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# Guide to Climate Change Adaptation in Cities



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# Foreword

Climate change is a serious challenge for cities around the world, particularly in developing countries where urbanization is happening at neck-breaking speed. It threatens to increase vulnerabilities, destroy economic gains, and hinder social and economic development. And the urban poor will bear the brunt of its effects since they live and work in informal settlements that are more exposed to hazards.

Building resilience and adapting to climate change is increasingly a high priority for cities. Besides mitigation, on which efforts have largely focused in the past, cities should today play a larger role in adaptation. The World Bank and various other development institutions are working with cities to strengthen their capacity to assess vulnerability to climate change impacts and to identify corresponding plans and investments to increase their resilience.

This guide on climate change adaptation in cities is intended to offer mayors and other city officials, in developing countries, practical guidance on how to respond to the challenges of climate change adaptation in their cities. It provides a comprehensive overview of key climate adaptation issues that are relevant to cities, offers examples of good practices and successful experiences, and is a useful guide to other available resources and policy tools on the topic.

The guide focuses on disaster risk management, the urban poor and other vulnerable groups, and access to climate finance. It builds up on the World Bank and its partners' research and experience in dealing with cities and climate change—mainly the 5th Urban Research Symposium, and the Mayors Task Force on Climate Change, Disaster Risk and the Urban Poor.

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# Executive Summary



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**Cities face significant impacts from climate change, both now and into the future. These impacts have potentially serious consequences for human health, livelihoods, and assets, especially for the urban poor, informal settlements, and other vulnerable groups.** Climate change impacts range from an increase in extreme weather events and flooding to hotter temperatures and public health concerns. Cities in low-elevation coastal zones, for instance, face the combined threat of sea-level rise and storm surges. The specific impacts on each city will depend on the actual changes in climate experienced (for example, higher temperatures or increased rainfall), which will vary from place to place.

**Climate change will increase the frequency at which some natural hazards occur, especially extreme weather events, and introduce new incremental impacts that are less immediate.** However, few climate impacts will be truly unfamiliar to cities. Cities have always lived with natural hazards, such as earthquakes, tsunamis, hurricanes, and flooding. In some

situations, cities will experience an increase in the frequency of existing climate-related hazards, such as flooding.

**Climate change adaptation is the process of preparing for, and adjusting proactively to, climate change—both negative impacts as well as potential opportunities. Cities are often the first responders to climate impacts.**

Because cities are dynamic systems that face unique climate impacts, their adaptation must be location specific and tailored to local circumstances. The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts, and develop responsive policies and investments that address these vulnerabilities.

**A resilient city is one that is prepared for existing and future climate impacts, thereby limiting their magnitude and severity.**

Once an impact occurs, a resilient city is able to respond quickly and effectively, in an equitable and efficient way. Building resilience requires not only robust decision making by those in positions of formal authority, but also a strong web of institutional and social relationships that can provide a safety net for vulnerable populations. Through both formal planning activities and informal preparations, cities can build their capacity to

adapt effectively to existing and future climate impacts, while also experimenting and innovating in policy making and planning.

**Increasing resilience in cities involves addressing basic poverty reduction and sustainable development goals. Instead of seeing vulnerability to climate impacts as an additional concern, cities can mainstream resilience into existing efforts.** Many cities are challenged by rapid urbanization, expansion of informal settlements, substantial poverty, inadequate infrastructure, and environmental degradation. These and other concerns (the “development deficit”) constrain cities’ ability to grow and prosper. Many of these same conditions also limit resilience to current climate variability (the “adaptation deficit”).

**Climate change considerations can be integrated with disaster risk reduction (DRR) in cities.** DRR efforts—already familiar to many—may be used as a platform from which to develop climate change adaptation plans. In practical terms, disaster risk reduction and climate adaptation can be integrated in many instances, although cities should also consider incremental or gradual changes in climate that affect government operations or community life in less immediate and visible ways than conventional disasters.

Entry points other than DRR, such as development planning, can also be used for adaptation efforts in cities.

**Approaches to collecting information on climate change impacts in a city can range from highly technical and resource-intensive, to simple and inexpensive.** Technically complex assessments are likely to require collaboration with external experts, if a city is not large or well-resourced with sufficient in-house capacity. Cities can look to local universities or regional collaborations, supplemented by international expertise, if needed. Community-based participatory approaches can integrate community perspectives and priorities, improving understanding of the social and locally specific consequences of climate change. Taking a combined or tiered approach can yield assessments of impacts that are grounded in community priorities and supported by sound science.

**An increasing number of cities around the world have begun to plan for climate change by developing stand-alone climate plans or incorporating climate considerations into existing plans, policies, and projects.** City officials are making major development decisions today that will have long legacies, offering important and time-sensitive opportunities to adapt.



Addressing climate change adaptation through the formal planning or policy-making process can make an effort more durable in the long term, especially for a city in which a commitment to addressing climate change is largely based on a few public officials. Informal efforts, as well as initiatives that do not address climate change explicitly but still contribute to resilience, can also be valuable starting points.

**Adaptation efforts in cities offer cobenefits for climate change mitigation and for local economic development.** Green building investments, for instance, provide natural cooling to occupants in times of extreme heat, while also reducing greenhouse gas emissions and offering benefits in terms of energy efficiency and cost savings. More broadly, adaptation investments in cities, such as those that increase the resilience and reliability of urban infrastructure, can improve broader economic performance by increasing city competitiveness and attractiveness for investors and the private sector in general.

**Cities can identify simple and low-cost (or no-cost) actions that can be implemented to increase resilience in their day-to-day operations. At the same time, given resource constraints and competing priorities, many cities may be able to pursue only a few large**

**investments in climate change adaptation.** This makes the evaluation and prioritization of potential adaptive responses all the more important. Cities can apply tools to identify and prioritize which proposed adaptive actions to pursue, as well as to evaluate the effectiveness of these actions once implementation is underway. Based on these analyses, cities can identify “no-regrets” actions that generate net social or economic benefits independent of climate change. Low-cost actions can include short-term clearing of solid waste from urban waterways to prevent localized flooding because of clogged drains and public awareness efforts to share information about emergency evacuation and public health risks.

**Climate change will place unique burdens on the urban poor, residents of informal settlements, and other vulnerable groups, such as women, children, the elderly and disabled, and minority populations.** To build resilience among these vulnerable groups, a city can do the following: 1) raise awareness about specific climate change impacts on the most vulnerable; 2) include vulnerable groups in the adaptation planning and policy-making process; 3) incorporate community-based adaptation into city plans, when appropriate; 4) support organizations that already work with the vulnerable groups; and 5) strengthen land administration and regulation,

including considering the benefits of improving security of tenure and service provision in informal settlements. In pursuing such efforts, it is important to fully recognize the resourcefulness of the informal sector in cities.

**Climate change adaptation in cities requires collaborative problem solving and coordination across sectors.** Cities are well positioned to act as conveners of a wide range of partners. Climate change will have impacts on many sectors: land use, housing, transportation, public health, water supply and sanitation, solid waste, food security, and energy (see Table 6.1 for a sample of climate impacts and corresponding adaptive responses in cities). Adaptation efforts in any of these sectors will often involve multiple government agencies, as well as broad partnerships that include other governments, local communities, nonprofit organizations, academic institutions, and the private sector.

**Financing adaptation in cities will involve drawing upon a combination of sources.** Climate finance is a complex field, and adaptation-specific funding is still relatively limited. Sources of concessional finance are mostly structured for access at the national level, posing an additional challenge for cities. Opportunities that cities can consider include the following: 1) existing own-

source revenues and tools and national sources of municipal finance; 2) grant resources and concessional finance from multilateral or bilateral institutions; and 3) market-based mechanisms to increase efficiency and the involvement of the private sector. Cities can use funding for adaptation to pilot new tools, scale up and catalyze action, and leverage more funding from other donors or the private sector.

**In summary, adaptation is not a one-time effort but an ongoing cycle of preparation, response, and revision.** It is a dynamic process, and one that should be revised over time based on new information. Underpinning the strongest adaptation processes will be leadership and commitment to measuring progress and assessing effectiveness. This will help ensure that cities invest scarce resources in truly adaptive ways and achieve the maximum cobenefits, while avoiding unintended consequences. Those cities that are able to integrate adaptation well with a broad spectrum of existing planning processes and goals—including priorities in disaster risk reduction, sustainable development, and poverty reduction—will be best positioned to thrive in this new era of climate change.

# 1. Introduction



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## Why this Guide?

Cities—especially in developing countries—are on the front lines of climate change impacts. These impacts range from an increase in extreme weather events and flooding to increased air temperatures and public health concerns. Climate change affects both human well-being and the economy, posing threats to the livelihoods and assets of people living in cities. Most vulnerable to these impacts are poor residents, the elderly, women, children, and communities living on the margins of society.

If climate change impacts are left unaddressed, they stand to exacerbate existing challenges and make it more difficult for cities and countries to achieve sustainable development and reduce poverty. Achieving these goals for individuals, families, and whole cities requires adapting to a changing climate. Cities and their residents stand to gain far more by starting to adapt today, rather than by waiting or not taking action at all.

Adaptation to climate change is within practical reach even for cities and communities that have resource constraints. Many tools are already available for cities to adapt—by leveraging existing work in disaster risk reduction, pursuing assessments of urban vulnerability that involve and prioritize the poor, and learning from adaptation strategies that have already been tested in other parts of the world. At the same time, those cities that develop and implement sound agendas for climate change resilience can reap additional benefits in the areas of green growth and poverty alleviation.

## Objectives and Focus of this Guide

This guide aims to provide cities in developing countries with practical insights on climate change adaptation. A number of documents already provide valuable information for cities on how to prepare for climate change impacts, both in general and for specific sectors. Building on existing sources, this guide seeks to address climate change adaptation for cities in developing countries with an additional discussion of

challenges facing informal settlements, the urban poor, and other vulnerable groups.

This guide specifically addresses an audience of mayors and municipal practitioners in developing countries. These leaders and managers face various existing challenges in running their cities—from waste disposal to policing to public health. When considered in light of these ongoing activities, climate change can be an opportunity for positive change and action in cities, rather than a competing priority for scarce resources.

With this context in mind, this guide uses disaster risk reduction—a familiar framework for many cities worldwide—as a practical starting point for climate change adaptation. Although the fields of disaster risk reduction and climate change adaptation have different origins and different practices, practitioners can find areas of convergence (see Chapter 3). Given resource and time constraints, cities can find cost-effective ways to integrate disaster and climate risk reduction activities at all stages, including vulnerability assessments, planning and prioritization of adaptive strategies, implementation, and measurement of success.

This guide is neither a technical document nor a description of a single methodology or tool. Instead, it provides high-level insights on how to develop a robust picture of climate change vulnerabilities that is also grounded in pressing community priorities, by consulting with both technical advisors and community stakeholders. Various methodologies and tools are described in this guide to help city practitioners gain familiarity with the range of available resources. The guide points to further resources for those readers wishing to learn more.

Based on direct feedback from stakeholders, this guide also shows how climate change can be linked to other important city issues, such as economic development, public health, sustainability, and food security. Rather than providing prescriptions in any of these areas, the guide provides actual examples of actions that have been taken at the local level to spark ideas, innovation, and knowledge exchange. Although this guide does not represent an exhaustive collection of best practices, and is not a step-by-step or how-to handbook, it offers relevant tips and general principles based on the experiences of others around the world to guide locally tailored action.

## Overview of this Guide's Structure

Chapter 2 provides brief background information on how climate change is expected to affect cities around the world, with disproportionate impacts on cities in developing countries.

Chapter 3 introduces the concept of adaptation—the process by which cities prepare for the specific impacts that they expect to face. More specifically, it:

- Provides reasons why cities should proactively undertake an adaptation process, which mayors and local leaders can use as material when explaining or justifying adaptive actions.
- Defines resilience, adaptation, and related “building block” concepts, including hazards, risk, exposure, sensitivity, and vulnerability.
- Shows how adaptation relates to disaster risk reduction and poverty alleviation, and shares principles to guide the adaptation process.

- Describes the different stakeholders and institutional actors that need to be involved in adaptation, as well as mechanisms for organizing an adaptation effort. This section includes information on how different stakeholders have adapted both formally and informally.

Based on these foundational concepts, Chapter 4 then shows how localities can develop roadmaps for adaptation, and how climate change adaptation could change the way cities operate. Specifically, it:

- Gives a range of tips and tools, including basic vulnerability and risk assessments—both technical and participatory—to help cities develop a better understanding of climate change risks and impacts. This section furnishes information on the features of each type of tool.
- Provides an overview of formal upstream actions that cities can take to respond to climate change, including examples of actual climate plans and policies that may be models to consider.

- Describes how cities can move from planning to action, including assessing the effectiveness of existing policies in light of new information and developing new responses to build resilience. This includes evaluating adaptive actions, understanding the robustness of policies in different scenarios, and setting indicators to measure progress over time.

Chapter 5 focuses on what cities can do to build the resilience of informal settlements, the urban poor, and other vulnerable groups. Chapter 6 analyzes and gives examples of city-level adaptation in the areas of land use, housing, water and sanitation, public health, transportation, food and agriculture, energy, and solid waste. Chapter 7 provides a simple overview of the financing mechanisms available to cities to fund these adaptation responses. Appendix I contains information on the basics of climate change science.

## 2. Climate Change Impacts on Cities



This chapter provides a brief overview of climate change impacts on cities, informal settlements, and the urban poor. Further material is available in Appendix I, which contains more detailed information on the science of climate change, including the following: an overview of weather and climate change; concepts related to projections of future climate change impacts; and an overview of potential climate change impacts in different regions of the world. In addition, Chapter 4 provides a number of resources for cities to find and understand information on climate change.

### The Range of Climate Change Impacts on Cities

Cities already face significant climatic and environmental challenges that are independent of climate change, such as the following (adapted from Rosenzweig and others 2011):

- The urban heat island effect—cities are generally warmer than surrounding rural areas because of higher heat absorption and

relatively limited cooling associated with vegetation and permeable surfaces

- Air pollution, which is exacerbated by high temperatures
- Existing climate extremes, such as hurricanes and typhoons (although the exact relationships with climate change have yet to be fully established)

Nonclimate related trends, such as land subsidence, can also be drivers of risk for natural hazards, such as flooding, as noted in a World Bank study of three Asian coastal megacities (World Bank 2010a).

In conjunction with these existing issues, the impacts of climate change on cities will depend on the actual changes in climate experienced, such as higher temperatures and increased rainfall. These will vary from place to place. For example, cities in low-elevation coastal zones with land subsidence may be affected by rising sea levels and storm surges. Cities in hot climates (or in temperate regions with hot summers) may be affected by longer and more severe heat waves. The World Bank's *Climate Resilient Cities* primer (available at [www.worldbank.org/eap/climatecities](http://www.worldbank.org/eap/climatecities)) provides guidance on how cities can scope possible climate change impacts based on their geographic

location (for example, sea level rise as a threat for coastal cities) (World Bank 2009).

Changes in climate will in turn have a range of short-term and long-term consequences for cities—on human health, physical assets, economic activities, and social systems—depending on how well prepared a city is and how it responds. Table 2.1 summarizes some possible impacts of climate change on cities, based on IPCC projections for the mid- to late 21st century (these projections do not account for any changes or developments in adaptive capacity), and the Assessment Report on Climate Change and Cities (ARC3) (Rosenzweig and others 2011).

In addition to direct impacts on cities, climate change will also affect cities indirectly through effects on areas and systems outside of cities. The following are some examples (the list is adapted from Rosenzweig and others 2011 and IPCC 2007, except where noted):

- Water quality and quantity may be reduced by expected increases in droughts, especially from sources (for example, snowpack) outside of city borders, with a host of consequences from threatened drinking water supply to reduced agricultural production that affects food security in cities (also see Chapter 6).

- Energy transmission and distribution may be overstressed because of increased incidence or duration of summer heat waves, in conjunction with energy demand for cooling.
- Cities may also experience greater in-migration from rural inhabitants pressured by drought or other climate extremes.
- Climate change is increasingly being discussed as an emerging global security issue—a threat to the well-being, safety, and survival of people around the world—although more evidence is needed to understand the nature of this relationship (Barnett and Adger 2005; IISD 2011).

Chapter 6 provides more information on the energy and food supply impacts for cities.

Cities are also economically vulnerable to climate change, not least because of high population density and concentrated economic wealth. In the absence of action, the expected costs to cities are high (see Chapter 7). Examples of historical and estimated costs of climate-related disasters include the following:

- Hurricane Katrina was estimated to cost the United States over \$100 billion (NOAA 2011).
- Changed tropical cyclone activity resulting from climate change could cost between \$28

| TABLE 2.1 POSSIBLE IMPACTS OF CLIMATE CHANGE ON CITIES  |   |  |
|---|---|--|
| Projected Change in Climate Phenomena (Likelihood)  | Consequences for Cities   | Geographic Locations Most Affected   |
| Warmer with fewer cold days and nights, more hot days and nights (virtually certain)<br>Hot spells/heat waves — increased frequency (very likely) | Exacerbation of the urban heat island effect, leading to increased risk of heat-related mortality and illness, especially for the elderly, chronically sick, very young, and socially isolated<br>Increased demand for cooling, and reduced energy demand for heating<br>Declining air quality in cities<br>Greater stress on water resources, including those that rely on snowmelt, from increased water demand, declining water quality<br>Wider geographical incidence of vector-borne diseases (for example, malaria spreading to higher-altitude cities)<br>Less disruption to transport from snow or ice | All, especially inland cities and cities reliant on snowpack for water supply            |
| Heavy precipitation events— increased frequency (very likely)<br>Intensity of tropical cyclone activity increases (likely)                        | Flooding, strong winds, and landslides<br>Disruption of public water supply and sewer systems, and adverse effects on quality of surface and groundwater<br>Damage and losses to physical assets and infrastructure: houses, public facilities, utilities<br>Increased risk of deaths, injuries, and illnesses (especially water-borne diseases)<br>Disruption of transport, commerce, and economic activity<br>Withdrawal of risk coverage in vulnerable areas by private insurers<br>Water stress may be relieved (short-term benefit)  | Coastal cities, those on riverbanks or marginal land in floodplains, mountainous regions |
| Areas affected by drought increase (likely)   | Greater stress on water resources, from increased water demand, declining water quality<br>Reduced energy supply from hydropower generation<br>Land degradation, with lower agricultural yields and increased risk of food shortages, and dust storms<br>Potential for population migration from rural to urban areas   | All, especially cities in regions unused to arid conditions                              |
| Rising sea level (virtually certain)  | Permanent erosion and submersion of land; and costs of coastal protection or costs of relocation<br>Decreased groundwater availability because of saline intrusion into aquifers<br>Exacerbated effects of tropical cyclones and storm surges, particularly coastal flooding  | Coastal cities   |

Note: As per IPCC, virtually certain refers to > 99 percent probability, very likely refers to > 90 percent probability, and likely refers to > 66 percent probability.  
Sources: Adapted from IPCC 2007 as cited in World Bank 2009; other sources include Rosenzweig and others 2011; World Bank 2009; UNEP 2009; Rosenzweig 2010.



billion and \$68 billion globally per year by 2100 (World Bank 2010b).

- In Manila, Bangkok, and Ho Chi Minh City, costs of damage from climate change-related flooding are likely to be substantial, ranging from 2 to 6 percent of regional GDP; a 1-in-30 year flood in Manila could cost between \$900 million and \$1.5 billion, given current flood control infrastructure (World Bank 2010a).

For city governments in general, climate change impacts will alter the environment in which residents live and agencies operate. Subsequent chapters of this guide describe how cities can better understand the specific impacts on their cities and suggest actions that cities can take to respond to these impacts.

## Climate Change Impacts Related to Urban Poverty and Informal Settlements

Rapid urbanization because of population growth and migration from rural areas, combined with lack of affordable housing, has been associated with the development of informal settlements on marginal land in and near cities. The urban

**TABLE 2.2 CONSEQUENCES OF SOME RECENT DISASTERS IN INFORMAL SETTLEMENTS: THE PHILIPPINES**

| Disaster Event  | Year | Consequences  |
|---|------|---|
| Trash slides at the Payatas solid waste dump in Quezon City | 2000 | Heavy rains from typhoons caused a 15-meter slope in the dump to collapse, burying hundreds of homes. Because of these events, 288 people were killed and several hundred families displaced. Subsequent flash floods affected the homes and livelihoods of many more people. |
| Landslide in Barangay Guinsaogon                            | 2006 | The whole <i>barangay</i> (district) was buried and another 80 <i>barangays</i> affected. A total of 154 deaths were recorded, 968 people reported missing, 3,742 displaced and 18,862 affected.  |
| Mount Mayon mudflow and floods                              | 2006 | Typhoons triggered huge floods, mudslides and avalanches. In the Bicol region alone, at least 208 people died and another 261 were reported missing. These settlements were recovering from a previous typhoon.   |
| Flash flood in Iloilo                                       | 2008 | In the city of Iloilo, 152 of its 180 <i>barangays</i> were affected by heavy rain and flooding. Up to 500 people were killed, and 261,335 were affected. Many houses were washed away and many households lost their documentation.  |

Source: IFRC 2010.

poor—an increasing number of whom are migrants from areas affected by climate change impacts—tend to live in marginal areas of the urban landscape: on steep slopes, along riverbanks and transportation corridors, and in floodplains.

People living in informal settlements (numbering nearly one billion worldwide, or nearly one-third of the world's urban population) often lack the following critical living conditions:

- Access to improved water
- Access to improved sanitation facilities
- Sufficient living area (not more than three people sharing a room)

- Structural quality and durability of dwellings
- Security of tenure (UN-HABITAT 2006; UN-HABITAT 2008)

As a direct result, many of these people live with a constant risk to their lives and homes from disasters, such as storms, floods, landslides, heat waves, and droughts. A number of disasters in the Philippines listed in Table 2.2 highlight how impacts of climate-related disasters on informal settlements have major consequences for housing among the urban poor.

Residents of informal settlements often lack the resources to invest in improving their living

environments. It can be extremely difficult for them to minimize the risk of economic losses and other impacts from disasters. Climate change impacts can, thus, lead to a deepening and broadening of poverty for those already living at or below the poverty line. Chapter 5 explores these concerns in further detail.

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## 3. Framing Adaptation in Cities



Climate change **adaptation** consists of “initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects” (IPCC 2007). Both through informal preparations and formal planning activities, cities can build their resilience and capacity to adapt to existing and future climate change impacts.

This chapter provides an overview of the reasons for cities to take a proactive approach to climate change adaptation. It then describes some basic adaptation concepts, the relationship between adaptation and disaster reduction, and the roles that different actors can play in adaptation.

### Why Adapt?

Adaptation is a smart option for cities in developing countries. The reasons outlined below are adapted from UN-HABITAT’s Local Leadership for Climate Action principles and ICLEI’s Climate Resilient Communities program (UN-HABITAT 2010; ICLEI 2009).

1. **It is certain that global, regional, and local climates will change in the future** (Hansen 2005). In many parts of the world, the climate is already noticeably different from historical climate. Climate change has serious direct and indirect impacts on cities (see Chapter 2).
2. **Climate change can affect a city's ability to achieve existing development goals.** Many cities in developing countries face significant challenges in providing safe and affordable housing, supplying quality drinking water and basic sanitation, providing energy to businesses and residents, ensuring safe and livable communities, and fostering an environment for economic success. Climate change and its associated impacts can jeopardize progress in meeting these needs. As the World Development Report 2010 noted, "development will get harder, not easier, with climate change" (see Box 3.1). This is true even in areas where progress has already been achieved. For example, severe flooding could lead to indirect impacts (such as a localized increase in water-borne diseases) that had been previously reduced by improved sanitation.

3. **Major development decisions taken today in cities have long-term implications, offering important and time-sensitive opportunities to adapt.** Paying for prevention upfront can avoid greater costs in the future. For example, building on low-cost,

marginal land can result in far higher costs years down the road, if and when disaster strikes. Conversely, one dollar of prevention today can avoid as much as four dollars of post-disaster reconstruction expenditure in the future (GFDRR 2010).

### BOX 3.1 THE WORLD DEVELOPMENT REPORT 2010

Building the capacity of local places, ecosystems, and people to adapt to climate change is a critical component of achieving the vision and intent of the Millennium Development Goals (MDGs). The World Development Report 2010 identified six key messages for adapting to climate change, while promoting development:

**Poverty reduction and sustainable development remain core global priorities.** A quarter of the population of developing countries still lives on less than \$1.25 a day. One billion people lack clean drinking water; 1.6 billion, electricity; and 3 billion, adequate sanitation. A quarter of all developing-country children are malnourished. Addressing these needs must remain the priorities both of developing countries and of development aid—recognizing that climate change can hamper the achievement of these goals.

**Climate change must be addressed urgently.** Climate change threatens all countries, with developing countries being the most vulnerable.

**Economic growth alone is unlikely to be sufficiently fast or equitable to counter threats from climate change, particularly if economic growth remains carbon-intensive and accelerates climate change.** Climate policy cannot be framed as a choice between growth and avoiding climate change. In fact, climate-smart policies are those that enhance development, reduce vulnerability, and finance the transition to low-carbon growth paths.

**A climate-smart world is within our reach if steps are taken to act now, act together, and act differently than in the past.**

**An equitable and effective global climate deal is needed.**

**Success hinges on changing behavior and shifting public opinion.**

*Source: World Bank 2010a.*

4. **Planning for future variability is not new and can help cities to capture sustainable development and disaster risk reduction benefits today.** For thousands of years, humans have adapted to their environments. In modern societies, adaptation can be considered part of a city's existing decision-making process. Despite uncertainties on the specific future impacts of climate change, cities can make informed decisions about how to increase resilience and adapt based on best available information (Dessler and Parson 2010). Cities may also find that effective strategies to manage present-day

concerns are also helpful in coping with climate change impacts—as many projected climate change impacts are more extreme, unpredictable, or frequent versions of what is already experienced today. Strategically planning for a range of climate change impacts can create opportunities to reduce existing vulnerability. For example, implementing a water conservation program in anticipation of increased future drought risk can offer immediate benefits for managing current droughts.

