn, O., 2008: *Risk governance: coping with uncertainty in a complex world*. Earthscan/James & James, .
- 52 Repetto, R. 2011a: Economic And Environmental Impacts Of Climate Change In Nevada, DEMOS, New York, NY.
53 Available at: <http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-nevada>

- 1 Repetto, R. 2011b: Economic And Environmental Impacts Of Climate Change In Arizona, DEMOS, New York,
2 NY. Available at: [http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-](http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-arizona)
3 [arizona](http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-arizona)
- 4 Repetto, R. 2012a: Economic And Environmental Impacts Of Climate Change In Virginia, DEMOS, New York,
5 NY. Available at: [http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-](http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-virginia)
6 [virginia](http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-virginia)
- 7 Repetto, R. 2012b: Economic And Environmental Impacts Of Climate Change In Florida, DEMOS, New York, NY.
8 Available at: <http://www.demos.org/publication/economic-and-environmental-impacts-climate-change-florida>
- 9 Repetto, R. 2012c: The Rising Risks of Climate Change in Massachusetts, Energy Future Coalition, Washington
10 DC. Available at:
11 <http://www.energyfuturecoalition.org/files/webfmuploads/Repetto%20Paper%20Massachusetts.pdf>
- 12 Repetto, R., 2012d: New Mexico’s Rising Climate Risks, UN Foundation, New York, NY. Available at:
13 [http://www.energyfuturecoalition.org/files/webfmuploads/04-18-](http://www.energyfuturecoalition.org/files/webfmuploads/04-18-12%20Repetto%20Paper%20New%20Mexico.pdf)
14 [12%20Repetto%20Paper%20New%20Mexico.pdf](http://www.energyfuturecoalition.org/files/webfmuploads/04-18-12%20Repetto%20Paper%20New%20Mexico.pdf)
- 15 Revi, A., 2005: Lessons from the deluge: priorities for multi-hazard risk mitigation. *Economic and Political Weekly*,
16 , 3911-3916.
- 17 Revi, Aromar 2007. Lessons from the Deluge: Priorities for Multi-Hazard Risk Mitigation in Rangarajan M.
18 *Environmental Issues in India*, Pearson Longman, New Delhi
- 19 Revi, A., 2008: Climate change risk: an adaptation and mitigation agenda for Indian cities. *Environment and*
20 *Urbanization*, **20(1)**, 207-229.
- 21 Rim, C., 2009: The effects of urbanization, geographical and topographical conditions on reference
22 evapotranspiration. *Climatic Change*, **97(3)**, 483-514.
- 23 Ring, I., 2008: Integrating local ecological services into intergovernmental fiscal transfers: the case of the ecological
24 ICMS in Brazil. *Land use Policy*, **25(4)**, 485-497.
- 25 Roberts, D., 2008a: Thinking globally, acting locally — institutionalizing climate change at the local government
26 level in Durban, South Africa. *Environment and Urbanization*, **20(2)**, 521-537.
- 27 Roberts, D., 2010: Prioritizing climate change adaptation and local level resilience in Durban, South Africa.
28 *Environment and Urbanization*, **22(2)**, 397-413.
- 29 Roberts, D., R. Boon, N. Diederichs, E. Douwes, N. Govender, A. Mcinnes, C. Mclean, S. O’Donoghue, and M.
30 Spires, 2012: Exploring ecosystem-based adaptation in Durban, South Africa: “learning-by-doing” at the local
31 government coal face. *Environment and Urbanization*, **24(1)**, 167-195.
- 32 Roberts, D. and S. O’Donoghue (2013), Urban environmental challenges and climate change action in Durban,
33 South Africa, submitted to *Environment and Urbanization*
- 34 Roberts, S., 2008b: Altering existing buildings in the UK. *Energy Policy*, **36(12)**, 4482-4486.
- 35 Roberts, S., 2008c: Effects of climate change on the built environment. *Energy Policy*, **36(12)**, 4552-4557
- 36 Rockström, J., W. Steffen, K. Noone, Å. Persson, F.S. Chapin III, E. Lambin, T.M. Lenton, M. Scheffer, C. Folke,
37 and H. Schellnhuber, 2009: Planetary boundaries: exploring the safe operating space for humanity. *Ecology and*
38 *Society*, **14(2)**, 32.
- 39 Rogers, C.D., C.J. Bouch, S. Williams, A.R. Barber, C.J. Baker, J.R. Bryson, D.N. Chapman, L. Chapman, J.
40 Coaffee, and I. Jefferson, 2012: Resistance and resilience—paradigms for critical local
41 infrastructure. Proceedings of Proceedings of the Institution of Civil Engineers. Municipal engineer, pp. 73-84.
- 42 Rojas Blanco, A.V., 2006: Local initiatives and adaptation to climate change. *Disasters*, **30(1)**, 140-147.
- 43 Romeo, C. and M. Zinzi, Impact of a cool roof application on the energy and comfort performance in an existing
44 non-residential building. A Sicilian case study. *Energy and Buildings*, **(0)**.
- 45 Romero Lankao, P., 2007: How do Local Governments in Mexico City Manage Global Warming? *Local*
46 *Environment*, **12(5)**, 519-535.
- 47 Romero Lankao, P., 2010: Water in Mexico City: what will climate change bring to its history of water-related
48 hazards and vulnerabilities? *Environment and Urbanization*, **22(1)**, 157-178.
- 49 Romero-Lankao, P. and D. Dodman, 2011: Cities in transition: transforming urban centers from hotbeds of GHG
50 emissions and vulnerability to seedbeds of sustainability and resilience: Introduction and Editorial overview.
51 *Current Opinion in Environmental Sustainability*, **3(3)**, 113-120.
- 52 Romero Lankao, P. and H. Qin, 2011: Conceptualizing urban vulnerability to global climate and environmental
53 change. *Current Opinion in Environmental Sustainability*, **3(3)**, 142-149.