5. **Adaptation can offer cobenefits for climate change mitigation, and a well-balanced city climate agenda can increase opportunities for accessing climate finance.** Some actions can reduce greenhouse gas (GHG) emissions while helping cities to adapt to expected climate change. Energy efficiency, for example, is a common strategy to reduce GHG emissions, while also decreasing electricity consumption, thereby reducing vulnerability to grid overload and outages. Likewise, water conservation not only reduces emissions by avoiding energy use for water treatment and distribution, but also helps a city prepare for future climate-related shortages. Moreover, pursuing a climate agenda with a balance

of both adaptation and mitigation measures can yield financial advantages, such as lower insurance rates and increased access to grant and concessional financing opportunities. Chapter 7 provides more detail on financing related to city-level adaptation.

## Basic Concepts Related to Adaptation

Cities have always experienced **natural hazard** events, some which are not climate related (such as earthquakes and tsunamis) and some which are climate related (such as hurricanes and flooding). These hazard events may become disasters, depending on the magnitude, location, and severity of impact on lives, livelihoods, and overall societal functioning. Climate change is expected to increase the frequency and severity of climate-related hazard events, including extreme weather, and to introduce new incremental impacts that are less obvious and immediate.

Many cities face existing challenges related to urban poverty, basic service delivery, and inadequate infrastructure that represent barriers to sustainable development—the “development deficit.” Many of these same conditions also limit resilience to disasters and existing climate

### DEFINITIONS OF SOME KEY TERMS

**Exposure** refers to the nature and degree to which a system is exposed to significant climatic variations (IPCC 2001).

**Sensitivity** refers to the degree to which a built, natural, or human system is directly or indirectly affected by changes in climate conditions (for example, temperature and precipitation) or specific climate-change impacts (for example, sea-level rise and increased water temperature). If a system is likely to be affected as a result of projected climate change, it should be considered sensitive to climate change (Snover and others 2007).

**Vulnerability** is the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, as well as the system's sensitivity and adaptive capacity (IPCC 2007).

**Adaptive capacity** refers to the capabilities, resources, and institutions of a country or region to implement effective adaptation measures (IPCC 2007).

variability (the existing “adaptation deficit”), as well as to more extensive and long-term climate change (World Bank 2010b).

Just as cities assess, manage, and limit the **risks** of disasters in order to protect their populations, they can similarly address the risks of climate change impacts. Managing these risks—and building long-term **resilience**—involves understanding the level of **exposure** and **sensitivity** to a given set of impacts, developing policies and investments that will limit **vulnerabilities**, and enhancing **adaptive capacity**.

A **resilient** city is one that is able to adapt to disaster and climate impacts now and in the future, thereby limiting the magnitude and severity of those impacts. Once an impact occurs, a resilient city is able to evolve cost-effectively and equitably for all stakeholders. Building resilience towards climate change requires robust decision making by those in positions of formal authority, as well as a strong web of institutional and social relationships that provides formal and informal safety nets for the most vulnerable populations.

Full definitions of the terms mentioned above are provided in the glossary.

## Integrating Climate Change Adaptation with Disaster Risk Reduction

Efforts to build resilience in cities can benefit from integrating climate change adaptation with existing efforts in disaster risk reduction (DRR) and other similar planning processes. As the report *Natural Hazards, Unnatural Disasters* articulates, cities can overcome greater exposure to climate change and hazard events through sound risk management—a significant and challenging task

(World Bank 2010c). Examples of analytical work that address DRR and climate change adaptation jointly are the *Climate Resilient Cities Primer* (World Bank 2009) and a more recent study on North African coastal cities (see Box 3.2). UNISDR has also integrated the two approaches in its ongoing global campaign for resilient cities (see Box 3.3).

Table 3.1 summarizes the differences between DRR and climate change adaptation, as well as areas of convergence. A combined DRR-adaptation approach might involve the following:

### BOX 3.2 ADAPTATION TO CLIMATE CHANGE AND NATURAL DISASTERS IN THE COASTAL CITIES OF NORTH AFRICA

An ongoing regional study funded by the World Bank and implemented in conjunction with the Arab Academy of Science, Technology and Maritime Transportation illustrates the intertwining of climate change and disaster risks. One of the underlying drivers of climate and hazard vulnerability in the Egyptian city of Alexandria, for example, is the “continuing urban expansion in new sites exposed to natural hazards.” By 2030, Alexandria faces a “medium risk of marine submersion and coastal erosion, and a comparatively lower risk of earthquake, tsunami, flooding, and water scarcity” as well as a potential uptick in diarrheal diseases and malaria, because of climate change. It is further estimated that “natural disasters and climate change impacts would cost the city of Alexandria approximately \$1.72 billion (in net present value terms) during 2010 to 2030...” related to water scarcity, earthquake-related damages, and public health concerns of which “climate change-related impacts are estimated to be around 18 percent of the total estimated cost.” The study made integrated climate change and natural disaster risk assessments of Casablanca and the Bouregreg Valley in Morocco, and the city of Tunis, Tunisia, based on highly detailed urban risk maps using digitized elevation models, satellite imagery, and GIS software. More information is available at <http://arabworld.worldbank.org> and [www.cmimarseille.org](http://www.cmimarseille.org).

Source: World Bank 2010d.

### BOX 3.3 UNISDR “TEN ESSENTIALS” FOR DISASTER RISK REDUCTION

In May 2010, UNISDR launched the global campaign “Making Cities Resilient—My City is Getting Ready!” to promote increased understanding and commitment by cities and local governments to risk reduction and to build cities that are resilient to disasters and climate change.

The overall target of the campaign is to get as many cities as possible committed to disaster risk reduction and to span a global network of engaged cities, provinces, and municipalities of different sizes, characteristics, risk profiles, and locations that can help and learn from each other. Building on the Hyogo Framework for Action, a “ten-point checklist” for making cities resilient (or benchmarking the level of disaster resilience in cities) is the guiding framework for commitments and for identifying good practice, tools, and resources in support of resilient cities. The ten principles include the following:

1. Put in place **organization and coordination** to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role regarding disaster risk reduction and preparedness.
2. **Assign a budget** for disaster risk reduction and provide incentives for homeowners, low-income families, communities, businesses, and public sector to invest in reducing the risks they face.
3. Maintain up-to-date data on hazards and vulnerabilities, **prepare risk assessments**, and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city’s resilience are readily available to the public and fully discussed with them.
4. Invest in and maintain **critical infrastructure that reduces risk**, such as flood drainage, adjusted where needed to cope with climate change.
5. Assess the **safety of all schools and health facilities** and upgrade these as necessary.
6. Apply and enforce **realistic, risk-compliant building regulations and land-use planning principles**. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible.
7. Ensure **education programs and training** on disaster risk reduction are in place in schools and local communities.
8. **Protect ecosystems and natural buffers** to mitigate floods, storm surges, and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices.
9. Install **early warning systems and emergency management** capacities in your city and hold regular public preparedness drills.
10. After any disaster, ensure that the **needs of the survivors are placed at the center of reconstruction** with support for them and their community organizations to design and help implement responses, including rebuilding homes and livelihoods.

A handbook for mayors and local government leaders entitled *Making Cities Safer and Resilient—Before Disasters Strike* (forthcoming in 2011) provides guidance on implementing the UNISDR “Ten Essentials.” More information on “My City is Getting Ready!” campaign and the handbook is available online at: <http://www.unisdr.org/campaign>.

Source: UNISDR 2010.



| TABLE 3.1 INITIAL DIFFERENCES AND AREAS OF CONVERGENCE BETWEEN DISASTER RISK REDUCTION (DRR) AND CLIMATE CHANGE ADAPTATION   |   |  |
|--|---|--|
| Differences  |   | Areas of Convergence   |
| Disaster Risk Reduction  | Climate Change Adaptation   |  |
| Relevant to all hazard types.  | Relevant to climate-related hazards.  | Climate-related hazards may in many cases be a worsening of current hazards, some of which may already be the focus of DRR.  |
| Historically focused on humanitarian assistance following a disaster event; increasingly focused on prevention, mitigation and preparedness, including changes to development processes.             | Historically rooted in scientific theory.   | Climate change adaptation (CCA) specialists now recruited from engineering, water and sanitation, agriculture, health, and DRR sectors.<br><br>Both DRR and CCA need to be mainstreamed into development decision processes. |
| Most concerned with the present—i.e., addressing existing risks.   | Most concerned with the future—i.e., addressing uncertainty/new risks.  | DRR increasingly forward-looking. Existing climate variability is an entry point for climate change adaptation.  |
| Traditional/indigenous knowledge at community level is one basis for preparedness and resilience.  | Traditional/indigenous knowledge at community level may be insufficient for resilience against types and scales of risks that are yet to be experienced.  | Examples where integration of scientific and traditional knowledge for DRR provide learning opportunities.   |
| Structural measures designed for safety levels modeled on current and historical evidence and risk tolerance.  | Structural measures designed for safety levels modeled on predicted changes, current and historical evidence, and risk tolerance. Some adaptation measures might address maladaptation from initial responses to disasters that are not sustainable or cost-effective in the long term. | DRR increasingly forward-looking in design of structural measures and safety standards.  |
| Traditional focus on vulnerability reduction and societal preparedness.  | Traditional focus on reduction of physical exposure through infrastructure investments (for example, sea walls).  | There is an increasing focus in climate change adaptation on community-focused vulnerability assessments that include measurement and improvement of social resilience.  |
| Community-based process stemming from experience, technical inputs, and external support.  | Community-based process stemming from policy agenda.  | Communities do not tend to differentiate between current and projected risks, presenting an opportunity to build resilience to both at the same time.  |
| Full range of established and developing tools (for example, legislation and institutional arrangements, early warning systems, insurance, building design codes, siting, and ecosystem protection). | Limited range of tools under development, evolving and expanding rapidly.   | Increasing recognition that more adaptation tools are needed, especially those that leverage DRR experience.   |
| Political and widespread recognition often quite weak.   | Political and widespread recognition increasingly strong.   | Climate-related disaster events are now more likely to be analyzed and debated with reference to climate change.   |
| Funding streams <i>ad hoc</i> and insufficient.  | Funding streams dedicated but still small relative to the problem.  | DRR community engaging in climate change adaptation funding mechanisms.  |

Adapted from Venton and La Trobe 2008; Cronin 2004; UNISDR 2003.

- Understanding vulnerabilities to existing patterns of disaster risks, especially climate-related hazards
- Working with vulnerable groups to understand and prioritize their existing concerns
- Compiling information on future changes in climate and how these are likely to affect historical disaster patterns of occurrence and/or create new patterns and locations of disaster occurrences
- Analyzing less visible climate changes, such as seasonal shifts, persistent drought, extended periods of extreme weather and temperature, and other slow-onset or incremental changes that can be nonetheless destructive
- Ensuring enhanced levels of preparedness for current patterns of climate risks and all hazards

- Ensuring that planning and decision making include strategies for dealing with disasters and climate hazards of both today and tomorrow
- Ensuring structural measures are designed for future climate risks, based on likely climate change scenarios

Chapter 4 describes some of the assessment tools that cities can use to undertake the above steps.

## The Roles of City Governments and Others in Adaptation

Adaptation can be undertaken by an individual for his or her own benefit, or it can consist of actions by governments and public bodies to protect their citizens (Adger 2005). Adapting to natural hazards—or in less optimal cases, reacting to them—is not new for many individuals, families, and cities around the world. Protecting livelihoods, assets, and access to such basic services as energy and water is a natural response when dealing with disasters and climate hazards.

### CITY GOVERNMENTS ARE OFTEN FIRST RESPONDERS AND PRIMARY LOCAL PLANNERS

City governments are responsible for decisions and actions related to the delivery of a wide range of services that ensure the well-being of their citizens: land use planning and zoning; water provision, sanitation, and drainage; housing construction, renovation, and regulation; economic development; public health and emergency management; transportation provision; and environmental protection. Many of these formal functions position cities well to undertake adaptation, because many services are vulnerable to disruption from climate change impacts, and because planning functions can serve as sources of adaptive capacity and strategies to reduce vulnerability.

Cities can take a major step toward sound development and climate change resilience simply by instituting and enforcing stronger management principles—a very substantial undertaking that does not lend itself to consistently easy solutions. Independent of climate change, many cities face significant obstacles in fulfilling their functions because of long-standing problems with governance, such as corruption, lack of transparency, and weak administration. These issues can hinder

#### THE IMPACT OF GOOD GOVERNANCE IN PHNOM PENH, CAMBODIA

By instituting efficient management practices and replacing underperforming staff at the Phnom Penh Water Supply Authority (PPWSA), this public utility in Cambodia increased its daily production of drinkable water by 360 percent. Reduced corruption has also helped the PPSWA to increase revenue and provide significantly more of Phnom Penh's residents with access to clean water (The Economist 2011).

the achievement of long-term development goals in general (World Bank 2007).

Cities tend to face two major needs in this area—first, a basic assessment of institutional capacity, and second, development of a shared understanding of roles and responsibilities that different actors can play in executing an adaptation agenda. A city can begin to address these needs by developing an institutional map of the different actors that may be involved in an adaptation effort, how they function in reality, and any capacity gaps that may remain to be filled. The World Bank's *Climate Resilient Cities Primer* provides a useful series of worksheets to support this type of exercise, and the World Bank's forthcoming Urban Risk Assessment includes an institutional assessment component.

#### CITY GOVERNMENTS CAN PLAY IMPORTANT CATALYTIC AND CONVENING ROLES IN ADAPTATION

There are many ways to organize and govern an adaptation process, whether with a dedicated climate change unit in the mayor's office or in the environment agency, an inter-agency task force of the city government, or a wider stakeholder group beyond the city government itself. In all of these approaches, city governments are well positioned to be an integrating force, fostering communications

and mutually beneficial partnerships among experts and stakeholders at multiple levels.

- Some cities can consider starting a climate leadership team within the government (see Box 3.4). Significant progress can be made by simply encouraging departments to communicate openly with one another about climate change impacts and shared adaptation strategies.
- External partnerships can also be useful in several ways. Some cities may not have the internal capacity to create and

maintain a team that is dedicated to climate change adaptation, in which case city officials may find that partnerships with civil society organizations can offer a strategic capacity-sharing benefit. Even cities that do have robust internal capacity, however, may find that a partnership provides an opportunity to catalyze improved coordination and innovation among individuals, groups, and city governments. In fact, because cities may face problems related to climate change impacts that originate outside of jurisdictional boundaries, they may find it critical to engage

#### BOX 3.4 FORMING A CLIMATE LEADERSHIP TEAM

Several basic elements are necessary for successful city leadership to set the course for climate change adaptation. These include the following:

- **Political support**, representing high-level commitment to adaptation, initiated and sustained by executive leadership of a mayor or other city officials, and supported by effective public communication
- **Operational knowledge** of the rules and norms of city operations, as well as relationships to city and external actors who may need to be involved in adaptation efforts
- **Scientific expertise or competency**, with which city staff can translate science into sound advice for decision makers

Some cities may find these ingredients within their organizations, while others will look to outside partners. Many cities may not have all the capacity needed within the city government itself, and could work instead as conveners to develop capacity-sharing partnerships among experts, city staff, and other stakeholders.

*Source: Authors.*

TABLE 3.2 COMMON ACTORS INVOLVED IN ADAPTATION

| Actor  | Roles   | Examples of Partnership in Cities   |
|--|---|---|
| Academic and Scientific Organizations              | Provide information on scientific developments, vulnerability, and information on potential policy responses.   | The World Bank's Regional Study on Adaptation to Climate Change and Natural Disasters in the Coastal Cities of North Africa is one example of university participation in climate change adaptation (see Box 3.2).  |
| Community-Based Organizations and Small Businesses | Can be helpful intermediaries, especially when led by influential individuals who know how to navigate local social networks.<br>May already be implementing adaptive management responses, whether formally or informally.   | In Viacha, Bolivia, local community members from 13 <i>barrios</i> elected two representatives to a new association, the Viacha Flood Victims Association (Asociacion de Damnificados de Viacha-ADV), in response to torrential rains and floods. The organization coordinates actions with local officials to channel resources and manage relief donations.   |
| Governments  | Departments or individual actors often serve as first responders to climate-related hazards and primary planners for hazard mitigation or disaster risk reduction.<br>Engage in planning of a wide range of vulnerable built and natural systems that affect the well-being of city residents.<br>Enforce stronger management policies to improve good governance.<br>Convene adaptation partnership among other cities; county, regional, state and federal entities; adjacent towns; special districts; and commissions (for example, for public schools, water, and energy). | Four cities in El Salvador and another from Honduras formed an inter-municipality association in response to Hurricane Mitch. The association serves as a platform for dialogue, as well as disaster response and relief coordination.<br>India's National Disaster Response Plan was formed by the High Powered Committee (HPC) on Disaster Management with the direct approval of the Prime Minister, led by a former Secretary to the Government of India. With a clear mandate from the Prime Minister, the planning process involved in-depth consultation of all affected ministries and departments, and initiated the formation of State and District plans "in order to bring about cohesiveness and uniformity."  |
| International Nongovernmental Organizations        | Support advocacy and dialogue about adaptation.<br>Offer strategic advice and technical assistance to cities on mitigation and adaptation.  | The Red Cross / Red Crescent Climate Centre "raises awareness; advocates for climate adaptation and disaster risk reduction; and integrates relevant information about climate change risks into Red Cross Red Crescent strategies, plans and activities." This includes educational programs to help national governments around the world alert communities to increasing risks from climate change.<br>Learning networks, such as Asian Cities Climate Change Resilience Network, funded by the Rockefeller Foundation and facilitated by the Institute for Social and Environmental Transition (ISET). More information is available online at: <a href="http://www.rockefellerfoundation.org/what-we-do/current-work/developing-climate-change-resilience/asian-cities-climate-change-resilience/">http://www.rockefellerfoundation.org/what-we-do/current-work/developing-climate-change-resilience/asian-cities-climate-change-resilience/</a> .<br>CARE offers an online information center on climate change, including publications and community stories about adaptation, as a supporting partner of the Adaptation Learning Mechanism. CARE also provides direct services and support to communities, ranging from water provision in Zambia and sanitation in Delhi informal settlements.<br>Mercy Corps is pursuing climate change adaptation through its 32 country offices, in recognition that climate change may exacerbate poverty and conflict in the countries and communities where the organization operates. One of the organization's primary efforts has been to develop partnerships with universities to develop effective ways of integrating climate change data in conflict analysis. |

*continued next page*

TABLE 3.2 COMMON ACTORS INVOLVED IN ADAPTATION (continued)

| Actor   | Roles  | Examples of Partnership in Cities  |
|---|--|--|
| United Nations and International Financial Institutions | <p>Provide financing for specific investments and projects, during and after emergencies and on an ongoing basis. (See Chapter 7 for more information on city-level adaptation financing opportunities.)</p> <p>Offer strategic advice and technical assistance to cities on mitigation and adaptation.</p>  | <p>The role of the World Bank Group in climate change adaptation is increasingly broad and deep. Adaptation is being mainstreamed into Bank operations, including financial decision making about grants and loans. It is also the subject of many Bank-produced events, trainings, and guidance materials.</p> <p>The Inter-American Development Bank (IDB) is helping mid-sized cities in Latin America and the Caribbean develop sustainability capacity and prepare for climate change through its Emerging Sustainable Cities Platform (see Chapter 4). More information is available at <a href="http://www.iadb.org/secci">www.iadb.org/secci</a>.</p> <p>The International Finance Corporation (IFC), a member of the World Bank Group, has developed a framework for assessing climate change risks to port operations as well as options for adapting to those risks (see Chapter 6 and Chapter 7).</p> <p>UN-HABITAT manages a Cities and Climate Change Initiative aimed specifically at building capacity among local partners to mitigate and adapt to climate change.</p>   |
| Large-scale Industry or Business                        | <p>Potentially interested in how to make their operations resilient to climate change impacts. Business vulnerability assessments and adaptation strategies may provide useful supplements to city-focused assessments described in Chapter 4.</p> <p>Key sources of employment, goods, and services for city population. By generating economic activity, they contribute to financial capacity for a city's government and population to adapt.</p> <p>Some businesses may be interested in adaptation investments as corporate philanthropy (also see Chapter 7).</p> | <p>In 2005, the Rabobank Foundation, a philanthropic arm of the Rabobank multinational corporation, launched a climate change risk reduction program in Jakarta focused on building the capacity of communities to cope with disaster risks and impacts. The Foundation partnered with the Indonesian Red Cross and counterparts from Germany and the Netherlands to design microcredit and microfinance products to help communities reduce their flooding risks, as well as deliver public education on risks and adaptation options. The program was designed to return 100 percent of Rabobank's funding through the microfinance program, and by 2009 had reached approximately 121,000 people.</p> <p>In conjunction with nongovernmental organizations, such as Red Cross, CARE, and WorldVision, Proctor and Gamble has distributed safe drinking water packets to communities in South and Southeast Asia in response to a range of disasters involving contaminated water. Proctor and Gamble has provided these packets at cost of production, without making a profit.</p> <p>See Box 7.6 on the partnership between Swiss Re and the World Bank on weather insurance in Malawi.</p> |

Sources: World Bank 2010c; Hardoy and Pandiella 2009; McGranahan and others 2007; CARE 2011; Red Cross / Red Crescent 2011; Rockefeller Foundation 2009; Mercy Corps 2007; IDB 2011; IFC 2011; UN-HABITAT 2011; Chandra 2008, Children's Safe Drinking Water 2008; WorldVision Singapore 2007; and USAID 2006, as cited in Sida 2009.

**BOX 3.5 COMMUNITY ENGAGEMENT IN ADAPTATION**

In 1986, the City of Rio de Janeiro's Municipal Secretariat of Social Development created the Community Reforestation Project. Also referred to as the Paid Self-Help Reforestation Project and the Mutirão Project, the initiative aims to control erosion and reduce associated landslide and flood risks through the reforestation of erosion-prone areas of the city, particularly where *favelas* (informal settlements) are located. Furthermore, the project aims to employ local residents and reintroduce native tree species, considered to be effective for erosion control, to the hillsides. The individual reforestation projects are carried out on relatively small areas of land, ranging from plots of one hectare to larger parcels of 18 to 30 hectares. In each area to be reforested, the project is implemented over a three- to four-year period.

Source: UNFCCC 2011.

**FURTHER RESOURCES**

*Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters* (World Bank 2009) is a guide for local governments in the East Asia Region to understand the concepts and consequences of climate change, how cities can be vulnerable to climate change, and early experiences and lessons of "early adapter" city governments in East Asia and around the world. It was published jointly by the World Bank, the Global Facility for Disaster Risk Reduction (GFDRR), and the United Nations International Strategy for Disaster Reduction (UNISDR) and is available online at: [http://siteresources.worldbank.org/INTEAPREGTOPURBDEV/Resources/Primer\\_e\\_book.pdf](http://siteresources.worldbank.org/INTEAPREGTOPURBDEV/Resources/Primer_e_book.pdf).

*Natural Hazards, Unnatural Disasters* (World Bank, 2010c) describes how deaths and damages from natural hazards are the unnatural disasters that often result from human acts of omission and commission. Although every disaster is unique, each one exposes actions that would have resulted in fewer deaths and less damage, had these actions been different. This report shows how prevention is possible and examines how decision makers can manage disaster risks cost-effectively. The document is available online at: <http://www.gfdrr.org/gfdrr/NHUD-home>.

a wider array of actors. This also has the positive cobenefit of strengthening communications and relationships among critical players, in turn building social resilience to cope with future risks.

**MANY DIFFERENT ACTORS HAVE IMPORTANT ROLES AS PARTNERS IN ADAPTATION**

A variety of actors have already begun to engage in adaptation efforts (see Table 3.2). These partners often add value to adaptation efforts in ways that cities alone cannot.

Academic organizations, as described in Table 3.2, offer important technical support to cities. Chapter 4 provides additional detail about engaging with

outside technical advisors. Cities can also influence the type of climate research that is conducted, so that research products can serve as relevant and useful decision support tools for cities.

Community-based organizations that work with the most vulnerable groups within the city (such as the elderly, children, low-income groups, and sick or disabled people) may be more trusted among close-knit social networks than some city governments. This means that community organizations may be good partners for raising awareness about climate change risks, developing potential adaptation actions, and influencing behavior in support of adaptation actions. They may also be able to increase the adaptive capacities of their target groups through the implementation of programs on health, hygiene, employment generation, and access to basic services. To varying extents, many communities self-organize and undertake informal adaptive actions, such as adding second floors to homes in areas regularly affected by flooding. Box 3.5 describes an example from Rio de Janeiro, where the city government has engaged with communities to increase resilience with multiple cobenefits.

International nongovernmental organizations (NGOs) that support advocacy and dialogue about climate change adaptation have important roles in bringing global attention to the climate-related crises faced

by underserved areas and may also offer strategic assistance to cities on both mitigation and adaptation.

Governments of neighboring jurisdictions over a wide metropolitan area can partner on shared adaptation strategies. City governments within a country can also band together to create political momentum for national action. Cities around the world can share lessons learned and knowledge on adaptation.

The private sector and development agencies often drive a large part of a city's economic and land use decisions, and can, thus, promote the city's resilience by making investment decisions that take climate impacts into consideration (for example, appropriate building designs in flood-prone zones, improved standards of waste and wastewater treatment, and promotion of green building designs that can cool occupants naturally).

### INTERNATIONAL NETWORKS FOR CLIMATE ACTION ARE GROWING RAPIDLY

Independently, as well as in concert, cities and local governments have proactively implemented climate actions over the past decade, showing their capacity to reduce GHG emissions while also preparing for climate impacts. In some instances, cities have gone above and beyond the commitments of

their own national governments in their pledges to reduce GHG emissions and direct implementation of climate plans (see Chapter 4). They have also banded together to show collective leadership. Some have taken an active international networking role in recent years, advocating for better recognition and empowerment of cities and local governments in the future (see Table 3.3).

#### MITIGATION AND ADAPTATION ARE COMPLEMENTARY AND ESSENTIAL

*Mitigation* and *adaptation* are complementary and essential aspects of climate protection. Addressing mitigation and adaptation jointly can maximize the benefits of actions taken and ensure that any action taken in pursuit of one goal does not undermine progress toward the other. On a global scale, successful early mitigation efforts may reduce future harms and related adaptation costs, but some climate change impacts are already unavoidable in some parts of the world and will require adaptation (ICLEI 2010).