- 1 Rosenberg, E.A., P.W. Keys, D.B. Booth, D. Hartley, J. Burkey, A.C. Steinemann, and D.P. Lettenmaier, 2010:
2 Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State.
3 *Climatic Change*, **102(1)**, 319-349.
- 4 Rosenzweig C, Solecki W. 2010 Eds: *Climate Change Adaptation in New York City: Building a Risk Management*
5 *Response*. New York Academy of Sciences 1196; 2010
- 6 Rosenzweig, C., W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, and P. Grabhorn (Eds.), 2011b. Responding to
7 Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change
8 Adaptation: Synthesis Report. New York State Energy Research and Development Authority.
- 9 Rosenzweig, C., Solecki, W.D., Degaetano, A. (2011c): Responding to Climate Change in New York State: The
10 ClimAID Report Integrated Assessment of Effective Climate Change Adaptation Final . Annals of the New
11 York Academy of Sciences. Volume 1244: December, 649 pages.
- 12 Rosenzweig, C., W. Solecki, S.A. Hammer, and S. Mehrotra, 2010: Cities lead the way in climate-change action.
13 *Nature*, **467(7318)**, 909-911.
- 14 Rosenzweig, C., W.D. Solecki, S.A. Hammer, and S. Mehrotra, 2011a: *Climate change and cities: first assessment*
15 *report of the Urban Climate Change Research Network*. Cambridge University Press, .
- 16 Rosenzweig, C., W.D. Solecki, L. Parshall, B. Lynn, J. Cox, R. Goldberg, S. Hodges, S. Gaffin, R.B. Slosberg and
17 P. Savio, 2009: Mitigating New York City's Heat Island: Integrating Stakeholder Perspectives and Scientific
18 Evaluation. *Bulletin of the American Meteorological Society*, **90(9)**, 1297-1312.
- 19 Roy, M., D. Hulme, and F. Jahan, 2013: Contrasting adaptation responses by squatters and low-income tenants in
20 Khulna, Bangladesh. *Environment and Urbanization*, .
- 21 Roy, S.B., L. Chen, E.H. Girvetz, E.P. Maurer, W.B. Mills, and T.M. Grieb, 2012: Projecting Water Withdrawal and
22 Supply for Future Decades in the US under Climate Change Scenarios. *Environmental Science & Technology*,
23 **46(5)**, 2545-2556.
- 24 Runhaar, H., H. Mees, A. Wardekker, J. van der Sluijs, and P.P. Driessen, 2012: Adaptation to climate change-
25 related risks in Dutch urban areas: stimuli and barriers. *Regional Environmental Change*, , 1-14.
- 26 Ruth, M., C. Bernier, N. Jollands, and N. Golubiewski, 2007: Adaptation of urban water supply infrastructure to
27 impacts from climate and socioeconomic changes: The case of Hamilton, New Zealand. *Water Resources*
28 *Management*, **21(6)**, 1031-1045.
- 29 Ruth, M., 2010: Economic and Social Benefits of Climate Information: Assessing the Cost of Inaction. *Procedia*
30 *Environmental Sciences*, **1**, 387-394.
- 31 Sabates-Wheeler, R., T. Mitchell and F. Ellis 2008: Avoiding Repetition: Time for CBA to Engage with the
32 Livelihoods Literature? in T. Tanner, T. Mitchell (Eds) Poverty in a Changing Climate IDS Bulletin 39 (4)
33 Brighton: Institute of Development Studies
- 34 Saber, H.H., M.C. Swinton, P. Kalinger, and R.M. Paroli, 2012: Long-term hygrothermal performance of white and
35 black roofs in North American climates. *Building and Environment*, **50(0)**, 141-154.
- 36 Sajjad, S., B. Hussain, M. Ahmed Khan, A. Raza, B. Zaman, and I. Ahmed, 2009: On rising temperature trends of
37 Karachi in Pakistan. *Climatic Change*, **96(4)**, 539-547.
- 38 Sanchez, A.B. and P. Poschen, 2009: The social and decent work dimensions of a new agreement on climate change.
39 *International Labour Office, Policy Integration Department*, .
- 40 Sánchez-Rodríguez, R., 2009: Learning to adapt to climate change in urban areas. A review of recent
41 contributions. *Current Opinion in Environmental Sustainability*, **1(2)**, 201-206.
- 42 Sánchez-Rodríguez, Roberto 2011: *Urban and Social Vulnerability to Climate Variability in Tijuana, Mexico in*
43 Kasperson, Roger and Mimi Berberian eds *Integrating Science and Policy Vulnerability and Resilience in*
44 *Global Environmental Change*. Earthscan
- 45 Santos, J. and S. Leite, 2009: Long-term variability of the temperature time series recorded in Lisbon. *Journal of*
46 *Applied Statistics*, **36(3)**, 323-337.
- 47 Sassen, S., 1994: Cities in a world economy. *Thousand Oaks*, .
- 48 Satterthwaite, D., 2008: Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions.
49 *Environment and Urbanization*, **20(2)**, 539-549.
- 50 Satterthwaite, D., 2009: The implications of population growth and urbanization for climate change. *Environment*
51 *and Urbanization*, **21(2)**, 545-567.
- 52 Satterthwaite, D., 2011: How urban societies can adapt to resource shortage and climate change. *Philosophical*
53 *Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **369(1942)**, 1762-1783.