TABLE 3.3 GLOBAL, NATIONAL, AND REGIONAL CITY NETWORKS FOR CLIMATE ACTION

| City Network/Partnership                                | Membership  |
|---|---|
| Global Networks   |   |
| C40 Cities Climate Leadership Group                     | 40 participating and 19 affiliate cities  |
| ICLEI-Local Governments for Sustainability              | > 1,200 cities, towns, counties   |
| United Cities Local Governments (UCLG/Metropolis)       | > 1,000 cities and 112 local governments  |
| World Mayors Council on Climate Change (WMCCC)          | > 50 members  |
| Cities Alliance   | 24 members—local authorities, governments, NGOs, and multilateral organizations |
| National and Regional Networks                          |   |
| Climate Alliance (Europe)                               | > 1,600 cities, municipalities and districts and > 50 associate members         |
| Covenant of Mayors (European Commission)                | > 2,700 Mayors  |
| U.S. Conference of Mayors (USCM)                        | 1,049 Mayors in 50 states have signed the USCM Climate Protection Agreement     |
| EUROCITIES  | Local governments of more than 140 large cities                                 |
| Asian Cities Climate Change Resilience Network (ACCCRN) | 11 cities in Asia   |
| CITYNET   | > 70 cities in Asia-Pacific region (full members)                               |

Sources: C40 Cities 2011; ICLEI 2011a; UCLG 2011; WMCCC 2011; Cities Alliance 2011; Climate Alliance 2011; Covenant of Mayors 2011; ICLEI 2011b; EuroCities 2011; Rockefeller Foundation 2011; CITYNET 2011.

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## 4. Developing a Roadmap for Adaptation



This chapter provides guidance on how a city can develop a specific roadmap for adaptation:

- Improving understanding of city-specific climate change impacts, with an introduction to different types of climate change assessments
- Developing city adaptation plans, policies, and actions
- Moving from planning to action by setting performance indicators and evaluating and prioritizing potential adaptation actions in cities

This chapter offers an overview of the types of resources that are available for these purposes. It does not provide the technical information that a city would need to complete these assessments or specify a particular planning approach that a city should take.

## Understanding Specific Climate Change Impacts in Cities

A first step in adapting to climate change is to understand how climate factors are likely to change in a specific geographic area, how people and city operations are likely to be affected by these changes, and how impacts may vary across sectors. Below are some basic risk management questions that a city official may use to frame this work (World Bank 2011, adapted from Kaplan; World Bank 2009):

- How likely is the occurrence of a hazard event or incremental change?
- Which people and what assets are at risk of harm, and in what ways?
- What is the range of possible economic losses resulting from climate change impacts?
- What background conditions or issues (including social, economic, and physical) minimize or exacerbate the impacts?

A city can answer these questions by conducting an **assessment of vulnerability, risk, and adaptive capacity** in city operations, specific sectors, and different communities and

demographic groups. In this context, an assessment is a process that brings the best-available science and other information to bear on decision making. (See Chapter 3 and the glossary for definitions of vulnerability, risk, and adaptive capacity.)

### SCOPING AN ASSESSMENT EXERCISE

Assessment tools that a city can use to develop an understanding of climate change impacts range on a spectrum from quick and informal to intensive and highly rigorous, with the associated costs and other resource requirements varying accordingly. Each city will need to determine the degree of detail or analytical precision desired to use the resulting information in planning, policy, or investment decisions.

A rough scoping of expected impacts and related risks can help city decision makers to decide on the extent and detail of further assessment efforts. Along these lines, the *Climate Resilient Cities Primer* provides a valuable initial assessment exercise for cities to understand their climate and disaster “hot spots”—at-risk areas that merit further attention and response (World Bank 2009). Characteristics of a hot spot include a combination of natural, physical, and institutional factors, as listed in the primer:

- Moderate to high level of one or more natural hazards
- Medium or high observed vulnerability in past disasters
- Moderate to high sectoral vulnerability to climate change
- Poor or nonexistent urban development plan or growth plan
- Poor compliance with urban development plan or growth plan
- Poor quality of building stock

### FURTHER RESOURCES

Participatory scenario development (PSD) is a process involving the participation of stakeholders to discuss and address future scenarios in a creative and actionable way. The World Bank and the International Institute for Sustainable Development (IISD) jointly published a capacity development manual in December 2010 for localities to conduct PSD approaches to climate change adaptation that involve and consider the poor. This emerging tool was also applied in the World Bank’s *Economics of Adaptation to Climate Change* analysis (World Bank 2010). The manual can be found online at: [http://climatechange.worldbank.org/sites/default/files/documents/ESSA-IISD\\_CapacityDevManual-EACC-Social.pdf](http://climatechange.worldbank.org/sites/default/files/documents/ESSA-IISD_CapacityDevManual-EACC-Social.pdf).

The UK Climate Impacts Programme (UKCIP) offers a range of tools and resources, including a database of case studies, on adaptation to climate change. In particular, LCLIP (Local Climate Impacts Profile) is a resource that local authorities can employ to understand their exposure to weather and climate in more detail. Another UKCIP tool is the Adaptation Wizard, which takes users (not specifically cities) through a process to determine vulnerability to climate change, identify key climate risks, and develop a climate change adaptation strategy. Further information is available at <http://www.ukcip.org.uk>.

- High population density
- Medium to large population or high decadal growth rate or high population density in case of low population
- Medium or high slum density or large proportion of informal population
- No comprehensive disaster response system
- Economic and/or political significance in regional or national context

To support a hot spot analysis, the primer provides worksheets that require a city to

gather information in the following categories, as follows:

- City description, including geographic location and demographic profile
- City governance, management structure, and financial resources
- Built environment (for example, existence of urban growth master plans, informal settlements, and historical buildings)
- Political and economic impacts (for example, whether the city is a center for political activity and economic value)

- Natural hazards (for example, exposure to nonclimate hazard events, such as earthquakes and tsunamis) and climate change impacts, if known, including those occurring outside of cities with effects on cities

Although this initial scoping exercise does not take the place of a full vulnerability or adaptive capacity assessment, it can help inform city decisions on how in-depth a subsequent analysis should be. Moreover, it can provide a cost-effective approach for those cities without funds to pursue the more in-depth analysis immediately. To achieve maximum benefit from a hot spot assessment, a

#### BOX 4.1 EXAMPLES OF WORLD BANK ANALYSIS ON CLIMATE CHANGE IMPACTS IN SPECIFIC CITIES

Culminating in a 2010 synthesis report, *Climate Risks and Adaptation in Asian Coastal Megacities*, the World Bank, the Asian Development Bank, and the Japan International Cooperation Agency jointly conducted in-depth analyses of climate change impacts in Ho Chi Minh City, Bangkok, and Metro Manila. The analyses in these cities involved (i) estimation of climate related risks through downscaling techniques, (ii) hydrological modeling to estimate city level impacts and representation through GIS maps, (iii) damage cost assessment, and (iv) prioritization of adaptation options through cost-benefit analysis. One of the city studies also included a fifth step of institutional analysis. Notably, this work considered indirect impacts, including the following: estimated costs associated with building damage; business, industrial, and daily wage income loss; and hospitalization because of disease outbreaks (World Bank 2010a). The report is available online at [http://siteresources.worldbank.org/EASTASIAPACIFICEXT/Resources/226300-1287600424406/coastal\\_megacities\\_full-report.pdf](http://siteresources.worldbank.org/EASTASIAPACIFICEXT/Resources/226300-1287600424406/coastal_megacities_full-report.pdf).

In June 2011, the World Bank released a summary of findings from a regional study on climate change adaptation and natural disaster preparedness in the North African coastal cities of Alexandria, Casablanca and Tunis, and Bouregreg Valley. The analysis was carried out in conjunction with a consortium of French consulting firms, national meteorological agencies, and local university partners (see Box 3.2). The approach consisted of (i) examination of existing patterns of urban growth, (ii) evaluation of urban exposure to risks through downscaled satellite imagery and meteorological data, (iii) an integrated urban risk assessment of climate and nonclimate related hazards (for example, flooding, earthquake, tsunami and marine submersions, coastal erosion, and water resources scarcity), and (iv) suggestions for adaptation responses in the areas of urban planning, institutional preparedness and infrastructure investments. The study is notable for its integrated view of disaster risk reduction and climate change adaptation (World Bank, 2010b). The report is available online at <http://arabworld.worldbank.org> and [www.cmimarseille.org](http://www.cmimarseille.org).

city official can also convene a range of internal and external stakeholders to pursue this exercise jointly (see also Chapter 3).

## OPTIONS FOR UNDERTAKING ASSESSMENTS

Multiple institutions work with cities to assess climate change impacts, employing a range of approaches. Although past vulnerability assessments have tended to focus on the physical dimensions of vulnerability to risks and climate hazards, more recent assessments have incorporated the social and economic dimensions related to the sensitivity and adaptive capacity of the potentially affected regions and their populations (ICLEI 2011a). Box 4.1 describes examples of recent analytical work that the World Bank has conducted with local partners on climate change impacts in specific cities.

A city that is ready to undertake a more detailed evaluation of climate change impacts has a number of options. Table 4.1 profiles the key features and examples of a variety of tools and approaches that cities can use in assessing climate change vulnerability, risk, and adaptive capacity. Many of these tools can be tailored to local circumstances:

- Focusing on government operations, a geographic area, specific sectors, or different

time scales (for example, looking forward to the year 2030 or 2050)

- Using more than one tool at the same time, depending on available resources and the amount of information desired
- Working with local partners to develop customized versions of specific tools, incorporating features of some of the tools described here

Although the table is not an exhaustive listing, it does illustrate the range of options that are available to a city. Moreover, these tools are not mutually exclusive; a city and its partners can decide to use different elements of these tools in a combined approach that suits local circumstances.

For any given source of information, due regard should be given to the credibility of the source in question. When evaluating sources of technical information about climate change impacts, city decision makers can find it beneficial to consider the following (list adapted from Snover and others 2007):

- Are the authors widely considered to be experts? In what discipline?
- Are the authors' conclusions based on reasonable assumptions?
- Do the authors have any potential political or financial biases?

- Has the research undergone peer review? Have other peer-reviewed studies reached similar conclusions? (Not all scientists may agree on research findings, but successful peer review of a study indicates that other experts in the field find the work to be credible.)
- Does the study reflect an assessment of uncertainty? (Even the most elaborate analysis is likely to contain uncertainties, which should be acknowledged and reflected in a transparent manner. Scientific reports should include a description of uncertainty, confidence levels, and/or probability of particular conditions occurring in the future.)
- How long ago was the study conducted? Do the conclusions still hold true?

Whatever tool is used, a city should emerge from the assessment process with a clearer picture of anticipated climate change impacts. However, in many cases an assessment exercise will generate a list of issues that is longer than is feasible for a city to tackle at once. In order to prioritize attention on specific vulnerabilities, a city may want to consider the decision criteria recommended by the IPCC to identify key vulnerabilities (see Box 4.2). Further insights on how to generate and prioritize adaptation responses are provided later in this chapter.

TABLE 4.1 ASSESSMENT TOOLS AVAILABLE TO CITIES

| Name of Tool (Primary Source/Creator)  | Description  | Benefits of Using the Tool   | Constraints to Using the Tool   | Examples   |
|--|--|--|---|--|
| ADAPT (ICLEI)<br><a href="http://www.icleiusa.org/programs/climate/Climate_Adaptation/adaptation-database-and-planning-tool-adapt">http://www.icleiusa.org/programs/climate/Climate_Adaptation/adaptation-database-and-planning-tool-adapt</a>   | Five-step climate change adaptation planning process and guide.<br><br>Used to conduct participatory vulnerability assessment.<br><br>Includes exposure, sensitivity, and adaptive capacity.   | Useful across many sectors.<br><br>Intended to generate analysis that will guide future action.  | Not available to all cities—only to ICLEI members.  | Cambridge, Massachusetts, USA.<br><br>Flagstaff, Arizona, USA  |
| Participatory Climate Change Adaptation Appraisal (PCCAA) / Rapid Risk and Institutional Appraisal (RRIA) (University of Manchester in collaboration with World Bank)<br><a href="http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/ESW_propoorurbanadaptationReport4947_GLBweb2.pdf">http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/ESW_propoorurbanadaptationReport4947_GLBweb2.pdf</a><br><br>Participatory scenario development, as applied in the Economics of Adaptation to Climate Change study (World Bank and International Institute for Sustainable Development) (see Further Resources below)<br><br>Examples of similar approaches include:<br><ul style="list-style-type: none"> <li>▪ Vulnerability and Capacity Assessment (International Federation of Red Cross and Red Crescent Societies)<br/><a href="http://www.ifrc.org/en/what-we-do/disaster-management/preparing-for-disaster/disaster-preparedness-tools/disaster-preparedness-tools/">http://www.ifrc.org/en/what-we-do/disaster-management/preparing-for-disaster/disaster-preparedness-tools/disaster-preparedness-tools/</a></li> <li>▪ Participatory Vulnerability Analysis (Action Aid)</li> <li>▪ Participatory Capacities and Vulnerabilities Assessment (Oxfam)</li> <li>▪ Climate Vulnerability and Capacity Analysis (CARE)</li> <li>▪ Shared learning dialogues (Asian Cities Climate Change Resilience Network, supported by Rockefeller Foundation in conjunction with the Institute for Social and Environmental Transition and Arup)<br/><a href="http://www.rockefellerfoundation.org/what-we-do/current-work/developing-climate-change-resilience/asian-cities-climate-change-resilience/">http://www.rockefellerfoundation.org/what-we-do/current-work/developing-climate-change-resilience/asian-cities-climate-change-resilience/</a></li> <li>▪ ProVention Consortium website profiles a number of participatory assessment methodologies<br/><a href="http://www.proventionconsortium.org/?pageid=43">http://www.proventionconsortium.org/?pageid=43</a></li> </ul> | <p>These tools:</p> <ul style="list-style-type: none"> <li>▪ Use interviews and other participatory tools to collect knowledge about: <ul style="list-style-type: none"> <li>▪ The experiences that poor households, small businesses, and local practitioners (for example, doctors or farmers) have had with climate change;</li> <li>▪ Possible future vulnerability to and risk of climate change impacts; and</li> <li>▪ Community and local institutional capacity to adapt to natural hazards.</li> </ul> </li> <li>▪ Identify activities to prevent or lessen the effects of expected vulnerabilities and risks.</li> <li>▪ Identify new ways to build adaptive capacity.</li> </ul> | <p>Involves communities, local authorities and humanitarian, and development organizations in the assessment from the outset.</p> <p>Complements national and sub-national risk, hazard, vulnerability, and capacity mapping exercises.</p> <p>“Quickly and cost-effectively introduc[es] into adaptation planning processes an appreciation of the significance of climate change impacts for poor people in informal urban settlements... and [identifies] how policy and institutional systems can best build on local realities to develop pro-poor urban climate change adaptation actions, particularly relating to resilience.” (Moser and others 2010)</p> | <p>Requires high level of collaboration.</p> <p>Can be time-consuming and staff-intensive.</p> <p>For IFRC tool, country must be an IFRC National Society member.</p> | <p>PCCAA/RRIA examples include Esteli, Nicaragua and Mombasa, Kenya</p> <p>IFRC assessment examples include communities in Nepal, the Solomon Islands, the Cayman Islands, Rwanda, and Yemen</p> |

*continued on next page*

| TABLE 4.1 ASSESSMENT TOOLS AVAILABLE TO CITIES (continued)  |   |  |  |  |
|---|---|--|--|--|
| Name of Tool (Primary Source/Creator)   | Description   | Benefits of Using the Tool   | Constraints to Using the Tool  | Examples   |
| Roadmap for Adapting to Coastal Risk (NOAA)*<br><a href="http://www.csc.noaa.gov/digitalcoast/training/roadmap/index.html">http://www.csc.noaa.gov/digitalcoast/training/roadmap/index.html</a> | "Participatory process for assessing a community's vulnerability to hazards and for incorporating relevant data and information about hazards and climate into ongoing local planning and decision-making." (NOAA 2011) | Provides useful information for many cities: workshop agendas, data sources and checklists.<br><br>Offers some information specific to coastal cities.   | Does not include adaptive capacity in assessing vulnerability.<br><br>Examples exclusively from USA. | Miami Dade County, Florida, USA  |
| Urban Risk Assessment (World Bank)  | Three principal pillars: institutional assessment, hazards assessment, and socioeconomic assessment.<br><br>A flexible framework with three levels of complexity, depending on needs of city.                           | Aims to strengthen coherence and consensus, minimize duplicative efforts, and bring convergence to related work undertaken across relevant organizations.  | Requires high level of collaboration.<br><br>Not a detailed toolkit or manual.                       | Forthcoming  |
| Spatial assessment and geographic information systems (GIS)-based analysis of numerous sources of data (LIDAR, satellite)   | Cities, local governments, and universities can employ GIS technology to develop a visual image (often a map) of vulnerabilities and risks.   | Projections can be tailored to specific geographical areas.<br><br>Produces data as well as high quality visuals.<br><br>Can leverage free / publicly available databases.<br><br>Can be combined with other geospatial data (for example: historical climate variability and future climate projections; insurance claim information to estimate potential costs relating to projected building damages; demographic data to reflect social vulnerability to heat waves). | Requires training, which can be expensive.<br><br>May require support from a local university.       | King County "Vulnerability of Major Wastewater Facilities to Flooding from Sea Level Rise" 2008 memorandum<br><a href="http://your.kingcounty.gov/dnrp/library/archive-documents/wtd/csi/csi-docs/0807_SLR_VF_TM.pdf">http://your.kingcounty.gov/dnrp/library/archive-documents/wtd/csi/csi-docs/0807_SLR_VF_TM.pdf</a><br><br>Spatial Planning and Climate Change Adaptation in Coastal Regions: The Case of Vietnam<br><a href="http://www.fig.net/pub/vietnam/papers/ts04d/ts04d_boateng_3574.pdf">http://www.fig.net/pub/vietnam/papers/ts04d/ts04d_boateng_3574.pdf</a> |

\* "Roadmap for Adapting to Coastal Risk" is a combination of NOAA tools formerly called community vulnerability assessment tool (CVAT) and risk and vulnerability assessment tool (RVAT). Sources: ICLEI 2011; Red Cross/Red Crescent Climate Centre 2011; Moser 2010; NOAA 2011; WRI 2011; King County 2008; Boateng 2009; ICLEI 2011.

#### BOX 4.2 DECISION CRITERIA FOR IDENTIFYING KEY VULNERABILITIES

A series of decision criteria have been identified by the IPCC to identify “key” vulnerabilities:

- **Magnitude**, the scale (for example, the geographic area or number of people affected) and intensity (for example, the degree of damage caused) of an impact
- **Timing**, the expected date range (for example, decade, year, or season) and rate at which the impact is likely to take place
- **Persistence and Reversibility of Impact**, whether the impact is expected to continue over a long period of time, and whether it can be reversed
- **Likelihood of Impact Occurring**, the probability of an outcome having occurred or occurring in the future, and Confidence of Impact Occurring, or the assessment that any statement about an outcome will prove correct
- **Potential for Adaptation**, the assessment that activities can be undertaken to lessen the projected harm
- **Distribution**, the spread of climate change impacts across regions, demographic categories (for example, income, gender, or age) and sectors
- **Importance of the Vulnerable System**, the priority that a community places on an asset or system

Adapted from IPCC 2007.

TABLE 4.2 TYPES AND EXAMPLES OF CITY CLIMATE PLANS

| Type of Plan   | Example  |
|--|--|
| Climate change mitigation plan   | Bangkok Action Plan on Global Warming Mitigation 2007-2012<br><a href="http://www.baq2008.org/climate-change">http://www.baq2008.org/climate-change</a><br><br>Mexico City target reduction of greenhouse gas emissions 12% by 2012<br><a href="http://www.sma.df.gob.mx/sma/index.php?opcion=26&amp;id=531">http://www.sma.df.gob.mx/sma/index.php?opcion=26&amp;id=531</a>   |
| Climate action plan—focused on both mitigation and adaptation                                | Quito Climate Change Strategy<br><a href="http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/docs/G2-Bonn2010-Zambrano-Barragan.pdf">http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/docs/G2-Bonn2010-Zambrano-Barragan.pdf</a><br><br>Cape Town Energy and Climate Change Strategy and Cape Town Framework for Adaptation to Climate Change<br><a href="http://www.capetown.gov.za/en/EnvironmentalResourceManagement/projects/climatechange/Pages/default.aspx">http://www.capetown.gov.za/en/EnvironmentalResourceManagement/projects/climatechange/Pages/default.aspx</a><br><br>Sao Paulo Municipal Act on Climate Change<br><a href="http://www.c40cities.org/docs/ccap-sao-paulo.pdf">http://www.c40cities.org/docs/ccap-sao-paulo.pdf</a><br><br>Chicago Climate Action Plan<br><a href="http://www.chicagoclimateaction.org/">http://www.chicagoclimateaction.org/</a> |
| Resilience or risk management plan   | Surat, India (also see Gorakhpur and Indore resilience strategies, supported by ACCCRN)<br><a href="http://www.suratclimatechange.org/page/19/surat-city-resilience-strategy-%E2%80%93-draft-document.html">http://www.suratclimatechange.org/page/19/surat-city-resilience-strategy-%E2%80%93-draft-document.html</a><br><br>Semarang, Indonesia, including land use planning, microfinance, coastal erosion, and disaster early warning systems, as profiled in UN-HABITAT’s <i>Planning for Climate Change</i> guide (UN-HABITAT, forthcoming).<br><br>Esmeraldas, Ecuador<br><a href="http://www.unhabitat.org/downloads/docs/6007_9628_Esmeraldas%20flyer%20oct09.pdf">http://www.unhabitat.org/downloads/docs/6007_9628_Esmeraldas%20flyer%20oct09.pdf</a>   |
| Climate change mainstreamed into long-term master plan                                       | The London Plan<br><a href="http://www.london.gov.uk/thelondonplan/climate/">http://www.london.gov.uk/thelondonplan/climate/</a><br><br>PlaNYC<br><a href="http://www.nyc.gov/html/planyc2030/html/home/home.shtml">http://www.nyc.gov/html/planyc2030/html/home/home.shtml</a>  |
| Sectoral plans (for example, transportation or water) that reflect climate change adaptation | Climate Change Adaptation Strategy and Framework (Highways Agency-UK Department for Transport)<br><a href="http://www.highways.gov.uk/aboutus/documents/CCAF-Strategy_and_Vol_1-Rev_B_Nov.pdf">http://www.highways.gov.uk/aboutus/documents/CCAF-Strategy_and_Vol_1-Rev_B_Nov.pdf</a>  |

Sources: Bangkok Metropolitan Administration 2007; C40 Cities 2011a; Zambrano-Barragán 2010; City of Cape Town 2011; C40 Cities 2011b; City of Chicago 2011; City of Surat 2011; UN-HABITAT forthcoming; UN-HABITAT, 2011; City of London, 2011a; City of New York 2011; UK Department for Transport 2009.



## Developing Adaptation Plans, Policies, and Actions

Cities can apply the knowledge gained from assessments described in the prior section at multiple levels.

- At the strategy and planning level, activities can include revising master plans (for example,

for land use, transportation, and other sectors) to reflect any significant changes in landscape (for example, sea level, coastal zones, or floodplains) and natural resources (for example, water supply), as well as related climate risks. Other related actions might include development of new strategies, high-level political initiatives, policy formulation, and new institutional structures.

- In terms of long-term investments, cities can decide to invest in infrastructure to build resilience to climate change, such as a levee, sea wall, or improved road network in a highly populated floodplain. These actions are sometimes more challenging to implement than planning efforts, because they often require substantial financial resources. In many instances, climate change adaptation alone will not be a sufficient rationale to justify an investment in a given location. However, when coupled with cobenefits and other considerations—such as sustainable transportation, livelihood enhancement, or even tourism promotion—these investments in resilience can be made more financially and politically feasible.
- At the operational level, climate change considerations can be integrated into day-to-day municipal operations and service delivery. These actions can include responses to extreme weather events, such as closing certain roads and rerouting traffic, or adaptations to incremental change, such as painting bus roofs white to reflect heat during periods of more extreme summer temperatures (Horton 2009).

**TABLE 4.3 TYPES AND EXAMPLES OF CLIMATE-SMART POLICIES**

| Type of Policy   | Example  |
|--|--|
| Legislative requirements that every policy or investment must have a climate lens                        | <p>Basque Country requirement that public managers incorporate environmental and climate considerations into their planning across all sectors. <a href="http://www.theclimategroup.org/our-news/news/2011/5/30/Basque-Country-approves-pioneering-climate-change-bill/">http://www.theclimategroup.org/our-news/news/2011/5/30/Basque-Country-approves-pioneering-climate-change-bill/</a></p> <p>King County, Washington (state, USA) Executive Orders and a King County Council Motion requiring agency officials to reduce greenhouse gas emissions and prepare for climate change across sectors of land use, transportation, environmental management, and energy. King County leadership encouraged officials to apply a climate change lens to government operations and policies, by “asking the climate question” of how climate change would affect their activities. <a href="http://your.kingcounty.gov/exec/news/2007/pdf/ClimatePlan.pdf">http://your.kingcounty.gov/exec/news/2007/pdf/ClimatePlan.pdf</a></p> |
| Amendments to sectoral policies and regulations, such as building codes, to reflect climate change risks | <p>In Fiji, to prevent damage from storm surges and sea level rise:</p> <ul style="list-style-type: none"> <li>■ Resorts are now built at least 2.6 m above mean sea level and 30 m off the high tide mark</li> <li>■ The building code prescribes that structures need to withstand wind speeds of 60 km per hour</li> </ul>  |
| Zoning and development changes to reflect increased vulnerability of specific locations and/or resources | <p>Climate change assessment in Durban, South Africa, is reflected in the city’s five-year Integrated Development Plan, and is also leading to a remapping of the city’s Open Space System Plan in order to protect the area’s biodiversity resources from the impacts of climate change, with implications for conservation areas and improved management of urban areas. <a href="http://eau.sagepub.com/content/20/2/521.full.pdf+html">http://eau.sagepub.com/content/20/2/521.full.pdf+html</a></p>   |

Sources: *The Climate Group 2011; King County 2007; UNWTO and UNEP 2008; Roberts 2008.*

**BOX 4.3 ENGAGING RESIDENTS AND COMMUNITY GROUPS IN ADAPTATION**

A number of communication products and platforms can be used to engage residents and community groups in the development of adaptation strategies, if they have not already been engaged in the assessment process. Objectives can include: (i) building awareness among residents regarding climate impacts that their city faces; (ii) informing residents about adaptation plans, policies, and actions that the city proposes to undertake in order to meet these threats and ensure their well-being; (iii) inviting the involvement of citizens in the decision-making process by soliciting their ideas and inputs; and (iv) suggesting how actions taken by individuals and groups can contribute toward the city's resilience.