- 1 Satterthwaite, D., Dodman, D. and Bicknell, J. 2009 Conclusions: Local Development and Adaptation. In Bicknell,
2 J., Dodman, D. and Satterthwaite, D. eds. *Adapting Cities to Climate Change: Understanding and Addressing*
3 *the Development Challenge*. London: Earthscan, 359-384
- 4 Satterthwaite, D., G. McGranahan, and C. Tacoli, 2010: Urbanization and its implications for food and farming.
5 *Philosophical Transactions of the Royal Society B: Biological Sciences*, **365(1554)**, 2809-2820.
- 6 Satterthwaite, D. and D. Mitlin (2013), *Reducing Urban Poverty in the Global South*, Routledge, Abingdon
- 7 Satterthwaite, D. and A. Sverdluk 2012, Energy Access and Housing for Low-income Groups in Urban Areas.,
8 Chapter 6 in Arnulf Grubler and David Fisk editors, *Energizing Cities*, Earthscan Publications, London.
- 9 Schaeffer, R., A.S. Szklo, A.F. Pereira de Lucena, B.S. Moreira Cesar Borba, L.P. Pupo Nogueira, F.P. Fleming, A.
10 Troccoli, M. Harrison, and M.S. Boulahya, 2011: Energy sector vulnerability to climate change: A review.
11 *Energy* 38(1): 1-12.
- 12 Scheinberg, A., S. Spies, M.H. Simpson, and A.P.J. Mol, 2011: Assessing urban recycling in low- and middle-
13 income countries: Building on modernised mixtures. *Habitat International*, **35(2)**, 188-198.
- 14 Scherba, A., D.J. Sailor, T.N. Rosenstiel, and C.C. Wamser, 2011: Modeling impacts of roof reflectivity, integrated
15 photovoltaic panels and green roof systems on sensible heat flux into the urban environment. *Building and*
16 *Environment*, **46(12)**, 2542-2551.
- 17 Schipper, L. and M. Pelling, 2006: Disaster risk, climate change and international development: scope for, and
18 challenges to, integration. *Disasters*, **30(1)**, 19-38.
- 19 Schmidhuber, J. and F.N. Tubiello, 2007: Global food security under climate change. *Proceedings of the National*
20 *Academy of Sciences*, **104(50)**, 19703-19708.
- 21 Schneider, A., M. Friedl, and D. Potere, 2009: A new map of global urban extent from MODIS satellite data.
22 *Environmental Research Letters*, **4(4)**, 044003.
- 23 Schroeder, H. & Bulkeley, H. 2008, *Governing Climate Change Post-2012: The Role of Global Cities Case-Study:*
24 *Los Angeles*.
- 25 Schroll, E., J. Lambrinos, T. Righetti, and D. Sandrock, 2011: The role of vegetation in regulating stormwater runoff
26 from green roofs in a winter rainfall climate. *Ecological Engineering*, **37(4)**, 595-600.
- 27 Schulze, R.E., 2011: Approaches towards practical adaptive management options for selected water-related sectors
28 in South Africa in a context of climate change. *Water SA*, **37(5)**, 621-646.
- 29 Schwarz N, Bauer A, Haase D 2011. Assessing climate impacts of local and regional planning policies -
30 Quantification of impacts for Leipzig (Germany). *Environmental Impact Assessment Review* 31, 97-111.
- 31 Sen, Z., 2009: Precipitation downscaling in climate modelling using a spatial dependence function. *International*
32 *Journal of Global Warming*, **1(1)**, 29-42.
- 33 Seto, K.C. and J.M. Shepherd, 2009: Global urban land-use trends and climate impacts. *Current Opinion in*
34 *Environmental Sustainability*, **1(1)**, 89-95.
- 35 Seto, K.C. and D. Satterthwaite, 2010: Interactions between urbanization and global environmental change. *Current*
36 *Opinion in Environmental Sustainability*, **2(3)**, 127-128.
- 37 Sharma, D. and S. Tomar, 2010: Mainstreaming climate change adaptation in Indian cities. *Environment and*
38 *Urbanization*, **22(2)**, 451-465.
- 39 Shaw, A., S. Sheppard, S. Burch, D. Flanders, A. Wiek, J. Carmichael, J. Robinson, and S. Cohen, 2009: Making
40 local futures tangible—Synthesizing, downscaling, and visualizing climate change scenarios for participatory
41 capacity building. *Global Environmental Change*, **19(4)**, 447-463.
- 42 Shaw, K. and K. Theobald, 2011: Resilient local government and climate change interventions in the UK. *Local*
43 *Environment*, **16(1)**, 1-15.
- 44 SHAW, R. and IEDM Team, 2009: Climate disaster resilience: Focus on coastal urban cities in Asia. *Asian Journal*
45 *of Environment and Disaster Management*, **1**, 101-116.
- 46 Shaw, R and Izumi, T. 2011 Roles of civil society in climate and disaster resilience of cities and local governments.
47 In Shaw , R and Sharma, A. eds. *Climate and Disaster Resilience in Cities*, Bingley, UK: Emerald Books: 261-
48 180.
- 49 Shaw, R. and A. Sharma, 2011: *Climate and disaster resilience in cities*. Emerald Group Publishing, .
- 50 Sheffield, P.E. and P.J. Landrigan, 2011: Global Climate Change and Children's Health: Threats and Strategies for
51 Prevention. *Environmental Health Perspectives*, **119(3)**, 291-8.
- 52 Shepherd, J., T. Mote, S. Nelson, S. McCutcheon, P. Knox, M. Roden, and J. Dowd, 2010: An overview of synoptic
53 and mesoscale factors contributing to the disastrous Atlanta flood of 2009. *Bull.Am.Meteor.Soc.Doi*, **10**.

- 1 Silver, Jonathan, et al. 2013. Climate change, urban vulnerability and economic development in Saint-Louis and
2 Bobo Dioulasso: Learning from across West African cities. *Local Environment: The International Journal of*
3 *Justice and Sustainability*. Forthcoming
- 4 Simmons, M.T., B. Gardiner, S. Windhager, and J. Tinsley, 2008: Green roofs are not created equal: the hydrologic
5 and thermal performance of six different extensive green roofs and reflective and non-reflective roofs in a sub-
6 tropical climate. *Urban Ecosystems*, **11(4)**, 339-348.
- 7 Simon, D., 2010: The challenges of global environmental change for urban Africa. Proceedings of Urban Forum, pp.
8 235-248.
- 9 SIMON, D. and H. LECK, 2010: Urbanizing the global environmental change and human security agendas. *Climate*
10 *and Development*, **2(3)**, 263-275.
- 11 Smith, B.J., M. Gomez-Heras, and S. McCabe, 2008: Understanding the decay of stone-built cultural heritage.
12 *Progress in Physical Geography*, **32(4)**, 439-461.
- 13 Smith, C. and G. Levermore, 2008: Designing urban spaces and buildings to improve sustainability and quality of
14 life in a warmer world. *Energy Policy*, **36(12)**, 4558-4562.
- 15 Smith, K.R. and P.J. Roebber, 2011: Green Roof Mitigation Potential for a Proxy Future Climate Scenario in
16 Chicago, Illinois. *Journal of Applied Meteorology and Climatology*, **50(3)**, 507-522.
- 17 Smith, M.S., L. Horrocks, A. Harvey, and C. Hamilton, 2011: Rethinking adaptation for a 4°C world. *Philosophical*
18 *Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **369(1934)**, 196-216.
- 19 Soares Moura da Costa, Heloísa (2009) Mudanças climáticas e cidades: contribuições para uma agenda de pesquisa
20 a partir da periferia em Hogan, Daniel é Marandola, Eduardo, População e mudança climática. Dimensões
21 humanas das mudanças ambientais globais. UNFPA, NEPO, UNICAMP, Campinas, Sao Paulo, Brasil.
- 22 Solecki, W., 2012: Urban environmental challenges and climate change action in New York City. *Environment and*
23 *Urbanization*, **24(2)**, 557-573.
- 24 Solecki, W. 2012. Moving toward urban sustainability: using lessons and legacies of the past. In Metropolitan
25 sustainability: Understanding and improving the urban environment, Edited by F Zeman. Woodhead Publishing
- 26 Solecki, W.D. and R.M. Leichenko, 2006: Urbanization and the metropolitan environment: lessons from New York
27 and Shanghai. *Environment: Science and Policy for Sustainable Development*, **48(4)**, 8-23.
- 28 Solecki, W., R. Leichenko, and K. O'Brien, 2011: Climate change adaptation strategies and disaster risk reduction in
29 cities: connections, contentions, and synergies. *Current Opinion in Environmental Sustainability*, **3(3)**, 135-141.
- 30 Solecki, W. and Murphy, C. 2012. Transition Theory and Understanding Urban Water Supply Systems In the
31 Context of Climate Change. Global Environmental Change, revised and resubmitted for publication
- 32 Solecki, W.D., C. Rosenzweig, L. Parshall, G. Pope, M. Clark, J. Cox, and M. Wiencke, 2005: Mitigation of the heat
33 island effect in urban New Jersey. *Global Environmental Change Part B: Environmental Hazards*, **6(1)**, 39-49.
- 34 Solnit, R., 2009: *A paradise built in hell: The extraordinary communities that arise in disaster*. Viking Press, .
- 35 Some, W., W. Hafidz, and G. Sauter, 2009: Renovation not relocation: the work of Paguyuban Warga Strenkali
36 (PWS) in Indonesia. *Environment and Urbanization*, **21(2)**, 463-475.
- 37 Stewart, I.D. 2011: A systematic review and scientific critique of methodology in modern urban heat island
38 literature, *International Journal of Climatology* 31(2) 200–217
- 39 Stewart, M.G., X. Wang, and M.N. Nguyen, 2011: Climate change impact and risks of concrete infrastructure
40 deterioration. *Engineering Structures*, **33(4)**, 1326-1337.
- 41 Stone Jr, B., 2007: Urban and rural temperature trends in proximity to large US cities: 1951–2000. *International*
42 *Journal of Climatology*, **27(13)**, 1801-1807.
- 43 Stone, B., J.J. Hess, and H. Frumkin, 2010: Urban Form and Extreme Heat Events: Are Sprawling Cities More
44 Vulnerable to Climate Change Than Compact Cities? *Environmental Health Perspectives*, **118(10)**, 1425-1428.
- 45 Stone, Brian. 2012. *The City and the Coming Climate: Change Change in the Places We Live*. Cambridge
46 University Press: New York.
- 47 Susca, T., S. Gaffin, and G. Dell'Osso, 2011: Positive effects of vegetation: Urban heat island and green roofs.
48 *Environmental Pollution*, **159(8)**, 2119-2126.
- 49 Sussman, E., D.C. Major, R. Deming, P.R. Esterman, A. Fadil, E. Fisher, A. Fred Fucci, R. Gordon, C. Harris, and
50 J.K. Healy, 2010: Law and regulation. *Annals of the New York Academy of Sciences*, **1196(1)**, 87-112.
- 51 Swart, R. and F. Raes, 2007: Making integration of adaptation and mitigation work: mainstreaming into sustainable
52 development policies? *Climate Policy*, **7(4)**, 288-303.
- 53 Tacoli, C., 2009: Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and*
54 *Urbanization*, **21(2)**, 513-525.