In addition to the participatory assessments described in Chapter 4, some of the approaches that can be used to engage residents in adaptation include the following:

- Communication products, such as pamphlets, that identify the climate vulnerabilities of the city and proposed adaptation activities and actions, as well as indicate where citizens can find more information and how they can get involved. Maps of vulnerability can be visually effective in communicating the local areas most likely to be affected by climate change.
- Public consultations in which adaptation plans are discussed, with reference to corresponding climate change impacts.
- Community meetings, potentially facilitated by NGOs, in different and diverse parts of a city.
- Using local media, social networks, and popular gathering places to spread climate change awareness and reach large audiences.

*Source: Based on direct experience of ICLEI – Local Governments for Sustainability.*

**BOX 4.4 NATIONAL GOVERNMENTS RECOGNIZING THE ROLE OF CITIES IN ADAPTATION**

A small, but growing, number of national governments around the world have adopted or considered adopting legislation that specifically addresses the role of cities in climate change adaptation (ICLEI 2011b). These efforts include the following:

- The Philippines' Climate Change Act (2009) and Disaster Risk Management Act (2008)
- The State of Chiapas, Mexico's Law on Adapting to and Mitigating Climate Change (2010)
- South Africa's Green Paper on National Climate Change Response (2011), which has involved the South African Local Government Association (SALGA)
- The Republic of Korea's National Climate Change Adaptation Master Plan through the Framework Act on Low Carbon, Green Growth (LCGG) (August 2010), through which local governments are developing their own five-year adaptation plans based on the national plan (<http://kacc.kei.re.kr/eng>)
- The Norwegian Climate Adaptation Programme "Cities of the Future" project collaboration (May 2007) between the national government and the country's 13 largest cities and how they can get involved. Maps of vulnerability can be visually effective in communicating the local areas most likely to be affected by climate change.

*Source: Based on direct experience of ICLEI – Local Governments for Sustainability.*

Incorporating or “mainstreaming” climate change information and adaptation goals into existing plans and activities can be a low-cost, or even no-cost, step for cities to take, allowing cities to address climate impacts systematically without losing sight of existing city issues or placing additional pressures on scarce resources.

### SMART CLIMATE PLANNING AND POLICIES

Different types of plans and policies will suit different cities, depending on expected local climate risks and unique political, resource, and capacity constraints. Some cities may start by developing a stand-alone climate action plan, while others may choose to mainstream climate change information into existing plans and policies. Tables 4.2 and 4.3 illustrate several types of planning and policy approaches that a city may choose to pursue. The C40 cities provide many examples of large city plans, available online at: <http://www.c40cities.org/ccap/>. Box 4.3 outlines ways that a city can engage the public and community groups during the planning stage of adaptation. Box 4.4 describes the handful of national governments that are explicitly recognizing the role of cities in national adaptation legislation.

## Moving from Planning to Action

Sound implementation of climate change adaptation plans also involves setting performance indicators and evaluating and prioritizing proposed actions.

### DEVELOPING PERFORMANCE INDICATORS FOR CLIMATE CHANGE ADAPTATION

Measurement, reporting, and verification are important steps in evaluating the efficiency and effectiveness of a climate change adaptation effort. Demonstrating that an adaptation action or suite of actions has minimized vulnerability, reduced risk, and increased adaptive capacity helps to inform future decisions and satisfy taxpayers and external funders. Yet, a fundamental challenge that some cities face is an information deficit: a lack of data for establishing baselines and for monitoring programmatic investments, activities, and outcomes. Cities may also lack access to external sources of data on population growth, energy consumption, water supply, and other important issues.

#### FURTHER RESOURCE

*Planning for Climate Change: A Strategic, Values-based Approach for Urban Planners* (UN-HABITAT forthcoming) provides planners with practical tools for addressing climate change in different urban planning processes, with the flexibility to be used as both a general resource and a step-by-step guide. These steps include preparing a monitoring and evaluation framework, determining monitoring and evaluation partners and responsibilities, establishing a documentation and reporting protocol, and evaluating results from a monitoring program.

In 2007, the Clean Air Partnership of Toronto released a summary of lessons learned from adaptation planning in six “early adapter” urban regions: London, New York, Boston, Halifax, Vancouver, and King County. The report is available online at: [http://adaptation.nrcan.gc.ca/projdb/pdf/171e\\_e.pdf](http://adaptation.nrcan.gc.ca/projdb/pdf/171e_e.pdf) (City of Toronto 2007).

PAKLIM, an Indonesian-German program, is offering an integrated climate action planning framework for Indonesian cities, intended to build the internal capacity of city officials to incorporate climate change into the design and implementation of their day-to-day business (ICLEI 2011c).

The Inter-American Development Bank (IDB) helps Latin American and Caribbean governments prepare for climate change impacts through its Emerging Sustainable Cities Platform, which supports mid-sized cities in the region to develop sustainability action plans with a focus on environmental and fiscal sustainability, climate change, and urban development (ICLEI 2011d). More information is available online at: [www.iadb.org/en/topics/cities/emerging-sustainable-cities-platform.2862.html](http://www.iadb.org/en/topics/cities/emerging-sustainable-cities-platform.2862.html).

In mid-2010, the Basque Government, the city council of Vitoria-Gasteiz, and the Unit of Environment of TECNALIA Research and Innovation launched a collaboration to support climate change adaptation planning efforts in the city. One of the project’s primary objectives is to raise awareness among Basque municipalities about the importance of incorporating adaptation into their sustainable development and climate change policies, with the city serving as a role model (ICLEI 2011e).

The Asian Cities Adapt partnership is working with eight cities in the Philippines and India to conduct local vulnerability assessments and subsequently develop concrete adaptation strategies. ICLEI – Local Governments for Sustainability will coordinate the project, in conjunction with the Potsdam Institute for Climate Impact Research, the Indian Institute of Technology – Delhi, and the University of the Philippines. More information is available online at <http://asian-cities-adapt.iclei-europe.org/>.

## FURTHER RESOURCES

ICLEI-Canada's *Changing Climate, Changing Communities—Municipal Climate Adaptation Guide and Workbook* provides guidance on how to establish indicators and baseline data for an assessment of city-level adaptive capacity (ICLEI 2011f). The guide and workbook are available online at <http://www.iclei.org>.

**TABLE 4.4 SUGGESTED RESOURCES FOR CLIMATE CHANGE ADAPTATION PERFORMANCE MEASURES AT THE CITY LEVEL**

| Resource   | Description  |
|--|--|
| Global City Indicators Facility  | Economic prosperity and innovation. <a href="http://www.cityindicators.org/">http://www.cityindicators.org/</a>  |
| Asian Green City Index   | Environmental performance of 22 major cities in Asia. <a href="http://www.siemens.com/press/pool/de/events/2011/corporate/2011-02-asia/asian-gci-report-e.pdf">http://www.siemens.com/press/pool/de/events/2011/corporate/2011-02-asia/asian-gci-report-e.pdf</a>  |
| Multi-Hazard City Risk Index   | Urban risk   |
| Local indicators of progress on implementation of the Hyogo Framework for Action | Based on 43 local context-specific indicators, supported by online monitoring tools.   |
| Climate Disaster Resilience Index (CDRI)   | In 2009, the Climate Disaster Resilience Initiative used the CDRI to measure the resilience of 15 cities across Asia to climate change and disaster risks. <a href="http://www.preventionweb.net/files/16576_16576metromanilacityprofile1.pdf">http://www.preventionweb.net/files/16576_16576metromanilacityprofile1.pdf</a> |

Sources: GCIF 2011; Siemens 2011; World Bank forthcoming; UNISDR 2008; ICLEI 2011.

The good news is that cities do not need to create entirely new performance indicators for climate change adaptation. Most city officials have at least a rough sense of the extent of existing problems in their jurisdictions, whether from data

that they already collect or informal knowledge from government program managers and community stakeholders. The most practical measures are likely to be reflective of existing community priorities, for which a city may already have data or to which political attention is already paid. Cities can also think creatively about how existing data resources, however limited, can be used to measure progress on adaptation.

### BOX 4.5 LONDON'S GREEN INFRASTRUCTURE AS A NO-REGRETS ADAPTATION STRATEGY

In London, the "Green Grid" initiative aims to reduce the risk and sensitivity of people, property, and nature to the urban heat island effect and surface water flooding, through a robust green infrastructure network (see glossary for definition of green infrastructure). Part of the program will be delivered through grant funding or sponsorship to catalyze business and public engagement; much will involve the individual London Boroughs as the primary delivery agents. Over the longer term, the program seeks to demonstrate that an urban greening program should be integral to urban regeneration because of the economic benefits of green infrastructure, measured by increased productivity and sustained private sector investment. The program has numerous ancillary benefits ("win-win opportunities") including carbon sequestration, biodiversity conservation, air quality improvement, and increase in the desirability of communities. For more information about green infrastructure, see Land Use section of Chapter 6.

Source: Benzie and others 2010; City of London 2011b.

All of this information can be used to support the development of proxy indicators of climate change adaptation as well as estimates of vulnerability, risk, and adaptive capacity. Often, these indicators are already considered as part of a vulnerability assessment. Examples of proxy indicators include the following:

- Percent of land area, or rough amount of land area, known to have informal settlements with inferior infrastructure
- Number of residents living in a floodplain or in a low-elevation coastal zone
- Number of homes without air conditioning or natural cooling in a city expected to experience more days of extreme high temperatures
- Presence of a cohesive social network in an informal settlement, including strong communications channels in times of crisis

Table 4.4 contains a sample of additional resources for city performance indicators.

## EVALUATING PROPOSED ADAPTATIONS

A city can compare proposed actions based on projected costs and benefits, and evaluate how well every action builds long-term resilience as measured by specified performance indicators. Several important dimensions of this evaluation process are outlined here.

City officials are frequently required to evaluate potential courses of action based on incomplete information about the range of future costs and benefits. Uncertainty about the scope and specifics of climate change impacts simply adds another layer of complexity to that decision-making process. However, experience from early adapters has yielded several insights in this area.

- Cities can seek to maximize benefits in areas beyond climate change adaptation, such as greenhouse gas emissions reductions, public health, and economic development. Actions that generate net social and/or economic benefits independent of climate change adaptation may be considered **no-regrets actions**, yielding greater political and financial support. For example, recent analysis has demonstrated the multiple

benefits of green infrastructure (Center for Clean Air Policy 2011), an example of which is described in Box 4.5.

- The incremental cost of adaptation can be considered in the context of—or in addition to—already planned development costs. For example, if a city is already exploring whether to invest in infrastructure or service to an informal settlement, the cost of adaptation

may be absorbed in development plans. On the other hand, if a city is considering buyout of residential properties explicitly because of a projected increase in frequency and severity of coastal flooding, the additional cost may be considered independently.

- Cities must also take caution to avoid **maladaptation**—“any changes in natural or human systems that inadvertently increase

### BOX 4.6 ROBUST DECISION MAKING

The Robust Decision Making (RDM) framework developed by the RAND Corporation is unique in three respects.

First, uncertainty is tackled through multiple views of the future. Although RDM does not rule out the use of some probabilistic information, it does not accept the representation of a deeply uncertain future through the use of a single joint probability distribution. Furthermore, a cobenefit of considering multiple views of the future is that it helps to build consensus and to avoid underestimating uncertainty.

Second, alternative policies are ranked according to a robustness (rather than an optimality) criterion. Optimal solutions are optimal with respect to the predicted future, and might behave poorly otherwise. The robustness criterion aims to select solutions that are good (but not necessarily optimal) whatever the future. Furthermore, a robust strategy explicitly incorporates a time dimension; in other words, it is designed to evolve over time in response to the availability of new information.

Third, RDM uses a vulnerability-and-response-option analysis framework to characterize uncertainty and to help identify and evaluate robust strategies. This is in sharp contrast with the traditional predict-then-act analysis. Hence, RDM starts with a candidate decision and then identifies the future conditions under which that decision is vulnerable. Then, RDM identifies a process to reduce those vulnerabilities, thus highlighting the trade-offs involved. With this latter information, decision makers are in a better position to choose their preferred strategy.

*Source: Lempert 2011.*

vulnerability to climatic stimuli, or an adaptation that does not succeed in reducing vulnerability but increases it instead” (IPCC 2001). This might include an adaptation action that is reactive to past disasters, but not proactive to include all possible outcomes of projected changes.

Evaluating the robustness of a proposed adaptation would include exploring the full range of possible impacts, and the costs and benefits in different scenarios. Box 4.6 describes the example of an approach being pioneered by the RAND Corporation to help decision makers identify the most effective courses of action under varying conditions.

### PRIORITIZING PROPOSED ADAPTATIONS

In light of scarce financial resources, cities need to prioritize adaptation actions in the context of other pressing concerns. Cities can take the familiar approach of cost-benefit or cost-effectiveness analysis, which can be used in conjunction with

the assessments described previously in this chapter. Cities can also begin to consider how adaptation investments can improve their economic performance and attractiveness to outside investors, by increasing the reliability of their infrastructure (ICLEI 2011g).

Additional factors to consider when prioritizing adaptation investments include the following:

- **Community priorities.** The factors guiding prioritization are highly specific to a given city—whether financial, technical (for example, magnitude or probability of impact occurring) or driven by political will and popular sentiment (for example, importance of the vulnerable system or risk tolerance). Political leaders and constituents may have different views on what constitutes the most urgent actions to take. For this reason—in conjunction with the assessment approaches outlined previously—cities may find it all the more beneficial to pursue a participatory process of prioritization that integrates both top-down and bottom-up, community-based perspectives.
- **Windows of opportunity for action.** Cities can link proposed adaptation actions to the local planning cycle, by aligning adaptation

actions with near-term priorities. Adaptation may be easier to address in this way, rather than in relation to less certain and longer time-scale projections. However, it remains important to maintain a forward-looking orientation, whenever possible.

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### FURTHER RESOURCES

*Preparing for Climate Change: A Guidebook for Local, Regional and State Governments* includes a chapter on setting priority planning areas. The guidebook can be downloaded online at: <http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf>

Source: Snover and others 2007.

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## 5. Informal Settlements, the Urban Poor, and Other Vulnerable Groups



photo: World Bank Photo Collection

This chapter provides guidance and resources on climate change adaptation in relation to the most vulnerable people in cities—residents of informal settlements, the urban poor, and other disadvantaged groups (for example, women, children, elderly, disabled and chronically ill, and minority communities). Many issues related to informal settlements and urban poverty are highly complex, with a large body of accompanying literature and experience—this chapter does not attempt to provide a comprehensive treatment of these topics.

### Understanding the Impacts of Climate Change on the Most Vulnerable

Several features of urban informal settlements make them particularly susceptible to risks from climate change impacts: lack of secure land tenure, lack of access to basic infrastructure and services, and overcrowding. These factors are not necessarily distinct from one another; for example, lack of access to basic services is often a consequence of insecurity of land tenure. Figure 5.1 describes

these aspects of informal settlements in context of larger trends driving vulnerability and limiting adaptive capacity of informal settlements. It also outlines the potential consequences of climate change associated with these vulnerabilities.

Table 5.1 provides a similar overview of trends driving climate change vulnerability of other disadvantaged groups, including women, children, the elderly, disabled, and chronically ill, and minorities and indigenous groups. These trends can leave these groups vulnerable to the following climate change impacts: illness or mortality during a crisis; separation from family (elderly and children); further loss of economic assets and livelihood; and disappearance of culture or cultural practices (indigenous groups).

A critical step in helping the most vulnerable adapt to climate change is to understand the specific impacts that they face in each city. The tools outlined in Chapter 4 can be helpful in this regard. Cities committed to developing a deeper understanding about the unique issues that climate change poses to informal settlements and these vulnerable groups can pursue in-depth participatory and community-based assessment approaches, as described in Table 4.1. Although cities may have limited to no quantitative data readily available about some vulnerable groups,

interviews of influential community leaders, residents and stakeholders (for example, doctors, teachers, or NGOs) can yield valuable information,

whether independently or as part of a broader assessment process.

**FIGURE 5.1 TRENDS DRIVING VULNERABILITY AND LIMITING ADAPTIVE CAPACITY OF INFORMAL SETTLEMENTS**

| Global and National Trends   | → Local Trends   | → Conditions Creating Vulnerability or Limiting Adaptive Capacity   | → Illustrations of Climate Change Impacts, If No Action Is Taken   |
|--|--|---|--|
| Inadequate urban economic development<br>Rural-urban migration leading to rapid urbanization<br>Lack of affordable formal housing in urban areas | Weak land administration and regulation<br>Creation of informal and unplanned settlements on marginal land (for example, floodplains, steep hillsides, or landfills)<br><b>Lack of secure land tenure*</b><br><b>Lack of access to infrastructure and basic services (for example, water, sanitation, public health, or electricity)*</b><br><b>Overcrowding and stress on existing infrastructure*</b><br>Social fragmentation, conflict, and crime | Deterrence of public and private investment and service provision, because of insecure tenure and/or illegality of settlement<br>Lack of economic assets (for example, property, money, or credit), political power, and education needed to adapt effectively<br>Concentrations of vulnerable communities and economic assets exposed to extreme hazards (for example, flooding from heavy rains or storm surges in coastal areas)<br>Structural weaknesses in housing and infrastructure, including inadequate drainage<br>Environmental degradation (for example, uncollected solid waste, untreated wastewater, contaminated waters near landfills, or reduction of protective ecosystem functions)<br>Public health concerns that weaken the adaptive capacity of an individual or community (for example, diarrhea or infant mortality) | Exacerbated flooding because of substandard drains blocked with uncollected garbage<br>Mortality and property loss, both localized and distributed across multiple communities<br>Faster spread of communicable diseases (for example, cholera and malaria) from stagnant flood waters and compromised immune systems<br>Exacerbated poverty and barriers to economic development<br>Increased stress on city services (for example, emergency response) in the future<br>Further social fragmentation |

Sources: Sida 2007; Moser and others 2010; UNISDR 2009; Bull-Kamanga and others 2003.

\*The boldfaced local trends (lack of secure land tenure, lack of access to infrastructure and services, and overcrowding) are also actual features of informal settlements.

Special considerations when undertaking such assessments include the following.

- As part of a vulnerability assessment, it is important to know where vulnerable groups are located, how much and what type of land they occupy, their daily cultural practices and

livelihoods, and any special requirements they may have (for example, special medical needs for the elderly, disabled, or chronically ill).

- To assess adaptive capacity, it is also useful to understand: knowledge and education levels (for example, whether individuals can

understand and respond to early warnings about climate risks), and features of social networks, including sources of support and culturally effective ways of communicating.

These assessments can also reveal other community concerns that could either hinder or help climate change adaptation (for example, fear of looting, uncertainty about possible shelter, anxiety about being displaced, and skepticism about whether an extreme weather warning is genuine and accurate) (Hardoy and Pandiella 2009).

| TABLE 5.1 CONDITIONS CREATING VULNERABILITY OF WOMEN, CHILDREN, ELDERLY, DISABLED, AND MINORITY GROUPS |   |
|--|---|
| Groups   | Conditions Creating Vulnerability   |
| Women  | Limited personal assets including limited or no land ownership.<br>Responsibility as caretakers and first responders.<br>Dependence on natural resources (for example, water or fuel).<br>Dependency on male family members.<br>Lack of education, related to limited or no power in decision making and/or lack of access to essential information (for example, early warnings).<br>Restrictive dress codes that limit mobility.<br>Coping skills (for example, tree climbing or swimming) taught only to boys. |
| Children   | Lack of independence and personal assets.<br>Reliance on parents/adults for decision making and protection.<br>Lack of physical strength compared to adults.<br>Lack of safe play areas.  |
| Elderly, disabled, and chronically ill   | Reliance on others for care (for example, medicine, food and/or evacuation procedures) and sometimes decision making (for example, health care residence).<br>Changes in family relationships, resulting in less reliability of family help ( <i>elderly</i> ).<br>Lack of assets and financial resources because of absence of insurance and/or pensions ( <i>elderly</i> ).   |
| Minority and indigenous groups   | Social or linguistic isolation.<br>Economic disadvantage.<br>Dependence on natural resources ( <i>poor and indigenous groups</i> ).   |

Sources: World Bank 2010; Moser and Satterthwaite 2010; Bartlett 2008; O'Brien 2007; Klineberg 2002.

## Building Adaptive Capacity among the Most Vulnerable

Cities can take a number of steps to help build the adaptive capacity of the most vulnerable. As described in Chapter 3, these climate change adaptation activities can be integrated with disaster risk reduction work that may already be ongoing. Box 5.1 summarizes the key findings from recent work at the World Bank for the Mayors Task Force on Climate Change, Disaster Risk and the Urban Poor. Box 5.2 describes the example of the city of Khulna, Bangladesh, where ongoing efforts address the needs of many of the city's most vulnerable residents.

## RAISING AWARENESS ABOUT THE SPECIFIC CLIMATE CHANGE IMPACTS ON THE MOST VULNERABLE.

Gaining and sharing knowledge about the unique impacts of climate change on vulnerable groups and in informal settlements can be powerful, as many communities have long been unrecognized

and underserved. In fact, city leaders can consider this type of assessment process as an investment in building awareness and commitment among city staff and other city residents to focus on the pressing concerns of poverty and inequity, a first step to building stronger adaptive capacity both in the city government and in the target community.

### BOX 5.1 MAYORS' TASK FORCE ON CLIMATE CHANGE, DISASTER RISK AND THE URBAN POOR

The Mayors' Task Force on Climate Change, Disaster Risk and the Urban Poor was initiated at the Mayors' Summit in Copenhagen in 2009 with the aim to improve understanding of these issues, identify good practice examples, and propose policy and investment programs to improve the resilience of the urban poor.

As part of the Mayors' Task Force, the World Bank carried out a global study on *Climate Change, Disaster Risk and the Urban Poor* that examined the intersection of these three areas in cities. Key findings from the study include:

- **The urban poor are on the front line.** The poor are particularly vulnerable to climate change and natural hazards due to where they live within cities, and the lack of reliable basic services.
- **City governments are the drivers for addressing risks.** Local governments play a vital role in providing basic services that are critical to improving the resilience of the urban poor.
- **City officials build resilience by mainstreaming risk reduction into urban management.** Climate change adaptation and disaster risk reduction can be best addressed and sustained over time through integration with existing urban planning and management practices.
- **Significant financial support is needed.** Local governments need to leverage existing and new resources to meet the shortfalls in service delivery and basic infrastructure adaptation.

In addition, as part of this effort, four city-level case studies—in Dar es Salaam, Jakarta, Mexico City, and Sao Paulo—applied the Urban Risk Assessment framework (see also Table 4.1). Further information is available through <http://www.worldbank.org/urban>.

## INCLUDING THE MOST VULNERABLE IN THE ADAPTATION PLANNING AND POLICY-MAKING PROCESS.

Once a city has made a commitment to include the most vulnerable in climate change impacts assessments, it will be a natural progression to engage these groups in the planning and

### BOX 5.2 URBAN GOVERNANCE AND INFRASTRUCTURE IMPROVEMENT IN KHULNA, BANGLADESH

The city of Khulna, Bangladesh, faces multiple climate change impacts, including flooding, cyclones, and drought, in addition to an array of existing conditions, such as high population density, rapid urbanization, low literacy rates, high malnutrition among children (56 percent), and low income levels. The city contains 520 of the country's 9,000 slums, and faces an influx of climate migrants. The German Development Cooperation has supported the Khulna City Corporation to develop its climate change resilience through a two-pronged approach addressing urban governance and infrastructure improvement. Efforts include capacity development for alternative water and sanitation plans, improved service delivery of safe drinking water for the city's slums and floating homes, and support of a sustainable pro-poor transportation plan.

Source: ICLEI 2011.

policy-making processes. Giving the most vulnerable a “seat at the table” at every stage of climate change adaptation can break new ground, reducing the persistent political disadvantages they tend to face. This type of action can have positive secondary effects, such as educating the rest of the city’s population about the problems that climate change poses to disadvantaged groups, and creating a model for more inclusive planning processes in other issue areas. Even more importantly, cities may gain new insights from informal local approaches already underway, as many communities living with the risks of disasters and climate variability have independently developed coping mechanisms of their own and can be extremely resourceful.

### **INCORPORATING COMMUNITY-BASED ADAPTATION INTO CITY PLANS, WHEN APPROPRIATE.**

Community-based adaptation (CBA) strategies can build long-term adaptive capacity. Approaches that draw on natural sources of adaptive capacity, such as women’s knowledge of natural resources, or the ingenuity of a homeowner committed to staying in his house, can be more durable than top-down prescriptions from a city official. Examples of municipal collaboration with residents include reducing landslide impacts through

reforestation and low-cost drainage technologies, such as storm-water channels to divert water from homes, and collection of roof water in barrels (SouthSouthNorth 2006).

Not all CBA strategies will be effective in the long term. For example, moving valuables to the top shelf of a cabinet in case of flooding or building a second floor of a house to allow temporary escape in a flood-prone location may alleviate short-term concerns about property loss (Satterthwaite 2011). However, if flooding continues to increase in frequency and intensity, these strategies may actually keep people and their assets in harm’s way, delaying the consequences of flooding, rather than avoiding them altogether. Moreover, communities may be reluctant to give up adaptive practices that were developed when no one was

helping them, especially if they are skeptical about the depth of a municipal government’s commitment to their needs. Through the work of a number of international NGOs, progress has been made on developing positive models for CBA, as well as tools for cities and other practitioners wanting to invest in developing adaptive capacity at the grassroots level (see Box 5.3).

### **SUPPORTING INSTITUTIONS THAT ALREADY WORK WITH THE MOST VULNERABLE.**

Many international and local nongovernmental actors and community-based organizations have already earned the trust of disadvantaged communities, based on a history of providing services that range from first response in cases of disaster to

#### **BOX 5.3 COMMUNITY-BASED ADAPTATION EXCHANGE**

Following the fifth Community-Based Adaptation (CBA) conference in Dhaka in 2011, the Global Initiative on CBA (GICBA) has been formally launched, including a Google Earth-based CBA platform for sharing knowledge, experiences, and good practices on CBA in a variety of contexts, including urban settings. These efforts are intended to share information about grassroots adaptation strategies generated by communities, developed in response to a growing awareness of the need to learn about what residents and stakeholder groups are already doing to adapt—rather than to impose top-down adaptation strategies on them. More information is available at <http://www.weadapt.org/gicba> and <http://community.eldis.org/cbax/>.

*Source: CBA Exchange 2011.*

investment in longer-term resilience. Partnership with or support of NGOs and community groups can make city efforts more effective, as these organizations can have a depth of knowledge about social networks, cultural practices, and locally effective communications that complement that of a city government. This can be especially true when city budgets are simply too limited to provide full attention to community needs.

### **STRENGTHENING LAND ADMINISTRATION AND REGULATION, AND EXPLORING THE BENEFITS OF GRANTING LAND TITLE TO INFORMAL SETTLEMENTS.**

The occupation of marginal land is a key factor affecting vulnerability among informal settlements and the urban poor, but is clearly a very difficult challenge to address. The primary solutions to

this persistent problem are complicated—coordinated commitment to 1) stronger land use administration and 2) investment in affordable housing on land that is not exposed to severe climate change risks.

Tenure security can provide incentives for residents of informal settlements to invest in upgrading their homes, contribute to building community infrastructure, and use their property as a productive asset, particularly when jobs and other sources of income are scarce. Evidence from the slums of Lima, Peru, indicates that when land is legally secure, its value is 12 times more than in areas classified as removable; furthermore, when property titles were provided to residents, the rate of housing renovations and improvements rose by 68 percent (Field 2005).

Yet, it is important to note that granting land title alone is not a solution to urban poverty. Legalization can actually lead to increased property prices and rents, potentially making the newly legalized settlement unaffordable for the poorest (Roy 2005). Formal land titling can also be expensive and bureaucratically complex, as evidenced in Rio de Janeiro where the Favela-Bairro project made slow progress on titling, despite successful investments in urban upgrading and basic services (Handzic 2010). Considerable research has

now established that the perception of tenure security for the poor—a sense of safety from being evicted—can be as important as the formal titling itself (Angel 1983; Skinner 1987; Razzazz 1993; Gilbert 2002). Thus, while land titling can open up new avenues for building adaptive capacity among informal settlements, it is also a nuanced and challenging topic without an easy path.

Chapter 6 provides more detail on the importance of sound land use and housing strategies to reduce vulnerability.

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### **FURTHER RESOURCES**

The Liveable and Just Toolkit is the result of a project by the Victorian Local Governance Association (VLGA) and Melbourne University's McCaughey Centre to explore how local governments across Victoria, Australia, are responding to the social and equity impacts of climate change. The toolkit provides a practical framework to integrate social and equity concerns into climate change responses, and it offers ideas for local governments to develop climate change responses that simultaneously work toward social justice. The toolkit is available online at: [www.vlga.org.au/Resources/Liveable\\_Just\\_Toolkit.aspx](http://www.vlga.org.au/Resources/Liveable_Just_Toolkit.aspx).

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## 6. Sector-Specific Adaptive Responses



This chapter provides a general overview of climate change impacts across the following sectors in cities: land use; housing; transportation; public health; water supply and sanitation; solid waste; food security; and energy. The sections on each sector also describe various approaches that can be adopted to address these impacts, with specific examples of adaptive responses that have been taken by cities around the world. Table 6.1 summarizes much of the information in this chapter, providing an overview of climate impacts, the sectors involved, and examples of adaptive responses.

### Adaptation Involves Collaboration across Sectors

Adaptation is a dynamic process that usually involves multiple sectors, complex and challenging issues, and possibly, large infrastructure projects. The most durable adaptation efforts, thus, require resourcefulness and collaboration (see, for example, Boxes 6.1 and 6.2). Adaptation can also



present opportunities for new collaboration that breaks down old organizational or political barriers among sectors. For example:

- A mayor who sets a firm expectation of collaboration across city sectors on adaptation can use this to rally transportation, housing, and land use planners to work together on safer residential zoning and transit-oriented development, with additional benefits for evacuation and emergency management.

#### BOX 6.1 AAJEEVIKA BUREAU

Climate change may involve rapid demographic shifts, impacting social services across sectors. For instance, service provision for individuals who migrate to cities on a temporary and sometimes seasonal basis involves cross-cutting collaboration that can be achieved through NGOs. As one example, the Indian NGO Aajeevika Bureau (“Livelihoods Bureau”) works to reduce the costs of mobility for migrants, including services to support personal security and freedom from violence, and to increase the returns on migrant wage labor, both for migrants and their families. Services include ID cards, job placement, shelter, and health insurance—a range of activities that require expertise in a variety of sectors. More information is available at <http://www.aajeevika.org/>.

#### BOX 6.2 URBAN FORM AND INFRASTRUCTURE

Development decisions that affect urban form and infrastructure require cross-sector collaboration involving a variety of city officials, depending on the local context.

**Urban form** is the physical shape of a city, including the spatial and geographical layout of buildings and infrastructure. Urban form has significant implications for sustainability and resilience: transit-oriented development in densely populated areas, for example, can have such benefits as lower greenhouse gas emissions from transportation, while the location of informal settlements in a floodplain without sound transportation options can make residents more vulnerable (World Bank 2011).

**Infrastructure** is the interlinked set of physical buildings and engineered systems that underpin an important sector or activity, such as housing, transportation, water supply, wastewater treatment, storm water drainage, food storage, and energy (see Chapter 6). Geographic location, engineering methods, and types of materials used to construct infrastructure are factors that determine its resilience, as well as the resilience of the community that relies on it. Examples of traditional infrastructure’s inability to meet the challenges of climate change include siting infrastructure on low-lying or marginal land prone to flooding, leakages from pipes because of

structural deficiencies, impervious surfaces that retain heat and lead to water pooling, and reliance on private automobiles for transportation (Inverde 2011a).

A single city agency usually does not have the authority for all planning decisions and investments that shape urban form; therefore, effective collaboration across agencies and even sectors is critical for successful adaptation of a city’s physical landscape. Moreover, city planning and infrastructure decisions can “lock in” urban form for long periods of time, especially when physical investments have extended life spans. In the absence of strong city planning, cities can experience sprawl and other unsustainable land use patterns because of uncontrolled growth. However, an increasing number of cities and countries are recognizing the need to approach infrastructure decisions strategically—such as Ho Chi Minh City, through its major investments in dike works, drainage, and waste and water management; and the Czech Republic through a research program that aims to increase the resilience of specific infrastructure areas (ICLEI 2011a).

*Source: Authors.*

TABLE 6.1 SAMPLE OF CLIMATE HAZARDS AND ADAPTIVE RESPONSES ACROSS SECTORS

| Projected Change in Climate Phenomena (Likelihood)  | Drivers of Urban Exposure and Vulnerability   | Consequences for Cities, if Unaddressed  | Sectors Involved   | Sample Adaptive Responses (not an exhaustive list)  | Relative Investment Level / Cost  |
|---|---|--|--|---|---|
| Warmer with fewer cold days and nights, more hot days and nights (virtually certain)<br><br>Hot spells/heat waves—increased frequency (very likely)   | Urban heat island effect.<br><br>Lack of electricity and cooling systems, especially in many informal settlements.                                      | Exacerbated air pollution<br><br>Heat-induced illness and death  | Transportation, housing, private sector building industry, public health | Green infrastructure, including improved vegetation and green building investments for natural cooling.   | Medium to high with significant economic and sustainable development cobenefits   |
|   |   |  |  | Retrofit of existing bus fleet with white roofs to reduce solar heat gain and ventilation to ensure adequate air circulation.<br><br>Undertaking public relations campaigns to encourage passengers to carry water with them to avoid heat stroke.  | Low to medium   |
|   | Lack of diversified energy supply and substandard energy infrastructure.  | Energy shocks and disruptions because of increased demand  | Energy   | Investment in clean energy and energy efficiency.   | Low to high, depending on the specific energy investment; significant cobenefits for economic prosperity and “green growth.”                                    |
| Heavy precipitation events—increased frequency (very likely)<br><br>Intensity of tropical cyclone activity increases (likely)<br><br>Rising sea level (virtually certain)<br><br><i>(continued next page)</i> | Rapid urban growth leading to informal settlements on marginal land with no roads or drainage systems, or drains that are clogged with debris and silt. | Exacerbated flooding and landslides  | Land use, housing, solid waste, public health, emergency management      | Development and enforcement of a sound land use plan that a) is based on understanding of climate change vulnerabilities, b) effectively encourages dense, mixed-use development in resilient areas, and c) engages ecological planning approaches outside of city limits (for example, village-level watershed management on the outskirts of a city, protection of mangroves and wetlands on nearby coastline). | High, involving significant political and staff investment  |
|   |   |  |  | Contaminated waters and spread of disease in stagnant waters  | Improved solid waste handling practices (for example, proximity to drinking water supply, corrosive-resistant containers) to prevent leakage and contamination. |
|   |   | Short-term clearance/disposal of solid waste from drains to prevent clogging.  |  |   | Low   |
|   |   | Public health engagement and risk prevention around likely flood-related diseases.   |  |   | Low   |
|   | Nonexistent or substandard transportation infrastructure.   | Blockage of emergency routes because of road flooding, resulting in delayed emergency evacuations<br><br>Losses in commercial activity | Transportation, emergency management, private sector                     | Investment in roads and other transportation choices for informal settlements.  | Medium to high  |
|   |   |  |  | Green infrastructure.   | Medium to high with significant economic and sustainable development cobenefits   |
|   |   |  |  | Relocation of storage yards for buses and train cars out of flood-prone areas to reduce the risk of damage or loss of this equipment.   | High  |

*continued next page*

| TABLE 6.1 SAMPLE OF CLIMATE HAZARDS AND ADAPTIVE RESPONSES ACROSS SECTORS |  |   |  |  |  |
|---|--|---|--|--|--|
| Projected Change in Climate Phenomena (Likelihood)                        | Drivers of Urban Exposure and Vulnerability  | Consequences for Cities, if Unaddressed   | Sectors Involved   | Sample Adaptive Responses (not an exhaustive list)   | Relative Investment Level / Cost   |
| Heavy precipitation events—increased frequency (very likely)              | Storm water infrastructure unable to deal with current or future runoff, compounded by deforestation / degradation of natural storm water filtering functions. | Increased runoff in absence of vegetated land<br>Increased flooding                                     | Sanitation, solid waste<br><br>Natural resources management                          | Short-term clearance/disposal of solid waste from drains to prevent clogging.  | Low  |
|   |  |   |  | Investment in “green infrastructure” and ecosystem planning to improve natural storm water function. (for example, contour planting, terracing and afforestation for erosion control). | Low (localized planting) to high (large-scale infrastructure or afforestation) with significant economic and environmental cobenefits. |
| Intensity of tropical cyclone activity increases (likely)                 | Already high population densities and concentrated commercial activities (for example, ports and industry), located in coastal cities or in river deltas.      | Loss of property and infrastructure, potentially before the end of their useful life                    | Private sector   | Relocation of facilities out of flood-prone areas.   | High   |
|   |  |   |  | Sea walls or other structural investments to protect against coastal flooding.   | High   |
| Rising sea level (virtually certain)                                      | Lower structural quality of homes, especially in informal settlements.   | Loss of property and life   | Housing, emergency management  | Retrofit of old buildings and improved design of new buildings (if residents remain in vulnerable location).   | Medium to high   |
|   |  |   |  | Stricter risk disclosure requirements for housing developers.  | Political and staff investment for sound enforcement   |
|   |  |   |  | Public awareness / emergency preparedness initiatives to educate residents on flooding risks.  | Low  |
|   | Location of aquifers, wastewater treatment plants and other infrastructure in coastal areas or on river deltas.  | Saltwater infiltration of infrastructure (for example, potable water supplies and wastewater treatment) | Water supply<br>Wastewater treatment   | Modification of pipes.   | Medium   |
| Areas affected by drought increase (likely)                               | Existing water scarcity and competing pressures for water use (for example, potable water, irrigation, wastewater, hydropower).                                | Exacerbated water scarcity and competition  | Water supply (with implications for energy sector in areas of hydropower generation) | Utility piped water supply (assuming water supply is resilient).   | Medium to high   |
|   |  |   |  | Reclaimed wastewater (resilient if properly managed).  | High   |
|   |  |   |  | Long-term demand management and water use efficiency programs.   | Low to medium  |
|   | Food shortages or higher food prices because of impacts in other parts of the region or world.   |   | Food and agriculture   | Raising public awareness and developing municipal competency about food supply.  | Low; with staff investment   |
|   |  |   |  | Promotion of urban agriculture.  | Staff investment and potential high costs, if involving land purchase  |
|   |  |   |  | Development of city-level food storage infrastructure.   | High   |

Sources: IPCC 2007; Foster and others 2011; Horton 2009; Action Aid 2006; UN-Habitat 2011; Simply Green 2009; Henriques 2009. See end of Chapter 6 for full list of citations.

- An official who establishes a clear goal of partnership on climate change adaptation may find the staff of a wastewater treatment agency more likely to collaborate with the local water utility on an adaptive water reuse program than in the past.

**TABLE 6.2 SAMPLE OF ADAPTATION GOALS THAT MAY REQUIRE COLLABORATION ACROSS SECTORS**

| Adaptation Goals  | Sectors Relevant to the Adaptation Process  |
|---|---|
| Deciding and enforcing where to promote expansion of industry, residential development, and transportation infrastructure, in order to limit related climate change risks to people and business.   | Land use, housing, emergency management, and transportation.  |
| Ensuring that communities have sufficient potable water and limiting climate-related health risks (for example, flooding exacerbated by clogged drains and disease related to contaminated flood waters) by investing in water and sanitation infrastructure. | Public health, water supply, sanitation, and solid waste.   |
| Long-term resilience of water, food, and energy supply.   | Water, food, transportation, energy (for water conveyance as well as food refrigeration), and emergency management. |
| Short-term logistics of emergency water and food relief.  | Water, food, transportation, energy (for water conveyance as well as food refrigeration), and emergency management. |

Source: Authors.

Table 6.2 reflects several climate change adaptation goals that may require cross-sector collaboration.

## Land Use

Land use refers to where and how people use land (for example, residential and commercial buildings, farmland, water supply, energy production, or forestry). Land-use planning in cities includes the management and regulation of those activities that exist within city boundaries, with the potential to shape urban form and infrastructure and, thus, affect many other sectors, ranging from housing and transportation to public health. See Boxes 6.2 and 6.3 for more discussion of urban form and infrastructure.

Globally, urban populations are projected to grow from 3.4 billion (in 2009) to 6.3 billion by 2050, with small cities absorbing over 40 percent of the expected increase (UN Department of Economics & Social Affairs 2009). In the fast growing metropolitan area of Concepcion, Chile, for example, 55 percent of the land developed between 1975 and 2000 was wetlands; the remainder was either agricultural or forest land (Pauchard and others 2005).

At the same time, city governments often lack sufficient staff, technical proficiency, or tools necessary to engage in effective planning efforts to direct urban growth. The responsibilities for planning, economic development, land tenure, and other functions that direct growth are often distributed among local, regional, and national-level governments and their subsidiaries, making coordination difficult. Poorly regulated land markets, lack of land tenure, limited enforcement of land use policies, and corruption all further limit the ability of city governments to direct urban growth.

## CLIMATE CHANGE IMPACTS

Flooding associated with rising sea levels will lead to increased inundation of low-lying areas in coastal cities, causing enormous losses in land and infrastructure values, if unaddressed. Significant infrastructure investments in coastal areas—such as port and industrial facilities—often contribute significantly to a city’s economy and typically have service lives in excess of 60 years. Such facilities in the most vulnerable coastal areas may need to be abandoned before the end of their useful lives, if risks are considered to be too high. Damage or abandonment of developed areas because of flooding may result in enormous losses in value of both land and infrastructure (World Bank Group 2010).

Localized flooding will disproportionately impact vulnerable communities located in high-risk urban areas. The urban poor often resort to constructing makeshift homes in areas of highest environmental risk. Informal settlements are often located on marginal lands that are affected disproportionately by increased rainfall—from low-lying floodplains to steep slopes prone to landslides. Low-income areas are also often the last areas to be provided with drainage infrastructure (Parkinson 2005). The settlements themselves can actually change and even create floodplains as a result of removal of vegetation (a natural flood barrier) or establishment of impervious surfaces, such as roads.

### ADAPTATION APPROACHES

Understanding which areas of a city are most likely to be affected by sea-level rise or localized flooding is an important initial step in taking action to reduce climate vulnerability. This type of assessment—perhaps most helpfully in the form of an actual map—can be combined or overlaid with information about development pressures and projected expansions of informal settlements. It would also be practical to consider information about new infrastructure and planning needs related to climate change in the context of existing development.

Cities can develop and enforce land-use plans that minimize climate change vulnerabilities and promote growth in resilient locations. A sound land-use plan that takes into account climate change vulnerabilities and is well-enforced—with infrastructure siting that is consistent with the plan—can be decisive in increasing the resilience of a community. Conversely, the lack of a plan or weak enforcement can leave a city's people and assets open to climate hazards.

As urban populations increase, one of the top priorities for cities to consider is preventing critical land uses (for example, residential construction or economic development) and infrastructure investments from occurring in vulnerable locations (for example, along waterways, in floodplains, or on steep slopes). Promoting denser, mixed-use residential communities can increase development in existing, safe development zones, and increase the supply of affordable housing near employment, a key driver of informal settlement growth. Dense, mixed-use development also conveys the benefit of producing lower greenhouse gas emissions by reducing the demand for transportation. Naturally, implementation may prove to be much more difficult than assessment, as residents may fear and resist relocation of their homes, or other disruptions associated with structural adaptation strategies.

### FURTHER RESOURCES

The forthcoming *Handbook on Urban Flood Risk Management*—funded by the Global Facility for Disaster Reduction and Recovery (GFDRR), and prepared by the World Bank in partnership with the Japan International Cooperation Agency (JICA) and the World Meteorological Organization (WMO)—will provide practical technical guidance to key policy and decision makers and technical specialists in cities in developing countries. The handbook will take a comprehensive view of flooding, including storm, river, and coastal flooding. It will contain such parameters as urban watershed modeling and management, urban planning (for example, building codes and zoning regulations and enforcement, and urban growth trends and patterns), infrastructure codes and scenario forecasts, drainage networks and links to solid waste management and sewerage, flood barriers (for example, embankments, walls, retention ponds, and natural “green” buffers), resettlement and relocation, institutional and policy/regulatory frameworks (including coordination across local government administrative boundaries), early warning systems, community-based flood risk management, and financing mechanisms. Based on global experiences and extensive local consultation, the handbook will include practical tools, checklists, templates, and links to resources.

Mapping vulnerabilities, understanding development pressures, and implementing policies and infrastructure investments that encourage urban expansion in safe areas can require land-use data and technical capacity. Smaller cities without the resources to pursue these planning activities in-house can consider collaborating with external partners, such as regional or national-level governments, who have expertise with planning tools, such as advanced geographical information system (GIS) and scenario-based planning methods.

### BOX 6.3 GREEN INFRASTRUCTURE AND ECOSYSTEM SERVICES

Aspects of traditional infrastructure, such as pervious material and suppression of native landscapes, can create undesirable conditions, such as hot city streets, flooded roads and sidewalks, hardened shorelines, and poor water and air quality. It is, however, possible to rebuild local resilience by pursuing creative “green infrastructure” projects that leverage natural ecosystem services. Ecosystem services are the benefits that people derive from natural ecosystems (Millennium Ecosystem Assessment 2005), such as the buffer that wetlands provide from hurricanes and floods, and air filtration and cooling by trees.

In Rio de Janeiro, Brazil, the community group Inverde is advocating through a Green Streets guide for the use of satoyama, a traditional Japanese landscape practice that supports sustainability (Inverde 2011b). The city of Bologna, Italy, has developed a public-private partnership to promote urban forestry, with the intention of sequestering carbon dioxide, mitigating the urban heat island effect, and reducing air pollution (ICLEI 2011b). Green infrastructure approaches can also be very localized, such as storm water reuse at both apartment buildings and individual apartments. Some approaches to obtain ecosystem services are familiar, such as strategic analysis of park distribution across the city of Chennai to help bring down temperatures in the summer.

These efforts can also have significant cobenefits, such as reducing greenhouse gas emissions, improving public health, and enhancing quality of life. For instance, in Bangladesh, cyclones that first hit the Sundarbans mangrove forest showed a much reduced storm surge and resulted in significantly fewer fatalities (Millennium Ecosystem Assessment 2005). In Taiwan, a strategic wetland conservation greenway along the west coast provides valuable habitat and diverse ecosystem services, including flood protection (Hsieh and others 2004). Although these efforts are not specifically city-related, they do offer the insight that sound environmental management can have important additional advantages.

One traditional tool for biodiversity management is the Integrated Environmental Assessment (IEA). A “community learning platform” in support of the IEA is available at [www.unep.org/ieacp/iea](http://www.unep.org/ieacp/iea). The GRaBs project (Green and Blue Space Adaptation for Urban Areas and Eco Towns) also provides a database of case studies on lessons related to green and blue infrastructure, including investments related to water bodies, rivers, streams, floodplains, and sustainable drainage systems. More information is available at <http://www.grabs-eu.org/casestudies.php>. See the glossary for definition of green infrastructure.

Because the links between land use and infrastructure are so strong, the most practical land use plan informs a city’s choices about the location of transportation, housing, environmentally protected areas, wastewater, drainage, and other investments, viewing these activities as a whole. Holistic land-use planning can accomplish the following:

- Keep the long-term cost of development down by building in areas that are less vulnerable to climate change impacts and costs
- Encourage coordinated transportation and housing investments, so that people can afford to live in safe conditions with sound transportation choices in cases of emergency
- Promote green infrastructure and sound watershed management (including urban forestry and village-level watershed protection outside of city limits), which can reduce storm water runoff, mitigate the urban heat island effect, and improve public health (see Box 6.3)
- Rehabilitate wetland riparian or estuarine habitats (for example, coastal mangroves) that provide a natural ecosystem service, such as flood protection.

## Housing and Buildings

Housing affects many aspects of city residents' lives, including transportation, employment, and public health. In many cities in developing countries, people who cannot afford homes in the formal housing sector end up living informally—without land tenure and without basic infrastructure and services. Homes in informal settlements are typically built incrementally over time, do not tend to use robust building techniques or materials, and are often constructed on marginal and unsafe lands (see Chapter 5). Housing officials at the city level face an array of challenges—ranging from insufficient capacity to lack of enforcement authority—in regulating and shaping these trends in informal settlements. Cities with insufficient capacity to keep sound administrative records on buildings, or without the necessary staff to regulate compliance, can find it difficult to prevent the construction of shoddy homes and buildings.

### CLIMATE CHANGE IMPACTS

Intense storms, including tropical cyclones, can have abrupt, but lasting, consequences for a city's homes and buildings (IPCC 2007 as cited in World Bank 2009). Because of their extreme nature, cyclones can induce erosion and landslides, which

can cause partial or complete building destruction. Such storms will have a disproportionate impact on those with homes of lower structural quality, especially those in informal settlements.

Floods pose risks for homes and buildings, particularly those located adjacent to rivers and deltas, and informal settlements on marginal land. Whether a home or building is affected by floods depends greatly on where it is located, although structural quality and elevation are also key factors. The immediate impact of flooding includes public health risk (see section Public Health of Chapter 6) and property damage, although dampness may also facilitate the accumulation of mold long after flooding has subsided, particularly in humid climates (FEMA 2011).

Increasing sea levels will impact homes and buildings in coastal communities. According to UN-HABITAT, coastal flooding affects 10 million people each year, a number expected to increase exponentially because of climate change (UN-HABITAT 2010). Because sea-level rise is not uniform across regions, some communities in places, such as subsiding deltas and the Pacific's small island states, are particularly vulnerable (IPCC 2007). Structural impacts of sea level rise can be more serious when combined with storm

surges, resulting in potential permanent damage to homes and displacement.

Increases in the frequency and severity of heat waves because of climate change pose additional risks for occupants of homes without cooling methods. Cities in Africa, Asia, and South America are particularly at risk of extreme heat (UN-HABITAT 2010), although regions that are typically temperate or even cool will also experience hotter temperatures for which they may not be prepared. Very young children, the elderly, and the infirm are most susceptible to heat strokes and other health risks of heat. Fires may also threaten residential areas, whether localized (for example, homes based near flammable materials associated with compost or landfills) or related to widespread regional forest fires, such as in the western United States.

When disasters strike, residents may need temporary shelter, as homes and buildings become uninhabitable. Although disaster response plans often take into consideration emergency shelter needs—for example, through the use of public buildings, such as schools or community centers—they often lack official arrangements for the longer-term post-disaster housing needs of evacuated residents. This can be true for residents of both informal and formal housing.

## ADAPTATION APPROACHES

Cities can regulate housing directly through building codes and zoning, and also indirectly influence housing markets through transportation and infrastructure planning and investment. Perhaps the most effective tools for a city to employ in regulating and providing affordable housing are a strong and enforced land-use plan and a complement of building codes that integrate safe housing with transportation choices, wastewater treatment, drainage, and other amenities. Cities can also pay closer attention to the vulnerability of places where people typically congregate, such as community centers or public squares, as well as other areas that people use in times of crisis, such as schools and sports facilities.