- 1 Tait, S.J., R.M. Ashley, A. Cashman, J. Blanksby, and A.J. Saul, 2008: Sewer system operation into the 21st
2 century, study of selected responses from a UK perspective. *Urban Water Journal*, **5(1)**, 79-88.
- 3 Tallis, M., G. Taylor, D. Sinnett, and P. Freer-Smith, 2011: Estimating the removal of atmospheric particulate
4 pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban
5 Planning*, **103(2)**, 129-138.
- 6 Tang, K., 2009: *Green CITYnomics: the urban war against climate change*. Greenleaf, .
- 7 Tanner, T., T. Mitchell, E. Polack, and B. Guenther, 2009: Urban governance for adaptation: assessing climate
8 change resilience in ten Asian cities. *IDS Working Papers*, **2009(315)**, 01-47.
- 9 TARU 2010: City resilience strategy Indore. Working Draft.*
- 10 TARU 2011: Surat City Resilience Strategy. City of Surat, Surat.*
- 11 Tayanç, M., U. İm, M. Doğruel, and M. Karaca, 2009: Climate change in Turkey for the last half century. *Climatic
12 Change*, **94(3)**, 483-502.
- 13 Taylor, C.A. and H.G. Stefan, 2009: Shallow groundwater temperature response to climate change and urbanization.
14 *Journal of Hydrology*, **375(3)**, 601-612.
- 15 TEEB 2010: The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature:A
16 synthesisof the approach, conclusions and recommendations of TEEB, Malta, Progress Press.
- 17 Teng, Fei and Alun Gu (2007), Climate Change: National and Local Policy Opportunities in China,, The Fondazione
18 Eni Enrico Mattei Note di Lavoro Series, Milan, 18 pages.
- 19 Thornbush, M. and H. Viles, 2007: Simulation of the dissolution of weathered versus unweathered limestone in
20 carbonic acid solutions of varying strength. *Earth Surface Processes and Landforms*, **32(6)**, 841-852.
- 21 Thorsson, S., F. Lindberg, J. Björklund, B. Holmer, and D. Rayner, 2011: Potential changes in outdoor thermal
22 comfort conditions in Gothenburg, Sweden due to climate change: the influence of urban geometry.
23 *International Journal of Climatology*, **31(2)**, 324-335.
- 24 Tidwell, V.C., P.H. Kobos, L.A. Malczynski, G. Klise, and C.R. Castillo, 2011: Exploring the water-thermoelectric
25 power Nexus. *Journal of Water Resources Planning and Management*, .
- 26 Tomlinson, C.J., L. Chapman, J.E. Thornes, and C.J. Baker, 2011: Including the urban heat island in spatial heat
27 health risk assessment strategies: a case study for Birmingham, UK. *International Journal of Health
28 Geographics*, **10(1)**, 42.
- 29 Tompkins, E.L., M.C. Lemos, and E. Boyd, 2008: A less disastrous disaster: Managing response to climate-driven
30 hazards in the Cayman Islands and NE Brazil. *Global Environmental Change*, **18(4)**, 736-745.
- 31 Tompkins, Emma, W. Neil Adger, Emily Boyd, Sophie Nicholson-Cole, Keith Weatherhead, and Nigel Arnell 2010:
32 Observed adaptation to climate change: UK evidence of transition to a well-adapting society, *Global
33 Environmental Change* 20(4), October, 627-635.
- 34 Toronto Environment Office 2008. Ahead of the storm; preparing Toronto for climate change highlights. City of
35 Toronto, Toronto.
- 36 Toronto, City of 2012: Heat Alert upgraded to Extreme Heat Alert, Toronto cooling centres open,
37 <http://wx.toronto.ca/inter/it/newsrel.nsf/0/a88c8f6d6291d6b685257a3a0042b732?OpenDocument>
- 38 Tubby, K. and J. Webber, 2010: Pests and diseases threatening urban trees under a changing climate. *Forestry*,
39 **83(4)**, 451-459.
- 40 Tyler, S., Orleans Reed, S. Macclune, K. and S. Chopde 2010.Planning for Urban Climate Resilience: Framework
41 and Examples from the Asian Cities Climate Change Resilience Network ACCCRN.Climate Resilience in
42 Concept and Practice Working Paper Series. Boulder, Colorado.
- 43 Tyler, S. and M. Moench 2012: A framework for urban climate resilience,, *Climate and Development*, 4(4) 311-326.
- 44 UCLG United Cities and Local Governments 2011: *Local Government Finance: The Challenges of the 21st
45 Century*, Edward Elgar Publishing Ltd, Cheltenham, 384 pp.
- 46 UN Millennium Project 2005: *A Home in the City, The report of the Millennium Project Taskforce on Improving the
47 Lives of Slum Dwellers*, Earthscan Publications, London and Sterling Va, 175 .
- 48 UNISDR 2008 Links between Disaster Risk Reduction, Development and Climate Change. Report prepared for the
49 Commission on Climate Change and Development, Sweden
- 50 UN-Habitat 2003: *The Challenge of Slums: Global Report on Human Settlements 2003*, London: Earthscan
51 Publications, 310 pp.
- 52 UN-Habitat 2007: *Enhancing Urban Safety and Security; Global Report on Human Settlements 2007*, London:
53 Earthscan Publications.