Structural adaptation strategies, such as building elevation and resilient design, tend to be more cost-effective and easier to implement when initiated at the time of construction. Structural approaches range from the retrofit of homes and buildings, such as addition of green roofs or sun shading to alleviate heat, water storage space and smart ventilation, to wholesale construction or deep upgrades (for example, elevation) of a building.

- In responses to floods, homes and buildings can be elevated, although such in-depth

structural renovations can be harder and more expensive to achieve than simply building resilient homes from the start (UN-HABITAT 2010).

- When new buildings are too expensive or otherwise not possible, retrofits can be attractive, especially for low-income or middle-income residents. In contrast, wealthy residents tend to be much more able and likely to rebuild or relocate their homes entirely, by virtue of greater financial resources—a specific example of having substantial adaptive capacity.
- Green homes and buildings can have both mitigation and adaptation cobenefits (Mehrotra and others 2009; TCPA 2007). In Tokyo, tax credits are offered to developers and low-interest loans are offered to homeowners who incorporate these strategies into planning. Such strategies have been implemented in Delhi as well.
- Simple strategies, such as light-colored roofs, can provide a cooling effect at low cost (ICLEI 2011c).

Nonstructural strategies—such as strict enforcement of zoning and building codes, risk disclosure requirements, and public outreach—are also

highly important, but often challenging to implement successfully in many cities.

- To implement building regulations effectively, government capacities in monitoring and enforcement are essential. Robust anticorruption efforts can be an important step to take in reducing the vulnerability of the housing sector to prevent circumvention of regulations, but they can be difficult to implement successfully. (See also Chapters 3 and 5).
- Cities can supplement regulatory action with transparency efforts, such as a requirement for developers to assess and disclose the geographic or structural risks of a housing development, and simultaneous public outreach to spread knowledge about homeowner risks.
- Cities can also persuade homeowners to relocate through a buyout program, if residential risks in a given location are simply too high to warrant staying and rebuilding (see Land Use section of Chapter 6), but the financial resources for such a program may be difficult to raise.
- In future, for example in response to dramatic sea-level rise, it is possible that some cities may decide to pursue a larger



and longer-term managed retreat strategy in areas at very high risk, where no other cost-effective solution has been identified (NOAA 2011). In highly developed residential and commercial areas, such an approach would undoubtedly come with great political and financial expense.

In considering various adaptation approaches for housing, it is important to recognize the constraints that many homeowners face. Homeowners may be unaware of the extent of their homes' structural vulnerability. Structural assessments to identify home vulnerabilities may be unaffordable and may also be unpopular, if changes involve temporary displacement or if structural vulnerabilities are considered so large that residents do not find changes to be worthy investments. When lacking appropriate financial resources, residents often resort to stopgap measures that may not be sustainable in the long term.

## Transportation

Transportation infrastructure—in four primary categories: roads, bridges and tunnels; passenger and freight rail; ports and inland waterways; and airports—comprises an extensive range of both public and private assets and services.

Transportation infrastructure is essential for both people and commerce, in daily life as well as in times of emergency: a city's transportation system is often inextricably linked with the effectiveness of its emergency response. Many cities in developing countries lack sound and diverse transportation infrastructure. Critical infrastructure either does not exist or is substandard relative to current climate hazards. Moreover, transportation agencies are often insufficiently staffed and funded.

### CLIMATE CHANGE IMPACTS

Cities have different transportation vulnerabilities, depending on their locations; for example, coastal cities with maritime ports face different issues from inland cities. In general, cities in all locations are likely to face the impacts of extreme storms and acute heat on their transportation infrastructure. Some of the greatest concerns include the following:

- Extreme storm events can paralyze transportation infrastructure, further isolating vulnerable communities with limited provisions, such as food or medicine, during emergencies.
  - Increased storm intensity can overwhelm the capacity of existing transport infrastructure, such as bridge clearances or drainage capacity.
- Airports, usually located near urban centers, can also be affected by changing wind patterns and extreme weather events.
- Acute heat can also cause a range of negative impacts across the transportation sector.
  - Loss of vegetation because of extreme heat or drought can lead to increased storm water runoff, which may wash away roads and bridges (Lwasa 2010).
  - Roads may suffer from pavement deterioration caused by high surface temperatures that can lead, in turn, to problems with expansion joints and long-term damage (Federal Government of Germany 2008).
  - Extreme heat conditions can cause the expansion of train rails, which may require slower speeds and cause delays.
  - Heaving in both roads and rails may shut down traffic or cause accidents.

## FURTHER RESOURCES

In April 2011, the IFC published “Climate Risk and Business: Ports,” a framework for evaluating the risks of climate change on port operations and associated options for adaptation. The report focuses on Terminal Marítimo Muelles el Bosque, a port in Cartagena, Colombia, but can be used to assess climate change vulnerabilities and adaptation options for other ports around the world. The report found several drivers of port vulnerability to climate change, including geographic locations on coasts, rivers, or lakes and reputational reliance on economic and infrastructure stability for success (IFC 2011). More information is available at: <http://www.ifc.org/ifcext/climatebusiness.nsf/Content/ClimateRiskandBusinessPorts>.

## ADAPTATION APPROACHES

Cities can integrate climate-resilient transportation priorities, including developing new transportation choices, with land-use plans and building codes.

- A general planning principle for all transportation networks is to avoid flood-sensitive areas as much as possible, and incorporate climate change into all relevant decisions concerning transportation infrastructure (Ministry of Agriculture and Forestry of Finland 2005; Coffee et al. 2010). For cities exposed to flooding, relocating existing storage yards for buses and train cars out of flood-prone areas can reduce the risk of damage to or loss of equipment.
- Expansion of transportation infrastructure and transit-oriented development is critical to ensure flexibility of evacuation options in

cases of emergency (Ministry of Agriculture and Forestry of Finland 2005). Inclusion of informal settlements in the transportation service area may require serving marginal land, but can also have cobenefits for economic development and poverty reduction by providing residents with better access to jobs and business opportunities.

- During construction, cities can “build once” to a higher standard, rather than to build to lower standards initially and then be forced to retrofit later. Examples of this include the following: increasing bridge clearances to accommodate higher water levels; increasing design specifications for culvert diameters; and reconsidering the design of road underpasses to account for heavy rains and flooding.
- Green infrastructure, such as pervious surfaces, can also help to make transportation more resilient, with direct advantages such as decreasing both ponding and runoff during rainstorms. Research has shown that pervious pavement can lead to a reduced need for road salt application on streets in the winter by as much as 75 percent, as well as a reduction in road noise of 10 decibels (CNT 2010 and Schwartz 2010, as cited in Foster and others 2011). These approaches

can be combined with nonmotorized transportation options, such as bicycle paths and pedestrian walkways, to reduce greenhouse gas emissions and achieve public health benefits (Frumkin and others 2004; Ewing and others 2008).

Cities have a variety of low-cost options for adaptation in the transportation sector. When resources are limited, cities can consider less expensive business practices or investments in shorter-lived infrastructure.

- All cities can improve transportation customer communications, such as proactively encouraging bus riders to bring water to avoid heat illness in case of extreme heat or sharing information about different evacuation options in case of emergency (Horton 2009; Ministry of Agriculture and Forestry of Finland 2005).
- Cities expecting average temperatures to rise can retrofit existing bus fleets with white roofs to reduce solar heat gain and ventilation to ensure adequate air circulation (Horton 2009).
- Coastal cities expecting sea-level rise can work with ports and maritime businesses to synchronize shipping schedules around high tides to avoid problems with bridge clearance.

Some transportation adaptation options will require collaboration with the private sector, because in many cities, private entities provide transportation infrastructure and services (see Chapter 7 on how city governments can work with the private sector to leverage funding for adaptation).

## Public Health

Cities often face the challenges of health care systems that are already strained by deficiencies in primary care and weaknesses in other services that are important for public health, such as water supply and sanitation. As described in Chapter 5, the poor often live in overcrowded areas where the absence of adequate sanitation and drainage leads to high environmental health risks, such as polluted and stagnant water that offers ideal breeding sites for mosquitoes (Kovats and Akhtar 2008, 165). Furthermore, particularly in cities of low-income countries, such health problems as poor nutrition and indoor air pollution already impair poor populations.

### CLIMATE CHANGE IMPACTS

The urban heat island effect can exacerbate heat waves and worsen air quality over time. Those living in slums and working outdoors are the

most exposed to extreme heat, but the deaths of 35,000 elderly people during the 2003 European heat wave shows that climate impacts can affect all cities regardless of income level (Confalonieri and others 2007, 397; Wolf and others 2010). Urban smog and related respiratory diseases have also been linked to increased temperatures (Confalonieri and others 2007, 402).

Both temperature and flooding increase the global burden of disease and premature deaths. In 2000, climate change was estimated to be responsible for approximately 2.4 percent of worldwide diarrhea and 6 percent of malaria in some middle income countries (WHO 2002, 72). Weather extremes can spur the spread of vector-borne diseases, such as malaria (Confalonieri and others 2007, 404). For example, areas where malaria was once eradicated by means of quinine, swamp drainage, and such pesticides as Southern Europe (Bowden and others 2008, 1085) as well as areas once immune, such as highland East Africa (Githeko and Ndegwa 2001, 54), will potentially become susceptible to malaria's resurgence. Moreover, water-borne diseases spread quickly during floods, as in Maputo where the disruption of water and sanitation services led to outbreaks of dysentery and cholera (ActionAid 2006, 6) and Mumbai where there was an increase in leptospirosis (Kovats and Akhtar 2009, 165). Stagnant

water in slums lacking adequate water and sanitation services can also create optimal conditions for dengue-carrying mosquitoes.

## ADAPTATION APPROACHES

Expanding health care services for the urban poor is a direct way to reduce climate change vulnerability and enhance adaptive capacity. Increased accessibility of formal health clinics and medical personnel to serve the poor enhances not only the well-being of poor residents but also their resilience to climate change impacts (WHO 2011).

Systems to monitor disease and provide early warnings about disasters can help to improve resilience by influencing behavior (WHO 2002, 227). This is especially true if such systems are deployed in conjunction with public awareness campaigns that effectively leverage community sources of knowledge and communications, such

### FURTHER RESOURCES

World Health Organization (WHO) has a long-standing commitment and program to protect public health from climate change impacts, which is implemented through WHO regional and headquarters offices. The program is intended "to strengthen the health system response to climate change, and to ensure that health is appropriately considered in decisions made by other sectors, such as energy and transport" (WHO 2011). More information is available at: <http://www.who.int/globalchange/en/>.

as women, kinship networks and community leaders (Wolf and others 2010).

Structural improvements in housing, transportation, water supply and sanitation, as described in the other sections of this chapter, are important long-term investments that can enhance living conditions, helping to avoid the public health risks described above (WHO 2011).

Examples of public health strategies in practice include the following:

- Rio de Janeiro developed an extensive website on dengue, outlining the symptoms of the disease, prevention measures, and places to go, if an individual contracts the disease. This information was also transmitted through the official antidengue effort that brought public health workers and other volunteers to the slums to educate residents about the disease (Governo do Rio de Janeiro 2011).
- Geographic information systems (GIS) have helped the Amazonian city of Manaus in Brazil to gather information and identify groups vulnerable to malaria (WHO 2010).
- A heat warning system in Shanghai alerts residents to high temperatures, and the Municipal Health Bureau ensures the

preparation of hospitals and public services during these extreme heat conditions (Tan 2003). Based on research conducted in Hong Kong, such steps could contribute to lower mortality compared to previous heat waves (Chau 2009).

## Water Supply and Sanitation

Clean water supply and sanitation are imperative for public health. Unsafe water and substandard sanitation infrastructure are presently among the primary risk factors for diarrhea, the second leading contributor to global disease burden (UN-Water 2011) (see Public Health section of Chapter 6).

Many cities grapple with the challenge of managing current water use and increasing demand against shrinking future water supply, especially as current water infrastructure and management tend to be inflexible (ICLEI 2011d). In some cases, water sources may be outside of city boundaries and not under city jurisdiction. Robust water administration can be technically complex and expensive, with critical activities as pumping, transportation, and desalination (in coastal areas) requiring energy-intensive infrastructure and highly skilled engineering and management staff. Moreover, many peri-urban areas

and informal settlements continue to face a deficit in sanitation infrastructure, which can undermine progress made on clean water (see also Chapter 5).

## CLIMATE CHANGE IMPACTS

Climate change is expected to intensify droughts, resulting in disruptions to water supply even in humid areas. Water-stressed regions with an annual per capita availability below 1,000m<sup>3</sup> are the most at risk; these include water basins in North Africa and the Middle East, the Mediterranean, South Asia, the United States and Mexico, northeast

### BOX 6.4 FINANCIAL AND HEALTH COBENEFITS OF WATER AND SANITATION

UN Water's 2010 *Global Annual Assessment of Sanitation and Drinking Water* has stated that the provision of improved sanitation and supply of drinking water could lead to a 90 percent reduction in diarrheal diseases. In addition, it has been estimated that every dollar of investment in water and sanitation can bring three to four dollars in benefits. As a result, the WHO Commission on Macroeconomics and Health has called the expansion of access to safe drinking water and basic sanitation a very cost-effective health intervention. These benefits are independent of climate change adaptation.

*Source: UN-Water 2010.*

Brazil, and western South America (Bates et al. 2008, 8). Many cities in arid areas of the world have learned to cope with ongoing scarcity, but others that have long depended on snowmelt, such as those in the Indus Basin and the Andes, may also face the threat of drought. Competition for water within cities, between urban areas and agricultural uses, and among regions, only stands to increase, if adaptive actions are not taken.

Climate change is also expected to result in increased and more frequent flooding because of the disappearance of natural systems that acts as temporal sponges or slow releasers (such as surrounding wetlands). In the absence of proper

sanitation, flooding can, in turn, lead to pollution of water with contaminants from human waste and debris.

### ADAPTATION APPROACHES

A primary low or no-regrets adaptation approach that can be taken to strengthen water supply in cities is to promote and expand sound and transparent water supply administration and sanitation. For example, water utilities can reduce water consumption that does not generate revenue through stricter administration to cut down on clandestine connections and unpaid bills (Danilenko 2010, 19) (see also Chapter 3 for the example of Phnom

**TABLE 6.3 SAMPLE OPTIONS FOR ADAPTATION IN SANITATION**

| Technology                                 | Features   | Issues   |
|--|--|--|
| Pit latrines                               | Small, adaptable design<br>Can be built quickly near existing infrastructure                       | Flooding poses a particular challenge, so may be inappropriate for dense urban areas with high risks of contamination.                               |
| Septic tanks                               | Small-scale sewage treatment system with no connection to main sewerage pipes                      | Flooding could trigger widespread contamination.   |
| Conventional sewerage and sewage treatment | Formal infrastructure<br>Dependent on water flow   | Risk from reduced water availability and flooding of combined sewers.<br>Cost and maintenance requirements.  |
| Condominial sewers                         | Small-diameter pipes at shallow depths under housing blocks, rather than in the middle of the road | Less dependent on water supply to flush waste, because of gravity transportation<br>Construction model tends to incorporate community participation. |

Source: Howard and others 2010; Bantram 2010; Watson 1995, 15.

### BOX 6.5 SAMPLE OPTIONS FOR CITY-LEVEL ADAPTATION IN WATER SUPPLY AND DEMAND

#### Supply-side:

- Desalination of sea water
- Expansion of rainwater storage
- Removal of invasive nonnative vegetation from riparian areas
- Wastewater reuse for watering parks and cleaning streets, and potentially for irrigation and drinking water, with higher levels of treatment

#### Demand-side:

- Improvement of water-use efficiency by recycling water or physical improvements (for example, pipe retrofits)
- Promotion of traditional practices for sustainable water use
- Expanded use of economic incentives, including metering and pricing to encourage water conservation (making sure to consider the existing price burden on residents of informal settlements, who may already be paying higher rates to private water sellers in comparison to residents in wealthy areas that receive municipal supply)
- Awareness raising about water conservation and reclaimed water (as relevant)

Sources: Adapted from IPCC 2008; Danilenko 2010; ADB 2006.

## WATER REUSE IN NAMIBIA AND SINGAPORE

In Windhoek, Namibia, direct potable reuse already constitutes the city's main drinking water supply (Danilenko 2010, 27), after education campaigns gained public acceptance.

In Singapore, with five treatment plants, the NEWater reclaimed water program now meets 30 percent of the country's water demand, with a projection of serving 50 percent of demand by the year 2060 (Government of Singapore 2010).

## FURTHER RESOURCES

Adapting Urban Water Systems to Climate Change—A Handbook for Decision Makers at the Local Level and associated web pages provide access to climate change adaptation resources and good practice examples for city and utility managers of water supply, wastewater, and storm water systems. The handbook was produced through collaboration by ICLEI-Europe, the International Water Association (<http://www.iwahq.org>) and UNESCO-IHE Institute for Water Education (<http://www.unesco-ihc.org/>) as part of the SWITCH project, a research initiative supported by the European Union and a cross-disciplinary team of 33 partners in 15 countries around the world (ICLEI 2011).

The handbook (<http://www.adaptationhandbook.org>) provides the following:

- Specific examples of climate change impacts on urban water infrastructure and water-reliant systems
- Case studies of cities that are working to adapt their water systems to climate change, such as Durban (South Africa), Hanoi (Vietnam), Infanta and General Nakar (the Philippines), Lima (Peru), London (UK), Melbourne (Australia), New York City (United States), Rotterdam (the Netherlands), Semarang (Indonesia), and Toronto (Canada)
- Detailed information on cobenefits of sustainable water management options, including alternative supplies, demand reduction, biogas production from sludge, grey water reuse, green infrastructure (for example, pervious pavements or green roofs), and rainwater harvesting

Additional resources are available at the SWITCH online training desk at <http://www.switchtraining.eu>.

Penh, where the water utility made significant improvements in order to reduce water losses and improve the reliability of the city's water supply). Box 6.4 describes the financial and health cobenefits of water and sanitation.

Many other options can be tailored to local circumstances, in collaboration with utility staff or technically adept humanitarian organizations. Box 6.5 provides a general sample of options for supply-side and demand-side water adaptation; Table 6.3 profiles several sanitation options. These are not exhaustive lists. Moreover, in order to analyze the costs and advantages of these options fully, many cities would benefit from technical knowledge exchanges with other cities around the world, as well as financial support and expertise from their respective national governments.

## Solid Waste

Solid waste originates from a variety of sources, with material types that include electronics, plastics, metals, glass, human fecal matter, and hazardous materials that may be toxic, corrosive, radioactive, flammable, or infectious. Solid waste disposal systems are often logistically complicated and costly, including an operational chain of collection, transfer, and disposal. Capital costs of technologically advanced treatment,

such as anaerobic digestion or incineration, can be prohibitively high (Tchobanoglous and Kreith 2002). As cities grow and need more land, suitable collection and disposal sites can be difficult to acquire and develop.

## CLIMATE CHANGE IMPACTS

In some developing country cities, solid waste disposal systems are often inadequate, if they exist at all. Solid waste is frequently dumped and accumulates in canals, waterways, and areas otherwise intended for water runoff or flood control (Zimmerman and Faris 2010). These conditions make these cities vulnerable to floods and contaminated water from moderate rainfall, let alone intense precipitation and potential storm surges expected with climate change. Areas of uncollected waste can spread existing sources of environmental pollution and health hazards from the materials described above, as well as expand breeding grounds for water and vector-borne diseases. Informal settlements near or on top of dumped waste can also experience landslides as a result of flooding and can catch fire as a result of temperature increases. Table 6.4 describes potential impacts across the solid waste sector, while Table 6.5 describes a sample of impacts specific to types of solid waste infrastructure.

## ADAPTATION APPROACHES

Reducing vulnerability to solid waste-related flooding in cities requires improvement in solid waste management practices. One step is to develop regular and proactive collection of solid waste from drains, streets, and waterways; this can be taken as a low-cost measure in advance of an anticipated storm (Simply Green 2009). Solid waste authorities can also reduce waste-related flooding risks by improving landfill siting decisions with information about geology, groundwater tables, flooding hazards, proximity to surface water, and proximity to vulnerable populations (UNEP 2009a).

Cities can also reduce vulnerability to health risks through practices that avoid or reduce high concentration of pollutants in water after periods of floods or droughts. In collection and disposal services, cities can increase the use of corrosive-resistant, lined and lidded storage systems; minimize accumulation of waste and informal disposal; increase the frequency of collection to remove organic wastes; and minimize the number and spatial coverage of waste disposal sites (UN-HABITAT 2011a). In transfer and transport services, cities can change waste management routes away from surface water supplies or flood plains and ensure accessibility of major routes.

**TABLE 6.4 POTENTIAL CLIMATE CHANGE IMPACTS ACROSS THE SOLID WASTE SECTOR**

| Climate Variable | Potential Change             | Potential Impacts on Solid Waste Management   |
|------------------|------------------------------|---|
| Temperature      | Annual warming               | Increased risk of combustion at open sites and composting.  |
|                  | Thawing permafrost or soils  | Over time, may disrupt drainage and surface water flow around landfill sites.   |
|                  | Increase in mean sea level   | Flooding of facilities and basement/underground-level equipment.<br>Floating waste may wash up with high precipitation or storm surges. |
| Precipitation    | Increased rainfall           | Saturated soils and decreased stability of slopes and landfill linings (if clay or soil based) at waste management sites.               |
|                  | More intense rainfall events | Flooding in areas with untreated, dumped waste carries the risk of groundwater contamination.   |
|                  |                              | Disruptions in the removal and transportation of solid waste.   |

Source: Adapted from Zimmerman and Faris 2010.

**TABLE 6.5 POTENTIAL CLIMATE CHANGE IMPACTS ON SOLID WASTE INFRASTRUCTURE**

| Infrastructure/Component       | Climate Variable | Potential Change     | Potential Impacts on Waste Management  |
|--------------------------------|------------------|----------------------|--|
| Closed and open disposal sites | Temperature      | Increase or decrease | Altered chemical composition of contaminants below the surface, changes in evaporation rates.  |
|                                | Precipitation    | Increase             | Unexpected leaching of contaminants in surface areas of closed landfills.  |
| Marine transfer stations       | Sea-level rise   | Increase             | Impacts on coastal docking and transfer facilities.  |
| Path or roadside refuse        | Precipitation    | Increase or decrease | Damage to waste containment facilities or structures.  |
|                                | Storm surges     | Increase             | Inundation of waste releases contaminants to waterways, pathways, and low-lying areas.<br>Potential for pools of standing contaminated water that promote water and vector-borne diseases. |

Source: Adapted from Zimmerman and Faris 2010.

More broadly, providing broader and better coverage of solid waste services throughout a city, particularly for informal settlements, would be the long-term solution. This involves strengthening existing solid waste operations through improvement of collection, disposal and transfer routes, siting of new facilities and waste management stations, and increased efficiency in the transfer and treatment of waste—efforts that would in any case

be needed in the solid waste sector independent of climate change. Many cities (particularly in low-income countries) face a variety of challenges in addressing solid waste, not least the financing of ongoing solid waste operations.

## Food Security

Urban areas typically produce very little of their own food, leaving urban residents overwhelmingly reliant on food supplies imported from distant rural areas and often even transcontinental shipping. Local food security (see Box 6.6) is often subject to a range of demographic and economic trends at global, national and local scales, including population growth, changes in consumption patterns as income levels rise, competition for agricultural land, and energy and transportation costs. These combined factors can strain food supplies, raise real food prices and make cities vulnerable to food shortages (Easterling and Aggarwal 2007).

### CLIMATE CHANGE IMPACTS

Overall, climate change will lead to insecurity in food supplies for many cities.

- The future may bring larger and more frequent shocks to food supplies and rises in real global food prices. These impacts

would be potentially serious for the most vulnerable populations: poor urban residents who currently struggle to afford food will be the first to be affected when prices rise. In addition, individuals who do not hold formal title to their land may not be able to plant supplementary gardens or own livestock (Anguelovski 2009), reducing their capacity to cope with price shocks. Public discontent over food price rises can also lead to social and political instability.

- Women, children, and minority groups may bear the burden of food crises disproportionately. Women of child-rearing age and young children have more complex nutritional needs and suffer the greatest health impacts during food shortages. In some places, women face cultural, legal, or security obstacles that make them depend on others for food procurement (Dubbeling and Santandreu 2003; Gabel 2005). Minority groups or displaced populations may also lack the social frameworks or market organization to secure consistent food stocks.
- Areas of a city with limited transportation accessibility, such as informal settlements, risk being cut off from food supplies during heavy storms, inland flooding, or coastal storm surges. Similarly, areas with limited

#### BOX 6.6 DIMENSIONS OF FOOD SECURITY

- **Food availability** is the need for sufficient quantity and quality of food to be available in the right place at the right time.
- **Food access** requires that people have adequate resources and the social right to produce or purchase suitable foods for a healthy diet.
- **Stability of access** is achieved when the food supply is uninterrupted.
- **Food consumption** concerns the elements or processes surrounding food that allow for healthy consumption patterns. For example, a lack of cooking fuel can render meat supplies useless, or a lack of clean drinking water may contaminate fresh produce. Any factor that improves the ability of a population to consume their food safely increases food security.

Sources: FAO 2003; Ruane 2010.



connections to a city's main electrical grid may see widespread spoiling of food supplies when electrical supply is interrupted.

## ADAPTATION APPROACHES

City governments do have options for meaningful action on food security, despite the fact that food production depends so heavily on regional, national, and even global conditions, and that agricultural policies tend to be set at the national level. Cities may already see the need to build food security,

with climate change simply serving as a new entry point or an additional reason for action.