- 1 UN-Habitat 2008: *Secure Land Rights for All*, Global Land Tool Network GLTN, Nairobi: UN Human Settlements
2 Programme.
- 3 UN-Habitat 2010: *Climate Change Assessment for Kampala, Uganda: A Summary*. Nairobi: UN Human Settlements
4 Programme.
- 5 UN-Habitat 2011a: *Global Report on Human Settlements 2011 - Cities and Climate Change*, Earthscan
6 Publications, London, 304 pages.
- 7 UN-Habitat 2011b: *Colored Water: Assessment Of Climate Change Vulnerability In Kelurahan Pabean Pekalongan*,
8 Central Java, United Nations Human Settlements Programme, Nairobi, 34 pages.
- 9 UN-Habitat 2011c *Adaptation Finance: Are Cities in Developing Countries Slipping Through the Cracks?* Cities
10 and Climate Change Initiative Policy Note 1, Nairobi: UN Human Settlements Programme.
- 11 UN-Habitat 2012a: *Urban Patterns for a Green Economy: Leveraging Density*, Nairobi, United Nations Human
12 Settlements Programme,
- 13 UN-Habitat 2012b: *Urban Patterns for a Green Economy: Clustering for Competitiveness*, Nairobi, United Nations
14 Human Settlements Programme.
- 15 UN-Habitat 2012c: *Urban Patterns for a Green Economy: Optimizing Infrastructure*, Nairobi, United Nations
16 Human Settlements Programme.
- 17 UN-Habitat 2012d: *Urban Patterns for a Green Economy: Working with Nature*, Nairobi, United Nations Human
18 Settlements Programme.
- 19 United Nations 2009: *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing*
20 *Climate*, ISDR, United Nations, Geneva, 207 pages
- 21 United Nations 2011: *Revealing Risk, Redefining Development: The 2011 Global Assessment Report on Disaster*
22 *Risk Reduction*, United Nations International Strategy for Disaster Reduction, Geneva, 178 pages.
- 23 United Nations 2012. *World Urbanization Prospects: The 2011 Revision*, Department of Economic and Social
24 Affairs, Population Division, <http://esa.un.org/unpd/wup/index.htm>.
- 25 United Nations Office on Drugs and Crime UNODC, 2008 *Preparándose para el futuro. Amenazas, riesgos,*
26 *vulnerabilidad y adaptación frente al cambio climático*, Colombia.
- 27 United Nations Population Fund: *State of the World Population 2007. Unleashing the potential of Urban*
28 *Growth*. United Nations; 2007.
- 29 Urwin, K. and A. Jordan, 2008: Does public policy support or undermine climate change adaptation? Exploring
30 policy interplay across different scales of governance. *Global Environmental Change*, **18(1)**, 180-191.
- 31 US EPA 2011: *Climate change vulnerability assessments: four case studies of water utility practices*. Global Change
32 Research Program, National Center for Environmental Assessment, Washington, DC; EPA/600/R-
33 10/077F. Available from the National Technical Information Service, Springfield, VA, and online at
34 <http://www.epa.gov/ncea>.
- 35 US NAS 2012. *Urban Meteorology: Forecasting, Monitoring, and Meeting Users' Needs*. National Academies Press.
36 Washington DC.
- 37 Vairavamoorthy, K., S.D. Gorantiwar, and A. Pathirana, 2008: Managing urban water supplies in developing
38 countries—Climate change and water scarcity scenarios. *Physics and Chemistry of the Earth, Parts A/B/C*, **33(5)**,
39 330-339.
- 40 Vale, L.J. and T.J. Campanella, 2005: *The resilient city: How modern cities recover from disaster*. Oxford
41 University Press, USA, .
- 42 van Aalst, M.K., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: The potential role
43 of participatory community risk assessment. *Global Environmental Change*, **18(1)**, 165-179.
- 44 Van der Brugge, R. and R. De Graaf, 2010: Linking water policy innovation and urban renewal: the case of
45 Rotterdam, The Netherlands. *Water Policy*, **12(3)**, 381-400.
- 46 van Vuuren, D.P., P.L. Lucas, and H. Hilderink, 2007: Downscaling drivers of global environmental change:
47 Enabling use of global SRES scenarios at the national and grid levels. *Global Environmental Change*, **17(1)**,
48 114-130.
- 49 Vano, J.A., N. Voisin, L. Cuo, A.F. Hamlet, M.M. Elsner, R.N. Palmer, A. Polebitski, and D.P. Lettenmaier, 2010:
50 Climate change impacts on water management in the Puget Sound region, Washington State, USA. *Climatic*
51 *Change*, **102(1)**, 261-286.
- 52 Viguie, V. and S. Hallegatte 2012 Trade-offs and synergies in urban climate policies: a multi-criteria analysis.
53 *Nature Climate Change*.

- 1 Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko, 2007: Linking vulnerability, adaptation, and resilience
2 science to practice: Pathways, players, and partnerships. *Global Environmental Change*, **17(3–4)**, 349-364.
- 3 Vojinovic, Z. and J. Van Teeffelen, 2007: An integrated stormwater management approach for small islands in
4 tropical climates. *Urban Water Journal*, **4(3)**, 211-231.
- 5 von Hesse, M., J. Kamiche and C. de la Torre (2008, Contribucion Tematica De America Latina Al Informe Bienal
6 De Evaluacion Mundial Sobre La Reduccion De Riesgo 2009, Background paper for United Nations 2009:
7 *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing Climate*, ISDR, United
8 Nations, Geneva
- 9 Voyde, E., E. Fassman, and R. Simcock, 2010: Hydrology of an extensive living roof under sub-tropical climate
10 conditions in Auckland, New Zealand. *Journal of Hydrology*, **394(3)**, 384-395.
- 11 Wackernagel, M., J. Kitzes, D. Moran, S. Goldfinger, and M. Thomas, 2006: The Ecological Footprint of cities and
12 regions: comparing resource availability with resource demand. *Environment and Urbanization*, **18(1)**, 103-112.
- 13 Wajih, S.A., Singh, B., Bartarya, E., Basu, S. and ACCCRN ISET Team 2010: Towards a resilient Gorakhpur.
14 Gorakhpur Environmental Action Group, Gorakhpur.*
- 15 Walsh, C.L., Dawson, R.J., Hall, J.W., Barr, S.L., Batty, M., Bristow, A., Carney, S., Dagoumas, A., Alistair Ford,
16 A.C., Harpham, C., Tight, M. Watters, H., Zanni 2011: A systems approach to assessment of climate change
17 mitigation and adaptation at the scale of whole cities, *Urban Design and Planning*. 1642: 75-84
- 18 Wamsler, C., 2007: Bridging the gaps: stakeholder-based strategies for risk reduction and financing for the urban
19 poor. *Environment and Urbanization*, **19(1)**, 115-142.
- 20 Wang, R., 2011: *The Routledge Handbook of Urban Ecology*. Taylor & Francis US, .
- 21 WARNER, R., 2009: Secular regime shifts, global warming and Sydney's water supply. *Geographical Research*,
22 **47(3)**, 227-241.
- 23 Warren, R., 2011: The role of interactions in a world implementing adaptation and mitigation solutions to climate
24 change. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*,
25 **369(1934)**, 217-241.
- 26 Weaver, C., X. Liang, J. Zhu, P. Adams, P. Amar, J. Avise, M. Caughey, J. Chen, R. Cohen, and E. Cooter, 2009: A
27 preliminary synthesis of modeled climate change impacts on US regional ozone concentrations. *Bulletin of the*
28 *American Meteorological Society*, 90 (12): 1843–1863, **90(PNNL-SA-61954)**.
- 29 WHO 2011a, "Urban Outdoor Air Pollution Database, WHO, August 2011.
- 30 WHO 2011b, Air quality and health, Fact sheet N°313, World Health Organization, Geneva
- 31 Wilbanks, T.J. and R.W. Kates, 2010: Beyond Adapting to Climate Change: Embedding Adaptation in Responses to
32 Multiple Threats and Stresses. *Annals of the Association of American Geographers*, **100(4)**, 719-728.
- 33 Wilbanks, Tom and Patricia Romero-Lankao with Manzhou Bao, Frans Berkhout, Sandy Cairncross, Jean-Paul
34 Ceron, Manmohan Kapshe, Robert Muir-Wood and Ricardo Zapata-Marti 2007, Chapter 7: Industry, Settlement
35 and Society., in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson Editors, *Climate*
36 *Change 2007: Impacts, Adaptation and Vulnerability.*, Cambridge University Press, Cambridge, 357-390.
- 37 Wilbanks, T., S. Fernandez, G. Backus, P. Garcia, K. Jonietz, P. Kirshen, M. Savonis, W. Solecki, L. Toole et al,
38 2012: Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report For The U.S.
39 Department of Energy in Support of the National Climate Assessment. Oak Ridge National Laboratory, Oak
40 Ridge, Tennessee. Available at: www.esd.ornl.gov/eess/Infrastructure.pdf
- 41 Wilby, R., 2007: A review of climate change impacts on the built environment. *Built Environment*, **33(1)**, 31-45.
- 42 Wilkinson, S.J. and R. Reed, 2009: Green roof retrofit potential in the central business district. *Property*
43 *Management*, **27(5)**, 284-301.
- 44 Wilson, E., 2006: Adapting to Climate Change at the Local Level: The Spatial Planning Response. *Local*
45 *Environment*, **11(6)**, 609-625.
- 46 Wilson, E. and J. Piper, 2008: Spatial planning for biodiversity in Europe's changing climate. *European*
47 *Environment*, **18(3)**, 135-151
- 48 Wilson, E., C. Termeer, H-L. P. Mees and P.P. J. Driessen 2011, Adaptation to climate change in urban areas:
49 Climate-greening London, Rotterdam, and Toronto *Climate Law* Vol 2, No 2, 251-280.
- 50 Wilson, E. and C. Termeer, 2011: Governance of climate change adaptation: Introduction to the Special Issue.
51 *Climate Law*, **2(2)**, 149-157.
- 52 Wilson, G., 2012: Community resilience and environmental transitions. *Earthscan, London*, .

- 1 Wolf, J., W.N. Adger, I. Lorenzoni, V. Abrahamson, and R. Raine, 2010: Social capital, individual responses to heat
2 waves and climate change adaptation: An empirical study of two UK cities. *Global Environmental Change*,
3 **20(1)**, 44-52.
- 4 Wong, S., 2009: Climate change and sustainable technology: re-linking poverty, gender, and governance. *Gender &*
5 *Development*, **17(1)**, 95-108.
- 6 Wong, T. and R. Brown, 2009: The water sensitive city: principles for practice. *Water Science and Technology*,
7 **60(3)**, 673-682.
- 8 World Bank 2008: *Reshaping Economic Geography; World Development Report 2009*, Washington DC: The World
9 Bank.
- 10 World Bank 2009: Climate resilient cities; a primer on reducing vulnerabilities to disasters. City profiles: Jakarta,
11 Indonesia, Washington DC: The World Bank.
- 12 World Bank 2010a: *World Development Report 2010: Development and Climate Change* Washington DC: The
13 World Bank.
- 14 World Bank 2010b: *Climate Risks and Adaptation in Asian Coastal Megacities*, Washington DC: The World Bank.
- 15 World Bank 2010c: *Pro-Poor Adaptation to Climate Change in Urban Centers; Case Studies of Vulnerability and*
16 *Resilience in Kenya and Nicaragua*, Social Development Department, Washington DC: The World Bank.
- 17 World Bank 2010d: Mainstreaming Gender in Road Transport: Operational Guidance for World Bank Staff,
18 Transport Papers-28, Washington DC: The World Bank.
- 19 World Bank 2010e: Economics of Adaptation to Climate Change: Synthesis Report. Washington DC: The World
20 Bank.. Accessed from
21 <http://climatechange.worldbank.org/sites/default/files/documents/EACCSynthesisReport.pdf>
- 22 World Bank 2010f: *Natural Hazards, Unnatural Disasters: The Economics of Effective Prevention*, Washington
23 DC: The World Bank.
- 24 World Bank, 2011: North African Coastal Cities: Climate Change Adaptation and Natural Disaster Preparedness in
25 the Coastal Cities of North Africa, Summary of Regional Study, Washington DC: The World Bank.
- 26 Xu, T., J. Sathaye, H. Akbari, V. Garg, and S. Tetali, 2012: Quantifying the direct benefits of cool roofs in an urban
27 setting: Reduced cooling energy use and lowered greenhouse gas emissions. *Building and Environment*, **48(0)**,
28 1-6.
- 29 Young, O.R., 2002: *The institutional dimensions of environmental change: fit, interplay, and scale*. MIT Press
- 30 Zanchettin, D., P. Traverso, and M. Tomasino, 2007: Observations on future sea level changes in the Venice lagoon.
31 *Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues*, , 41-53.
- 32 Zenawi, M. and J. Stoltenberg, 2010: Report of the Secretary General's High-Level Advisory Group on Climate
33 Change Financing. *United Nations*, **5(11)**.
- 34 Zhang, J., Y.H. Sui, and X.B. Geng, 2011: Landscape Design of Urban Green Space Adaptive to Global Climate
35 Change a Review. *Advanced Materials Research*, **243**, 6842-6845.
- 36 Ziervogel, G., P. Johnston, M. Matthew, and P. Mukheibir, 2010: Using climate information for supporting climate
37 change adaptation in water resource management in South Africa. *Climatic Change*, **103(3)**, 537-554.
- 38 Zimmerman, R. and C. Faris, 2010: Chapter 4: Infrastructure impacts and adaptation challenges. *Annals of the New*
39 *York Academy of Sciences*, **1196(1)**, 63-86.
- 40 Zimmerman, R. and C. Faris, 2011: Climate change mitigation and adaptation in North American cities. *Current*
41 *Opinion in Environmental Sustainability*, **3(3)**, 181-187.
- 42 Zinzi, M. and S. Agnoli, 2012: Cool and green roofs. An energy and comfort comparison between passive cooling
43 and mitigation urban heat island techniques for residential buildings in the Mediterranean region. *Energy and*
44 *Buildings*, **55(0)**, 66-76.
- 45