Cities can develop local food governance structures (such as a food policy council), raise awareness, and build partnerships on food security. Through partnerships with regional farmers and universities, cities can position themselves as centers of innovation and leaders on food awareness. Cities do not necessarily have to create these partnerships from scratch, but can leverage existing regional networks of institutions focused

on agricultural innovation (Juma 2011). Activities can include the following:

- Establishing an educational exchange with regional farmers to raise awareness about food supply among the general public and exploring social reliance on certain foods that may become scarce or expensive in the future
- Tapping into local and regional expertise around new technologies and cultivation methods that support the diversification of agriculture (Ministry of Agriculture and Forestry of Finland 2005)

### BOX 6.7 URBAN AGRICULTURE IN ECUADOR AND CUBA

Two examples of urban agriculture illustrate its benefits as a win-win strategy to develop food security, while also generating cobenefits in other areas:

- The city of Quito, Ecuador, created a program called AGRUPAR within the metropolitan economic development corporation to aid urban farmers. The program provided the farmers with seeds and training to help improve their agricultural production and commercialization, as well as strengthen their management skills (Anguelovski 2009).
- Faced with a food crisis in the 1990s, Cuba embarked upon a massive effort to promote urban farming, for which day-to-day implementation primarily fell to Havana city officials (Gonzales Novo and Murphy 2001). In Havana, city laws were changed so that gardeners could have legal priority for any unused space; citizens could approach the local government to request specific plots.

Cities can choose to set aside municipal land for urban agriculture through zoning and regulation, ensuring through these land use policies that urban food production will have a place as the city grows. By locating city-owned plots near poor areas and giving priority over the plots to those most in need, city governments can help to build the resilience of vulnerable populations (Henriques 2009).

### FOOD PLANNING IN DURBAN, SOUTH AFRICA

To ensure food security for low-income populations, the city of Durban, South Africa, has initiated field trials of different crops in various locations to simulate future climate projections (Carmin, Roberts, and Anguelovski 2009). The program intends to measure not only the yields of the crops, but also the crops' social acceptability, palatability, and substitutability for traditional crops.

### FURTHER RESOURCES

The *Cities Farming for the Future* program supports 21 cities around the world in multistakeholder policy development and action planning on urban agriculture. More information is available at <http://www.ruaf.org>.

*Food for the Cities* is a multidisciplinary initiative of FAO, coordinating direct assistance to cities through a variety of programs, including the Special Programme for Food Security, the FAO's Decentralized Cooperation Programmes, FAO emergency operations, and TeleFood. More information is available online at <ftp://ftp.fao.org/docrep/fao/012/ak824e/ak824e00.pdf>.

- Promoting urban community gardening as a supplementary source of food, a way to raise public awareness about the complexities of food production, and a small source of food in times of crisis (Mougeot 2006)

City governments can provide social safety nets to protect the poor from hunger. If food availability is a problem, city governments may have the option of distributing food stocks from city warehouses or external donors. In the event that food access has been compromised due to a sudden jump in prices, such financial programs as food subsidies or direct aid may be necessary. Targeted direct cash transfers may be the fastest way to help populations with very limited resources (Brahmbhatt and Christiaensen 2008). Food-for-work requirements may be helpful to garner broad political support for this type of initiative. Finally, city governments can also consider strategies to help residents of informal settlements develop additional sources of food (for example, community gardens and individual livestock), even if they do not hold formal title to their land.

Cities can invest in supplementary food supplies and storage facilities in coordination with emergency response plans to prepare for cases of food shortage. The implementation of material strategies, such as urban agriculture (see Box

6.7), and improving food-related infrastructure (for example, emergency storage facilities) can be valuable. Cities can also establish or improve policies outlining decision-making authority and communications, as well as food distribution priorities, for use in a time of food crisis. Often this can be done with the assistance of regional or national governments.

## Energy

Urban prosperity and quality of life depend in large part on the services of the energy sector to support the energy needs of households, businesses, transportation, health care, water management, and food systems. These needs include lighting, heating, and cooling in both residential and commercial buildings and fuel for transportation and industry (EIA 2010). Many cities currently import energy from distant locations, and city governments often do not have direct control over energy supplies.

### CLIMATE CHANGE IMPACTS

Extreme weather events and acute temperatures can impact energy reliability for city users. The information below is drawn primarily from Ebinger and Vergara's 2011 report for the Energy Sector

Management Assistance Program (ESMAP), unless otherwise noted.

- Extreme weather impacts on electricity transmission and distribution lines can lead to 1) interruption or complete loss of electricity supply and 2) voltage fluctuation, which can damage electrical equipment, even without a complete loss of power. Related disruptions can have consequences for residential and commercial buildings, as well as important city infrastructure and services that rely on electricity, such as health and police facilities, ground and air transportation, wastewater treatment, financial institutions, and telecommunications.
- Extreme heat can increase demand for cooling in all occupied buildings, putting even more pressure on local electricity supply. Energy disruptions in these circumstances, when electricity or air conditioning is not available, can also pose health risks and even threat of death for elderly, disabled, and hospitalized individuals (Klineberg 2002). See section on public health issues for more information.
- Changes in wind intensity, storms, landslides, and erosion can affect pipelines and other transportation infrastructure used for fuel

transport to cities (Cointreau 2010). Offshore oil and gas infrastructure, for example, includes pipelines and fixed platforms that are inherently vulnerable to intense storms at sea (UNEP, IISD, UNITAR 2009). Damage to these facilities can drive up global and regional energy prices. Inundation of roads from flooding can also create barriers to fuel transportation, potentially leading to increased prices and localized reduction in fuel supply.

Energy production and operations may be vulnerable to even small shifts in climate.

- Hydropower generation is especially vulnerable to small climate changes because of its direct dependence on hydrological factors, including precipitation, snowpack, and the volume and timing of stream flows. Changes in climate can affect thermal and nuclear power plant generation cycles, as efficiencies and water needs for heating and cooling are designed for particular ambient conditions, including temperature, pressure, and humidity.
- Climate change may also affect emerging energy technologies. Biomass and biofuels may be affected by potentially lower crop yields associated with changing temperatures (see

also the discussion of agriculture in Food Security section of Chapter 6). Wind and wave energy generation depend on climate variables, such as wind speed, energy density of wind, atmospheric motion, and water vapor content. The impacts of climate change on these areas are still being studied.

### ADAPTATION APPROACHES

Broadly speaking, a sustainable energy system—including energy efficiency, low-carbon urban development strategies, and renewable energy sources—is an important ingredient of city resilience. Developing these approaches at the city level, especially in the area of diversified and distributed renewable energy, may be quicker and more effective at building local energy security than waiting for large-scale energy solutions. These approaches can also yield numerous cobenefits directly for the city and prepare the city for a future in which greenhouse gas emissions and fossil fuel energy may be limited by law.

Energy efficiency, conservation, and renewable energy investments serve as “win-win” adaptation strategies. Conservation and efficiency programs can reduce peak electricity demand and limit the risk of blackouts, while developing distributed energy systems involving cogeneration

and local renewable energy can buffer the effects of interruptions in transmission. At the same time, these investments can also yield multiple potential benefits: financial savings, job creation, and business growth; reduced greenhouse gas emissions and improvements in local air quality; and reduced dependence on imported fossil fuels through diversified local energy production (UN-HABITAT 2011b).

City governments can work with energy utilities and emergency response officials to conduct specific vulnerability assessments, create or enhance emergency warning systems, revisit planning time frames, and adjust design standards to reflect climate impacts on the energy sector (UNEP 2009b; City of Chicago 2001). In planning for potential energy disruptions, cities and other stakeholders can consider such factors as the availability of

### FURTHER RESOURCES

The Energy Sector Management Assistance Program (ESMAP), through the Energy Efficient Cities Initiative (EECI), offers energy planning support to city officials. The Tool for Rapid Assessment of City Energy (TRACE) recommends cost-effective opportunities for energy savings in transportation, buildings, water and waste water, public lighting, solid waste management, and power and heating systems. TRACE is currently being deployed in the cities of Gaziantep (Turkey), Da Nang (Vietnam), Quezon City and Cebu (the Philippines), and Surabaya (Indonesia). More information about TRACE is available online at: <http://www.esmap.org/esmap/node/1143>.

*Source: World Bank 2011.*

backup power, the length of time before serious consequences of energy disruption are felt, the specific nature of consequences from interrupted energy supply, and the demographics of those affected.

Energy sector adaptation can also involve city activities in other sectors, such as buildings, land use, and water resource management.

- Green infrastructure and buildings, including natural forms of shading and highly reflective surfaces or materials, can reduce energy demand for cooling or heating, while positively affecting economic development (Foster and others 2011). Cities can regulate design and retrofit standards to encourage these investments in both new and old buildings.
- A city land-use planning process can be an arena in which stakeholders make and institutionalize key decisions relating to the energy sector, such as where to site energy infrastructure. In particular, cities can advocate, or even mandate, that energy infrastructure be sited or relocated away from vulnerable locations, such as low-lying coastal areas.

- River basin management can also be essential to protecting hydropower potential. Although city officials may not directly control hydropower generation, knowledge of water resource management issues can help ensure that plans for hydropower effectively and equitably balance competing citywide and regional demands for water, including for drinking water, irrigation, hydropower, and fisheries.

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## 7. Financing Adaptation in Cities



photo: Kamira / Shutterstock Images

Many adaptation actions in cities will require the mobilization of financial resources, with the scale of the financial requirements varying depending on the nature of these actions. These actions can range from very large capital investments in infrastructure and other elements of the built environment, to changes in recurrent expenditures based on day-to-day municipal operations. Although the upfront financial costs today can be large, the benefits of taking adaptation actions can outweigh the costs (see Chapter 3).

Since strategies to reduce vulnerability and build adaptive capacity commonly involve basic service provision, cities can seek financial resources from a wide array of local, national, and international sources, both public and private. For climate-specific international funding, cities can benefit from pursuing projects that support a joint mitigation and adaptation agenda, but these funds are limited and can be expected to meet only a portion of cities' total financing needs.

This chapter provides an overview of the costs of adaptation, the existing options for cities to finance adaptation, and ways to create an enabling

financial environment for adaptation. It also offers examples of effective financing approaches in cities that are relevant for adaptation.

## The Costs of Adaptation

Climate change adaptation will add to financial burdens already weighing on cities in developing countries. In any given city, the costs incurred in adapting to changes in climate will depend on that city's particular circumstances—the specific adaptation actions pursued in response to climate impacts experienced. In all cases, the costs of adaptation can be compared to the costs of inaction,

to help create a better understanding of the costs and benefits of alternative courses of action.

At the global level, a 2010 World Bank report on the Economics of Adaptation to Climate Change (EACC) estimated the annual global costs of adaptation for the period 2010–50 to range between \$71.2 billion and \$81.5 billion, depending on the future climate scenario selected. This result is somewhat higher than earlier UNFCCC estimates from 2007. Based on the sectoral breakdowns, more than 80 percent of these costs would be in sectors related to urban areas (see Table 7.1 below). This estimate does not include costs associated with addressing any existing “adaptation deficit”—a lack of capacity to cope with current

climate variability—that countries and cities may face. It also does not account for costs related to nonclimate disaster risks, such as earthquakes and tsunamis, which represented the majority of costs in a World Bank study of three North African coastal cities (see Box 3.3).

Naturally, the scale of adaptation finance needs for a city depends on the city's particular circumstances that drive the nature of specific adaptation activities. City-level adaptation activities that can incur incremental costs include the following (adapted from World Bank 2010b):

- Assessments of vulnerability, risk, and adaptive capacity
- Planning and related community engagement
- Early warning systems and associated public education
- Modification to the proposed design of an investment, resulting in increased construction expenses
- Additional service provision (for example, emergency flood management)
- Increased maintenance and repair costs associated with adaptation
- Conferences, workshops, and trainings for city staff on adaptation

| TABLE 7.1 ANNUAL ADAPTATION COST ESTIMATES FROM UNFCCC AND EACC, BY SECTOR, IN BILLIONS OF DOLLARS |               |                     |                |
|--|---------------|---------------------|----------------|
| Sector   | UNFCCC (2007) | EACC Study Scenario |                |
|  |               | NCAR (wettest)      | CSIRO (driest) |
| Infrastructure   | 2-41          | 27.5                | 13             |
| Coastal Zones  | 5             | 28.5                | 27.6           |
| Water Supply and Flood Protection  | 9             | 14.4                | 19.7           |
| Agriculture, Forestry, Fisheries   | 7             | 2.6                 | 2.5            |
| Human Health   | 5             | 2                   | 1.5            |
| Extreme Weather Events   | —             | 6.7                 | 6.4            |
| <b>Total</b>   | <b>28-67</b>  | <b>81.5</b>         | <b>71.2</b>    |

Note: NCAR is The National Centre for Atmospheric Research, and CSIRO is the Commonwealth Scientific and Industrial Research Climate.

Sources: UNFCCC 2007; World Bank 2010a (The Economics of Adaptation to Climate Change study team).

- Measurement, reporting, and verification of adaptation data over time

Calculating the projected costs and benefits of a specific adaptation activity is a key aspect of the city planning process prior to seeking financing options. Chapter 4 provides guidance on assessing the costs and benefits of adaptation as part of a prioritization process, but cities will need more precise calculations when seeking financing. At the city level, there is as yet no common established method of quantifying climate risks and, therefore, adaptation benefits. This situation poses a particular challenge for cities when securing concessional resources. Box 7.1 summarizes recent estimates that have been made for several coastal megacities in Asia.

#### BOX 7.1 COSTS OF CLIMATE CHANGE IMPACTS IN ASIAN COASTAL MEGACITIES

*Climate Risks and Adaptation in Asian Coastal Megacities: A Synthesis Report*—a two-year collaborative study by the Asian Development Bank, the Japan International Cooperation Agency, and the World Bank—studied the vulnerability of four Asian coastal cities to the impacts of climate change. If current climate trends continue, flooding in Bangkok, Ho Chi Minh City, and Manila is likely to occur more frequently by 2050. Costs from major flood events are estimated to run into billions of dollars, depending on the city and climate change scenario considered, with urban poor populations likely to be especially hard hit. The additional damage from climate change is estimated to be in the range of 2 to 6 percent of regional gross domestic product (GDP). In Metro Manila, without infrastructure improvements, under a high-climate-change scenario a 100-year return period flood could cause aggregate damages of up to 24 percent of regional GDP.

*Reproduced from World Bank 2010c. Also cited in World Bank 2010b.*

## Adaptation Finance Options for Cities

Dedicated funding for adaptation has begun to flow only recently, at about \$1 billion per year (World Bank 2010d). New sources of funding, such as the Green Climate Fund first introduced at UNFCCC COP-15 in Copenhagen, continue to be discussed. It remains unclear, however, how funds such as this will operate. There is also uncertainty surrounding the overall commitment to provide \$100 billion per year for climate change by 2020, and what proportion of this total will be available for adaptation.

Cities have often found it difficult to access available adaptation funding, as well as climate finance more broadly. The reasons for this include difficulties in accessing information on climate finance and limited capacity and experience at the city level to deal with some of its complexities. Such initiatives as the Climate Finance Options website (mentioned above) and capacity building programs have been developed in response to these needs.

Cities also find that the general structure and design of climate finance mechanisms are oriented towards the national level. Most dedicated global funding for adaptation currently flows through national channels, primarily based on priorities set in nationally-adopted climate frameworks, such as National Adaptation Programmes of Action (NAPAs) (UNFCCCa 2011). In order for cities to access more funding, they have to be recognized as important potential partners and implementers of adaptation projects. This has led groups of cities and local government networks to advocate

#### FURTHER RESOURCES

Cities may also find it valuable to research the costs that adaptation projects have incurred around the world. Climate Finance Options (<http://www.climatefinanceoptions.org>), an informational website sponsored by the World Bank and UNDP, and the Adaptation Learning Mechanism website (<http://www.adaptationlearning.net>), both contain project-level information that may be useful for this purpose (Climate Finance Options 2011; Adaptation Learning Mechanism 2011).

for greater recognition and funding for cities and local governments in international climate change frameworks.

However, even if adaptation funding increases with dedicated programs for cities, international funding sources will still likely be insufficient to cover all the adaptation needs of cities. Developing competency in securing funds for local-level adaptation is, therefore, critical for city officials (Brugmann 2011). Various funding sources, such as general funding for sustainable development, private sector sources, and a city's own investment

#### **BOX 7.2 STRATEGIC OPTIONS TO LEVERAGE PRIVATE CAPITAL FOR ADAPTATION IN CITIES**

A recent white paper entitled “Financing the Resilient City” reframes the adaptation challenge in terms of a performance metric for cities. Given the large amounts of capital that the private sector is investing in local infrastructure, the paper outlines a framework for integrating climate change and other risk reduction actions into broader private sector and market-driven instruments in cities. Additionally, it identifies less expensive planning and assessment actions, while using market-based investments to pay for more expensive infrastructure upgrades.

*Source: Brugmann 2011.*

and operating budget, will be essential. Alternative approaches, such as reframing climate change adaptation as resilience upgrades (Brugmann 2011), can also be pursued (see Box 7.2).

This section provides an overview of three broad categories of funding that cities can consider for adaptation: municipal and national finance; grant resources and concessional finance from multi-lateral and bilateral agencies; and market-based opportunities. Although this section does not provide an exhaustive description of the complex array of climate funding opportunities currently available, more detailed information can be found at the Climate Finance Options website (<http://www.climatefinanceoptions.org>).

### **MUNICIPAL AND NATIONAL FINANCE**

Because of their limited financial resources, cities often have to make difficult choices among competing priorities, and climate change adaptation may not initially rise to the top of the list of priorities. As described in prior chapters, however, cities can often build resilience to climate change impacts by investing in already-needed basic services and infrastructure. Seen in that light, adaptation actions would be strong candidates for financing from municipal sources.

**Own-source revenue**—funds generated by a government agency from service payments, taxes, fees, and other receipts—can be used to fund adaptation investments, such as improvements in infrastructure. This source depends on a number of factors specific to a given city, including its legal and institutional authority to raise revenues, the functions that city agencies perform, and public sentiment about taxation (UN-HABITAT 2009).

**Taxes, fees, and charges** are several examples of own-source revenue. These can be designed with specific policy objectives in mind. Table 7.2 summarizes a number of these forms that have potential climate change adaptation benefits in urban land use and buildings. Taxes, especially property taxes, are a potentially powerful tool. Fees and charges can be ideal for funding local services for which specific beneficiaries can be identified and nonpayers excluded. User fees are particularly effective when they recover full costs and are paid according to individual or household use, as these give users incentives for more efficient use of resources.

**Bonds** can be issued to finance long-term investments or current expenditure related to adaptation. Bonds have some advantages compared to loans, with longer maturities, lower interest rates (depending on the credit rating of the borrower), and

simplified collateral requirements. Disadvantages include a higher capacity requirement at the borrower level for preparing and repaying the bonds.

**National financing** for cities varies according to the specific circumstances in a given country. Transfers to local governments may include funds that flow from **national agencies** of transportation, environment, health, and disaster for adaptation activities and investments. In many countries, these are most likely to be general sources of funding (for example, disaster risk reduction or water resource planning) that a city can opt to use in support of adaptation goals.

**TABLE 7.2 LAND USE AND BUILDING TAXES, FEES, AND CHARGES RELATED TO ADAPTATION**

|                  |  |
|------------------|--|
| Taxes            | <p>Property taxes can provide incentives for compact and resilient cities, for example, promoting dwelling types that are denser and away from vulnerable areas.</p> <p>A special area tax could be applied on vulnerable areas, or a set of cascading taxes could be implemented that gradually increases with proximity to vulnerable areas, such as a floodplain.</p> |
| Fees and Charges | <p>Development charges could be used to counter urban sprawl. In general, area-specific charges could give developers incentives to develop compactly and in less vulnerable areas.</p>  |

Source: Authors, adapted from Kamal-Chaoui and Robert 2009.

## MULTILATERAL AND BILATERAL FINANCE

In general, both multilateral and bilateral sources are designed for implementation of national strategies and programs (World Bank 2010b). Access to these may be routed through national governments, requiring coordination and consultation between national and subnational authorities. These sources can be used to fund activities ranging from capacity building and technical assistance, to municipal infrastructure. Examples of sources include the following:

- Global Environment Facility (GEF) (<http://www.thegef.org/gef/>) and the GEF Small Grants Programme (SGP) (<http://sgp.undp.org/>)
- Climate Investment Funds (CIFs) (<http://www.climateinvestmentfunds.org/cif/>), including the Strategic Climate Fund (SCF), which supports the Pilot Program for Climate Resilience (PPCR – see Box 7.3)
- Least Developed Countries Fund (LDCF) and Special Climate Change Fund (SCCF) (<http://www.unfccc.int>)

### BOX 7.3 STRATEGIC PROGRAM FOR CLIMATE RESILIENCE IN BANGLADESH

Located between the Himalayas and the Bay of Bengal, Bangladesh is prone to floods, torrential rains, erosion, and cyclones. It is highly vulnerable to sea-level rise and storm surges with its densely populated, low-lying coastal zones. After a cyclone killed 140,000 people in 1991, the government took action to improve resilience and emergency preparedness. In 2005, it developed a NAPA, which was updated in 2009, soon followed by the Bangladesh Climate Change Strategy and Action Plan (BCCSAP).

Funding from the Pilot Program for Climate Resilience (PPCR) has supported implementation of the BCCSAP, specifically to promote climate-resilient agriculture and food security, improve coastal embankments and afforestation, and fortify water supplies and infrastructure in 12 vulnerable coastal communities. Decentralized government structures and community groups will play a pivotal role in ensuring that programs are flexible and adapted to local needs. As of late 2010, Bangladesh has proposed a \$286 million budget for PPCR to fund water supply, sanitation, and infrastructure improvements to build adaptive capacity in the coastal communities, as well as a \$400,000 feasibility study of climate resilient housing options in the coastal region. Private sector engagement will be critical to enable the program to continue independently of PPCR.

Sources: CIF 2010; Ministry of Environment and Forest and Ministry of Finance 2010; PPCR 2010.

- Adaptation Fund (AF) (<http://www.adaptation-fund.org/>)
- Global Facility for Disaster Reduction and Recovery (GFDRR) (<http://www.gfdr.org/gfdr/>)
- Multilateral Development Banks (MDBs—see, for example, Box 7.4)
- The Millennium Development Goal Achievement Fund

Salient features of these sources are summarized in Table 7.3. The World Bank's issues brief on *Climate Finance in the Urban Context* is also a valuable resource for more information, available online at: <http://wbi.worldbank.org/wbi/Data/wbi/wbicms/files/drupal-acquia/wbi/578590revised0101Public10DCFIB0141A.pdf>.

#### BOX 7.4 WATER AND SEWERAGE MANAGEMENT IN YEREVAN, ARMENIA

Prior to the year 2000, the Yerevan Water and Sewerage Enterprise (YWSE) was in poor financial health with a very dilapidated system. Collections only reached 20 percent, and the utility could not cover its operations and maintenance costs. The infrastructure, inherited from the Soviet era, was in very poor condition, with outdated energy-intensive pumps that frequently broke down and a leaky distribution network with an estimated 72 percent water loss. As a result, service was of very poor quality.

In response, the government of Armenia solicited private sector expertise. In 2000, YWSE entered into a five-year performance-based management contract with private operator Acea Spa Utility (Acea). Over the course of the contract, Acea invested in infrastructure improvements that led to the following: a substantial increase in the duration of water supply from 6 to 18 hours per day; improvement of collection rates from 20 to 80 percent (or over 100 percent including arrears); and a reduction of electricity consumption by 30 percent, resulting in over \$4.8 million in annual savings.

The entire project cost was over \$28.9 million for capital investments, management contract fees, and operator bonuses, including over \$3.4 million to Acea for managing YWSE for five years, and over \$1.4 million in a performance-based bonus for achieving most of the performance targets. The capital investment fund and management contract were financed in part through a \$30.87 million investment from the World Bank.

Source: ESMAP 2011.

## MARKET-BASED FINANCING

Market-based financing offers significant opportunities for investments in cities, including for adaptation. This section describes some of these instruments, which often involve the private sector. The private sector will be an important source of adaptation funding for both private assets and public infrastructure, as observed in the World Development Report 2010. City engagement with the private sector on adaptation could involve the following:

- Privately-held infrastructure that provides public services (for example, transportation, electric power networks, water systems, and solid waste)
- Private properties that can be leveraged to improve adaptive capacity (for example, downtown buildings that could be renovated with green roofs to minimize the urban heat island effect)
- Leverage of private finance to fund a range of dedicated adaptation investments, whether or not a private company has a direct interest in the project

TABLE 7.3 MULTILATERAL AND BILATERAL ADAPTATION FINANCING SOURCES

|   | Global Environment Facility                          | Global Environment Facility Small Grants Programme | Pilot Programme for Climate Resilience   | Least Developed Countries Fund | Special Climate Change Fund | Adaptation Fund  | Global Facility for Disaster Risk Reduction (Track 2) | Multilateral Development Banks            | Private Sector Arms of Multilateral Development Banks | Millennium Development Goal Achievement Fund                                 |
|---|--|--|--|--------------------------------|-----------------------------|--|---|---|---|--|
| <b>FOCUS AREA</b>                                     |  |  |  |                                |                             |  |   |   |   |  |
| Mitigation  | *  | *  |  |                                | *                           |  |   | *   | *   | *  |
| Adaptation  | *  | *  | *  | *                              | *                           | *  | *   | *   | *   | *  |
| Sustainable Development                               | *  |  |  |                                |                             |  |   | *   | *   | *  |
| Disaster Risk Reduction                               |  |  |  |                                |                             |  | *   | *   | *   |  |
| <b>TYPE OF ACTIVITY FUNDED (Restrictions, if any)</b> |  |  |  |                                |                             |  |   |   |   |  |
| Capacity Building                                     | *  | *  | *  |                                |                             | *  | *   | *   | *   | *  |
| Technical Assistance                                  | *  | *  | *  | *                              | *                           | *  | *   | *   | *   | *  |
| Investment  | *  | *(Pilots)  | *  | *                              | *(Institutional)            | *  | *(Post-disaster)                                      | *   | *   | *  |
| <b>TYPE OF FUNDING</b>                                |  |  |  |                                |                             |  |   |   |   |  |
| Grant   | *  | *  | *  | *                              | *                           | *  | *   | *   | *   | *  |
| Loan  |  |  | *  |                                |                             |  |   | *   | *   |  |
| Guarantee   |  |  |  |                                |                             |  |   | *   |   |  |
| <b>FUNDING AMOUNT PER PROJECT</b>                     |  |  |  |                                |                             |  |   |   |   |  |
|   | Up to several million                                | Up to \$50,000                                     | Up to \$1.5 million for preparation.<br>In the range of \$100 million for program. | Average \$3.6 million          | Average \$4.2 million       | Several million  | Several hundred thousand in Track 2.                  | Very broad range of millions to billions. | Very broad range, up to several hundred million.      | Several million; in the range of \$4-8 million.                              |
| <b>ELIGIBLE INSTITUTIONS (Eligible Countries)</b>     |  |  |  |                                |                             |  |   |   |   |  |
| Community-based Organizations                         | All eligible; national government approval required. | *  |  |                                |                             | All eligible with emphasis on most vulnerable developing countries; national government approval required. |   |   |   | All eligible in the 57 MDG countries; national government approval required. |
| Nongovernmental Organizations                         |  | *  |  |                                |                             |  |   |   |   |  |
| Private Sector  |  |  |  |                                |                             |  |   |   | *   |  |
| Local Government                                      |  |  |  |                                |                             |  |   |   | *   |  |
| National Government                                   |  |  | *  | *                              | *(LDCs)                     |  | *(Most vulnerable DCs)                                | *(Most vulnerable DCs)                    | *   |  |

Sources: GEF 2011; UNDP 2011; CIF 2011; UNFCCC 2011; Adaptation Fund 2011; GFDRR 2011; World Bank 2010b; MDG 2011.