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)						
<i>Major area, region, country or area</i>	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
<i>Percent of the population in urban areas</i>						
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
<i>Percent of the world's urban population</i>						
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				
Local government investment capacity	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				
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	<ul style="list-style-type: none"> ◆ 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) 	<ul style="list-style-type: none"> ◆ Urban infrastructure and services ◆ Urban adaptation programmes and planning processes ◆ Urban capacity building 	<ul style="list-style-type: none"> ◆ 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	<ul style="list-style-type: none"> ◆ Concessions and private finance initiatives (PFIs) to build, operate and/or maintain key infrastructure ◆ Energy performance contracting 	<ul style="list-style-type: none"> ◆ Medium to large-scale infrastructure with strong private goods (to allow rents for private sector) 	<ul style="list-style-type: none"> ◆ Cities with strong capacity for legal oversight and management
Local or national - Private or Public	National or local financial markets	<ul style="list-style-type: none"> ◆ Commercial loans, ◆ Private bonds ◆ Municipal bonds 	<ul style="list-style-type: none"> ◆ Basic Physical Infrastructure (need for collateral) 	<ul style="list-style-type: none"> ◆ Well-functioning local or national financial markets that city governments can access
National - public	National (or state/provincial) revenue transfers or incentive mechanisms	<ul style="list-style-type: none"> ◆ Revenue transfers from central or regional government ◆ PES or other incentive measures 	<ul style="list-style-type: none"> ◆ Urban Payment for Environmental Services in Brazil ◆ Sweden’s KLIMP Climate Investment programme 	<ul style="list-style-type: none"> ◆ Cities with good relations with national governments, strong administrative capacity to design and implement policies and plans
International – private	Market-based investment	<ul style="list-style-type: none"> ◆ Foreign Direct Investment, Joint Ventures 	<ul style="list-style-type: none"> ◆ Industrial infrastructure ◆ Power generation infrastructure 	<ul style="list-style-type: none"> ◆ Cities with strong national enabling conditions and policies for investment
International sources	Grants, concessional financing (e.g. Adaptation Fund)	<ul style="list-style-type: none"> ◆ Grants, concessional loans and loan guarantees through bilateral and multilateral development assistance ◆ Philanthropic grants 	<ul style="list-style-type: none"> ◆ Urban capacity building ◆ Urban infrastructure adaptation planning 	<ul style="list-style-type: none"> ◆ Typically requires strong MLG – cities with good relations with national governments ◆ Cities with low levels of administrative and financial market capacity

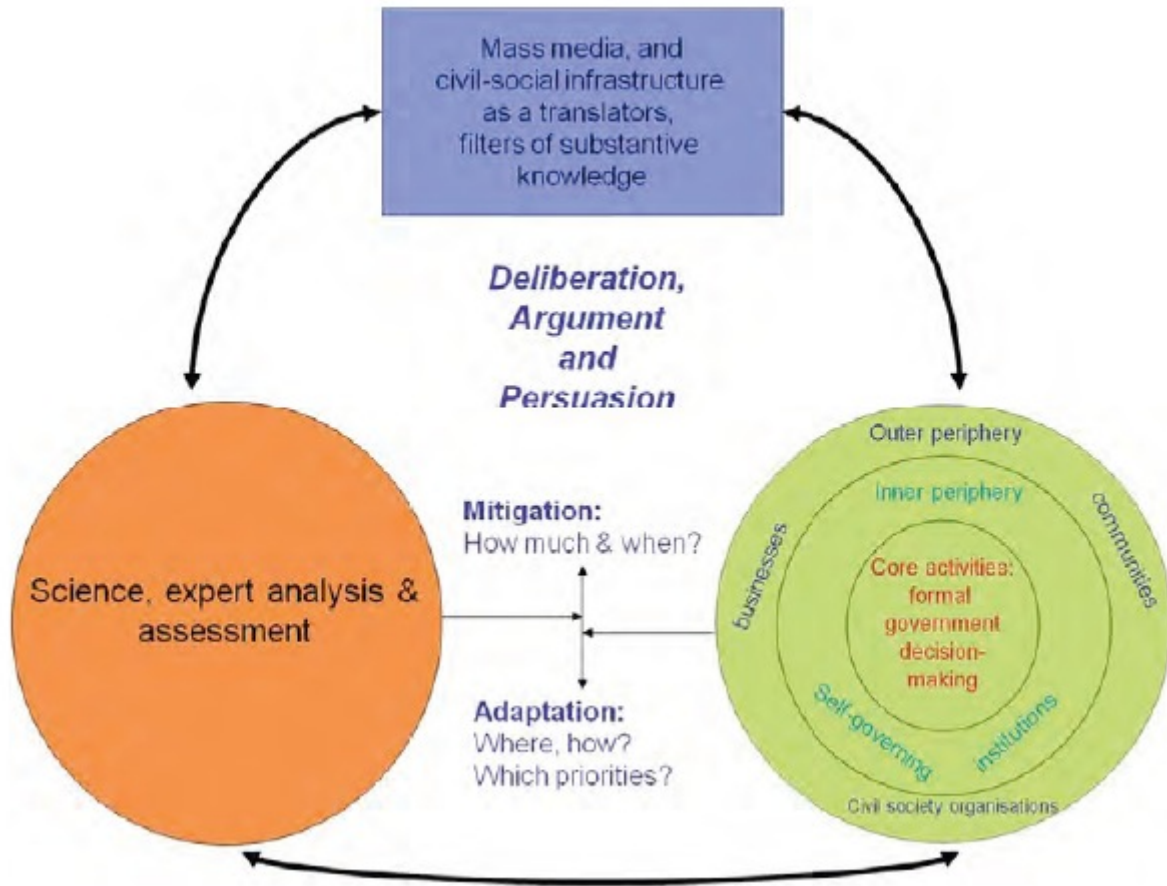


Figure 8-1: Circulation of power for public decisionmaking on climate change. Source: adapted from Corfee-Morlot, Cochran, Teasdale, and Hallegatte, 2011.

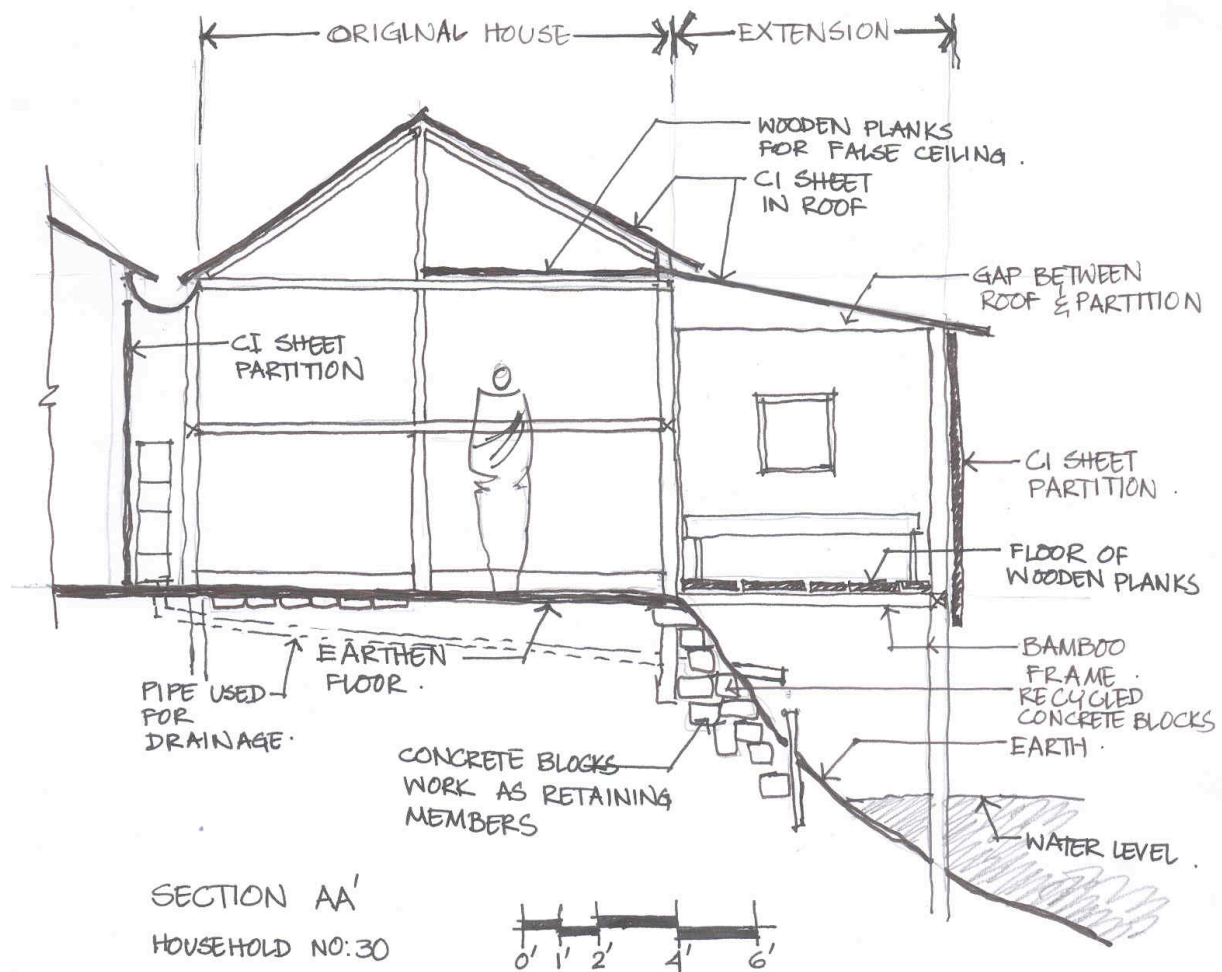


Figure 8-2: Household adaptation - a cross section of a shelter in an informal settlement in Dhaka (Korail) showing measures to cope with flooding and high temperatures. Source: Jabeen et al, 2010.

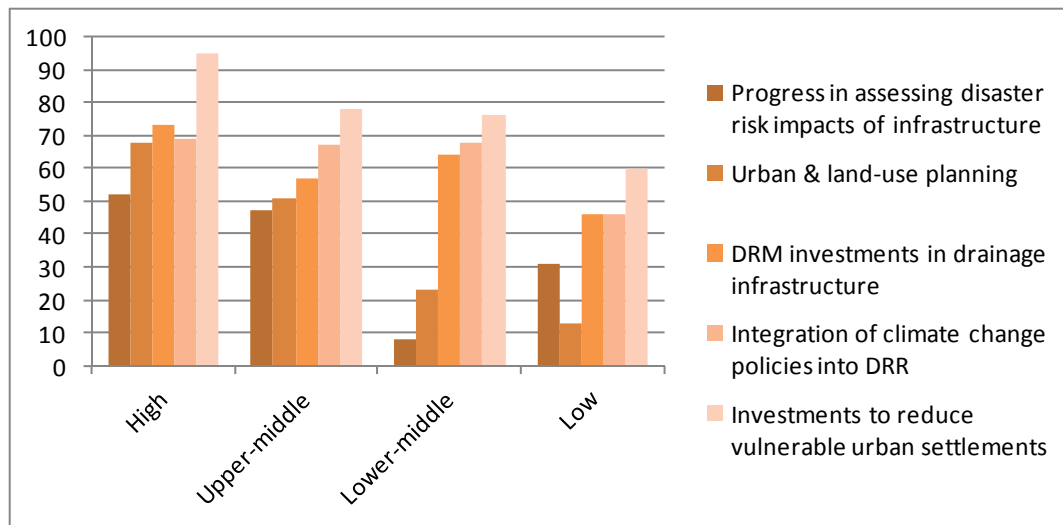


Figure 8-3: Progress reported by 82 governments in addressing some key aspects of Disaster Risk Reduction by countries' per capita income. Source: United Nations, 2011.

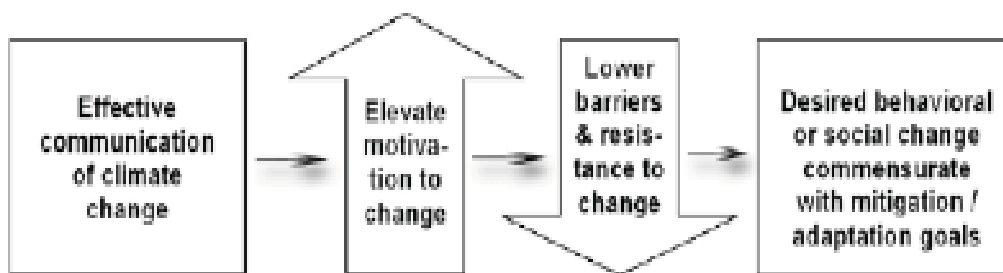


Figure 8-4: The basic challenge of effective climate change communication to change behaviour and norms. Source: Moser and Luers, 2008.