## Carbon Finance

Cities that deal with waste management, energy efficiency, and access to energy can be beneficiaries of the carbon market. Many cities are exploring ways to use carbon finance to leverage private and public funding. For example:

- The South Africa City Network is developing a program of energy projects in different
- South African cities based on establishing a framework for carbon finance.
- Amman has partnered with the World Bank's Carbon Partnership Facility (CPF) on that city's low-carbon development strategy and is now a pilot for the Citywide Approach to Carbon Finance (see also World Bank 2010c).
- In Sao Paulo, the revenues from carbon finance have been used to support community

development, thus contributing to building resilience (see Box 7.5).

Further information can be found at <http://wbcarbonfinance.org>.

## Insurance

Insurance and other risk management instruments serve important functions for cities and countries when disasters strike, covering the risks of high-severity, low-frequency events for individuals, public institutions, and private entities. However,

### BOX 7.5 SAO PAULO LANDFILL GAS PROJECT

The Bandeirantes landfill gas recovery facility in São Paulo transforms biogas into a cleaner source of energy and also serves as a source of revenue for community upgrades in nearby neighborhoods. The collected biogas is sold as fuel to the Bandeirantes Thermoelectric power plant, a clean energy power plant, and the sale of carbon credits approved under the CDM have funded parks designed to restore vegetation and control floods, among many other amenities. At the same time, the project has improved local air quality, mitigated climate change through the reduction of methane emissions, supplied 400,000 inhabitants with energy, and created more than 30 local jobs.

As a public-private partnership, the landfill gas recovery facility is operated by Biogás, a private company contracted by the city of São Paulo through a bidding process that was led by the Brazilian government. Biogás took responsibility for the project's financing and risks, as well as the legal procedures that involved CDM approval. Biogás invested R\$12 million in the installation of the gas capture system in 2003, along with R\$45 million in the same year by Unibanco, a private Brazilian bank.

According to the concession agreement, 100 percent of the energy and 50 percent of the carbon credits produced by the landfills belong to Biogás to be traded in the market, while the city of São Paulo has the right to sell the balance of the carbon credits. The city of São Paulo received €13,096,890 in 2007 through the auction of certified emissions reductions (CERs) generated between December 2003 and December 2006.

*Source: ICLEI 2009.*

### BOX 7.6 MULTICAT MEXICO

In 2006, the Mexican government insured its catastrophe reserve fund, the Fondo de Desastres Naturales (FONDEN), against natural disasters with a mix of reinsurance and a catastrophe bond. The resulting contract was linked to a parametric trigger in terms of magnitude and depth of seismicity for the three-year period 2007–09. In 2008, the Mexican government spent \$1.2 billion from the reserve fund to cover rescue and rebuilding operations after Hurricanes Stan and Wilma. The government then decided to work with the World Bank on a new catastrophe bond. As a result, Mexico successfully established the MultiCat Mexico 2009, with the World Bank acting as arranger.

*Source: World Bank 2009.*



private sector insurance is not always robust in developing countries and may not be accessible to the poorest communities.

Dedicated insurance can help to ensure access to immediate liquidity to finance emergency relief and reconstruction operations. For example, the World Bank has developed a catastrophe bond issuance platform, called the MultiCat program, which allows developing country governments to use a standard framework to buy parametric insurance on affordable terms (World Bank 2009; GFDRR 2011b). Box 7.6 describes the MultiCat instrument developed for Mexico. A pool of cities could also use a similar instrument, reducing the average risk for investors and considerably reducing insurance costs through diversification.

### Guarantees

Guarantees are used to improve investor confidence in cases of risk (for example, the lack of a track record of bond issuance). Credit enhancements provided by MDBs can help cities access credit at more affordable terms than would otherwise be available. Through a partial credit guarantee, the guarantor shares the risk of debt service default with lenders on some predetermined basis. This tool can be used to protect private lenders and investors against the

risk of a government failing to perform its contractual obligations. Box 7.7 describes a project in Colombia in which a company sought a partial credit guarantee from the IFC in order to issue a longer-term bond.

### Public Private Partnerships (PPPs)

Many governments are turning to the private sector to design, build, finance, and operate public infrastructure facilities, while receiving a financial return through fees charged to users or payment from the public sector. Public Private

#### BOX 7.7 BOND AND GUARANTEE COMBINED TO FINANCE WATER SUPPLY

In Barranquilla, Colombia, the company Sociedad Acueducto extended water and sewerage services to the southwest area of the city, connecting 350,000 low-income inhabitants to the network. In order to make this investment, the company decided to issue a long-term, local currency bond of \$63 million to refinance its debt. To allow bond maturity of up to ten years in the local capital market, the company sought credit enhancement through the IFC in the form of a partial credit guarantee for up to a maximum of 25 percent of the principal amount.

Source: IFC website 2011.

Partnership (PPP) contracts can vary broadly from a concession to a service contract, but the public sector retains ultimate accountability to the user for providing the service. The main benefit of

#### BOX 7.8 STORMWATER MANAGEMENT AND ROAD TUNNEL (SMART), KUALA LUMPUR, MALAYSIA

Recurring floods and ongoing traffic congestion have had an adverse economic impact on Kuala Lumpur's central business district. The city has addressed both issues with a dual-purpose tunnel that carries both vehicular traffic and storm water, under normal use. During episodes of very heavy rainfall, usually occurring a few times a year, the part of the tunnel that normally carries vehicular traffic can also be used to channel additional storm water.

A joint venture of Malaysian Mining Corporation (MMC) Berhad and Gamuda Berhad served as the contractor for the tunnel. Gamuda proposed a public-private funding initiative for the \$514 million project, with government financing of \$342 million and the remaining \$163 million funded by Gamuda and MMC. The joint venture operates the project under a 40-year concession, collecting a toll of RM2 (66 U.S. cents) from the 30,000 vehicles that use the tunnel daily.

Source: Authors; RoadTraffic-Technology.com 2011; Ingenia 2007.

a PPP is to mobilize private capital, while also improving service quality and the management of the facility. PPPs are now broadly used for public services, such as public transport or water supply, as well as for infrastructure management, such

as highways. Organizations, such as the Public-Private Infrastructure Advisory Facility (PPIAF), can facilitate these arrangements. Box 7.8 describes an example of a PPP in Kuala Lumpur, Malaysia,

which has improved traffic flow, while increasing the city's resilience to heavy rainfall events.

## Creating an Enabling Financial Environment for Adaptation

Both national and local governments can help to create an environment that enables cities, the private sector, and other stakeholders to undertake adaptation actions. Some measures that can be pursued in this regard are described in Table 7.4.

**TABLE 7.4 MEASURES TO CREATE AN ENABLING FINANCIAL ENVIRONMENT FOR ADAPTATION**

| Category of Government Action  | Purpose  | Examples  |
|--|--|---|
| Assessment, measurement, reporting, and verification                 | Demonstrate a commitment to evidence-based and transparent adaptation investment.<br>Demonstrate the logic of public investments and attract additional funding.   | Publication of vulnerability, risk, or adaptive capacity assessments.<br>Tracking and public reporting of adaptation performance indicators on a city's website.  |
| Regulation, plans, and policies                                      | Raise and maintain confidence that the operating environment of a given sector (for example, land use) will be consistent.<br>Demonstrate a commitment to climate change adaptation and an ability to deliver service effectively.<br>Develop a culture of proactive leadership and innovation.    | Sound, consistent and transparent land use administration.<br>Climate-smart policies to influence private sector activity, ranging from stricter land use administration to guide development away from vulnerable floodplain lands, to positive incentives to promote green infrastructure among building and infrastructure developers. |
| Fiscal incentives  | Cover the incremental costs of adaptation (for example, building a stronger foundation for a facility already under construction).<br>Encourage investments primarily dedicated to adaptation (for example, increasing the elevation of existing buildings in zones exposed to frequent flooding). | Tax benefits, subsidies, property taxes differentiated by risk, differentiated insurance premiums, subsidized loans.<br>Provision of cash payments for home renovations that reduce vulnerability can motivate some homeowners, especially if viewed as a time-limited opportunity.   |
| Inducement prizes and public recognition of corporate responsibility | Promote excellence and leadership by example among private sector actors.  | Green building ratings.<br>Corporate sustainability awards.   |

Source: World Bank 2010e and Authors.

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## 8. Conclusion



This guide fulfills several functions for cities embarking on a climate change adaptation effort. It has described an array of adaptation tools and resources that cities in developing countries can employ in understanding and developing responses to climate change impacts, while reinforcing the need to build on existing bodies of work in the field of disaster risk reduction. It has also provided current information on the functions and features of adaptation tools, as well as pointers to further sources of information for those wishing to explore these topics in greater detail.

In addition, this guide has attempted to communicate this information in a way that is useful and practical to city officials in developing countries, in light of particular needs and capacity constraints. Given the concerns facing these cities, the guide has emphasized the unique impacts of climate change on informal settlements, the urban poor, and other vulnerable groups.

Specifically, the preceding chapters of this guide have provided information on the following:

- Aspects of potential climate change impacts on cities
- The basic concepts of adaptation
- Reasons for cities to start adapting now
- Potential partners for adaptation in cities
- Tools to assess vulnerability, risk, and adaptive capacity in cities
- Climate-smart plans and policies for cities
- Setting adaptation performance indicators and evaluating proposed courses of action
- The unique vulnerabilities of the urban poor, residents of informal settlements, and other groups, as well as ways to help them adapt
- Illustrations of sector-specific impacts and adaptation strategies
- Opportunities for financing adaptation in cities

Cities can consider these items as a checklist or roadmap to support their adaptation processes, but it is important to note that adaptation will not be complete, even when all of these tasks have been undertaken. Adaptation is not a one-time effort, but an ongoing cycle of preparation, response, and evolution, in this way similar to disaster risk reduction and sustainable development. Moreover, adaptation is a dynamic process that should be updated periodically based on measurement, evaluation, and learning. Given that this is a rapidly evolving field, the Urban Development Unit of the World Bank will provide updates to this information at <http://www.worldbank.org/urban>.

Over time, the strongest adaptation efforts will be marked by long-term commitment on the part of city leaders and officials to pursue measurable results that yield benefits not only for adaptation but also for sustainable development, disaster risk reduction, and poverty alleviation. Cities that integrate adaptation with these existing priorities will be well positioned to thrive in the new era of climate change.

# Appendix: The Basics of Climate Change Science

The Earth's temperature has increased over the last century, which the international scientific community attributes to greenhouse gas emissions generated by human activities (IPCC 2007a). There is now scientific consensus that these emissions and related temperature increase have led to changes in global and regional climate patterns, which will have a range of impacts on cities and communities around the world (Oreskes 2004).

## Overview of Weather and Climate Change

Cities around the world are familiar with changes in weather. Climate of a given region is defined as the average weather condition over a period of years (Dessler and Parson 2006). Both weather and climate vary from one part of the world to another, based on sunlight, distance from oceans, and altitude (NCAR 2011).

Global and regional climates can also experience changes over time, whether as short-lived cyclical

phenomena or longer-term trends (NCAR 2011). Both natural phenomena and human-induced changes in the atmosphere can change the climate of the planet (IPCC 2007a).

In the past several decades, scientists across the world have observed global changes that they attribute to human causes (IPCC 2007a). Notably, the Earth's average surface temperature and ocean temperature have increased over the past century—and especially in the past 20 years. These shifts in global climate patterns and their resulting impacts are what the international scientific community refers to as “global climate change” (Dessler and Parson 2006).

## What is the Cause of Climate Change?

Historically the Earth has maintained an estimated average temperature of 15°C, ideal for human and other life. Certain gases that naturally occur in the atmosphere keep heat close to the Earth through

what is called the “greenhouse effect” (see Figure A.1). These “greenhouse gases,” such as water vapor, carbon dioxide, methane, and nitrous oxide, are an important part of the atmosphere, because they keep Earth from being too cold for life (Dessler and Parson 2006).

Over the past 100 years, the atmospheric concentrations of these gases have increased (see Figure A.2), resulting in greater heat from sunlight remaining close to Earth, warming up the land surface and oceans significantly (see Figure A.3). The international scientific community broadly agrees that this rising global air temperature is due to human activities that emit carbon dioxide, methane, and other greenhouse gases into the atmosphere, including the burning of fossil fuels, deforestation, and forest degradation (Oreskes 2004; see Figure A.4). In other words, industrial-era human activities and associated increases in atmospheric concentrations of greenhouse gases have led to what scientists now term as the “enhanced greenhouse effect” (IPCC 2007a).

There is further evidence that air temperature increase has led to a rise in ocean temperature, melting of glaciers (also known as snowpack) and sea ice, and a rise in sea levels (see Table A.1). These observations reinforce the scientific consensus that human activities are changing the global climate (Dessler and Parson 2006).

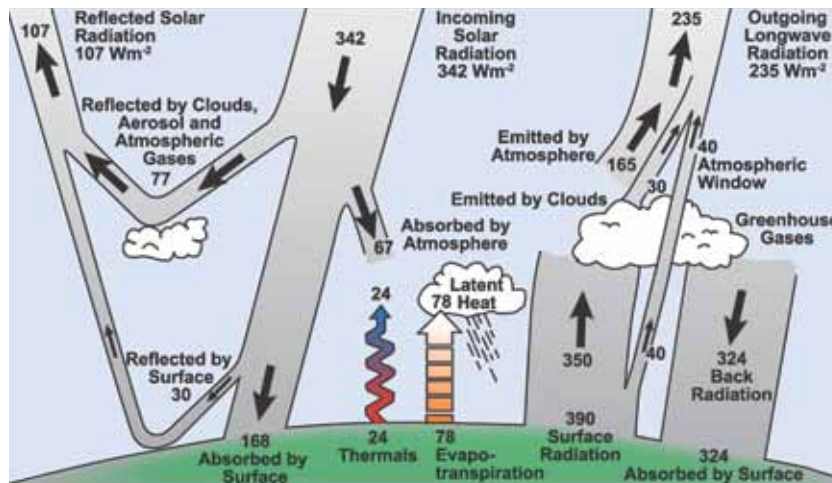
## Projections of Future Climate Change Impacts

Global climate models describe how the Earth system works, predicting how it would react in the future based on the addition of greenhouse gases to the atmosphere, deforestation, and other changes by humans (NCAR 2011). Because the

Earth's climate is very complex, climate models must be based on some assumptions. As understanding of the Earth's climate becomes more advanced, climate models can become increasingly precise.

Based on these models and other climate observations, the Intergovernmental Panel on Climate Change (IPCC) assesses the current state

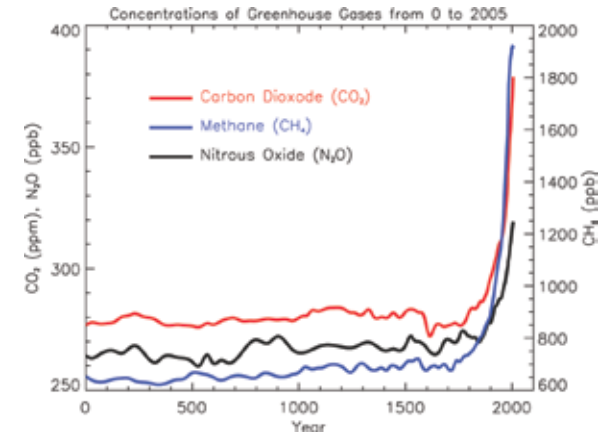
FIGURE A.1 THE GREENHOUSE EFFECT—NATURAL AND HUMAN-INDUCED



Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. *Source:* Kiehl and Trenberth (1997).

*Reproduced with permission from IPCC 2007a.*

FIGURE A.2 ATMOSPHERIC CONCENTRATIONS OF GREENHOUSE GASES FROM YEAR 0 TO YEAR 2005



Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample.

*Reproduced with permission from IPCC 2007a.*



of knowledge on climate change and related impacts (IPCC 2011). Comprised of thousands of the world's leading scientists from across 194 nations, the IPCC was established by the United Nations Environment Programme and the World Meteorological Organization to provide a consensus-based view of climate change, drawing on numerous reports and findings. IPCC assessment reports, which are published every five years, undergo an extensive peer-review and government-review process to ensure both objectivity and technical thoroughness. The IPCC Fourth Assessment Report published in 2007 includes an

authoritative analysis of global climate impacts, as well as a summary for policy makers (IPCC 2007b; Oreskes 2004).

The IPCC has developed consensus that climate change is happening. The IPCC's analysis of the scale and specific nature of future impacts depends in large part on the extent of global average temperature increase resulting from greenhouse gas emissions (see Figure A.5). Several concepts described below illustrate the different factors to be considered when developing a specific understanding of future impacts.

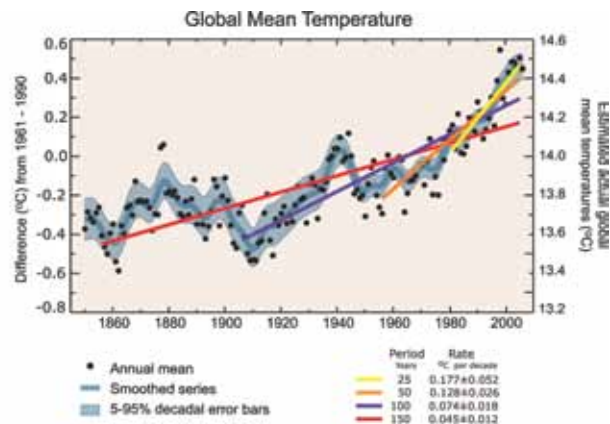
#### FURTHER RESOURCES

The Intergovernmental Panel on Climate Change (IPCC) produces peer-reviewed reports about the causes and impacts of global climate change, based on international consensus. More information is available online at: <http://www.ipcc.ch/index.htm>.

The U.S. National Center for Atmospheric Research provides a website describing basic concepts of weather, climate and climate change at [http://eo.ucar.edu/basics/cc\\_1.html](http://eo.ucar.edu/basics/cc_1.html).

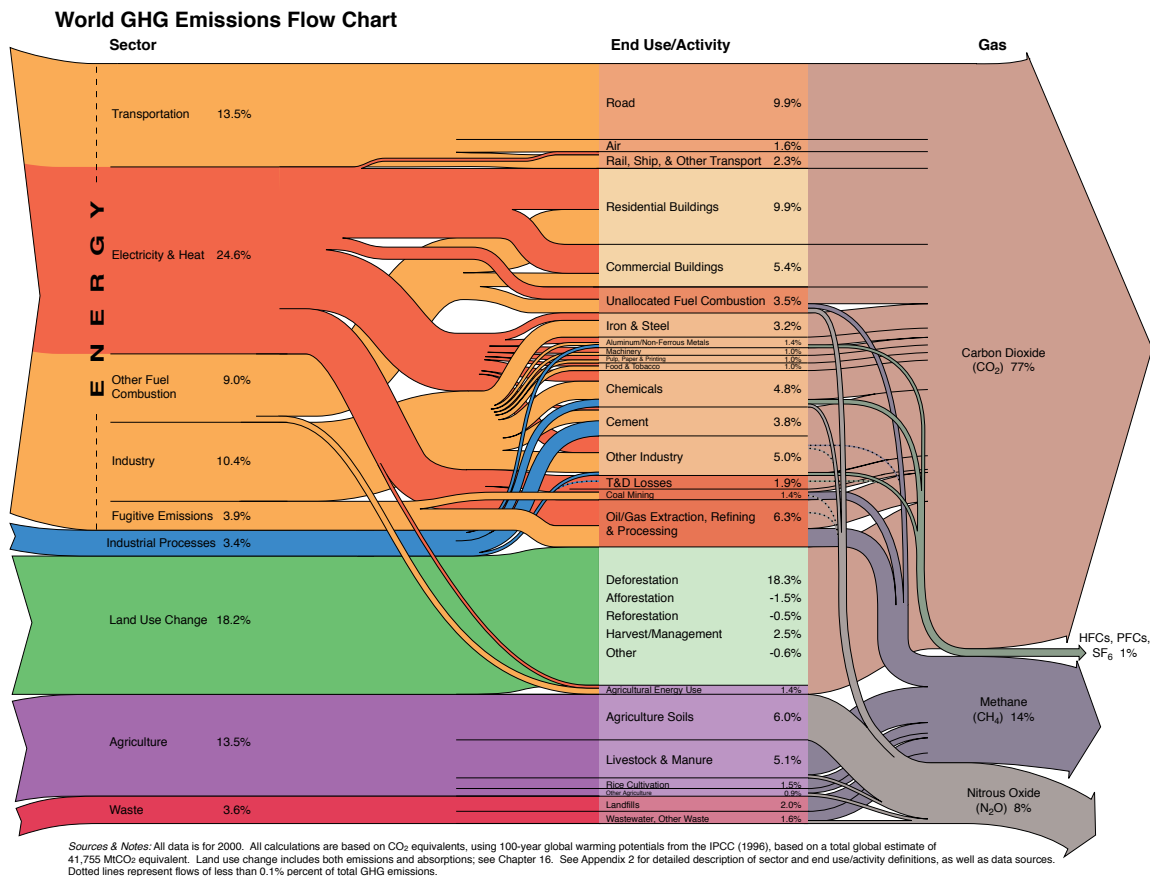
The U.S. National Oceanic and Atmospheric Administration website provides educational resources on concepts related to climate change. Available at <http://www.education.noaa.gov/Climate/>.

FIGURE A.3 GLOBAL MEAN TEMPERATURE OVER TIME



Reproduced with permission from IPCC 2007a.

FIGURE A.4 WORLD GREENHOUSE GAS EMISSIONS FLOW CHART—WORLD RESOURCES INSTITUTE CLIMATE ANALYSIS INDICATOR TOOL



Reproduced with permission from World Resources Institute 2005.

A **positive feedback** may intensify climate changes, while a **negative feedback** may reduce them (IPCC 2007c). Climate feedback in general refers to an interaction between processes in the climate system, in which an initial process triggers changes in secondary processes that in turn influence the initial one.

An example of a positive feedback might be higher temperatures (as the initial process) leading to melting of the arctic ice, in turn leading to less reflection of solar radiation, which results in higher temperatures.

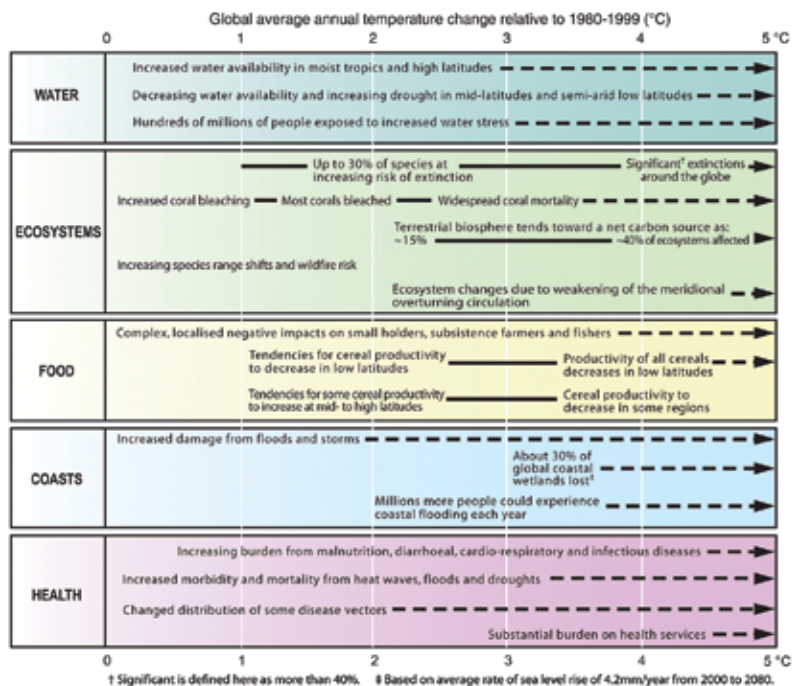
An example of a negative feedback might be higher temperatures increasing the amount of cloud cover (thickness or extent) that could reduce incoming solar radiation and so limit the increase in temperature.

**Inertia** related to climate change mitigation refers to “the difficulty of change resulting from pre-existing conditions within society such as physical man-made capital, natural capital and social non-physical capital, including institutions, regulations and norms” (IPCC 2007c). **Thermal inertia** of the ocean “introduces a lag to the warming of the climate system after concentrations of greenhouse gases are stabilized” (IPCC 2007a).

The term **tipping point** commonly refers to a critical threshold at which a tiny disruption can “qualitatively alter the state or development of a system” (PNAS 2008). In context of climate change, the understanding of tipping points is evolving; most recently they have been defined as

the points at which “human activities may have the potential to push components of the Earth system past critical states into qualitatively different modes of operation, implying large-scale impacts on human and ecological systems.”

**FIGURE A.5 PROJECTED IMPACTS BASED ON GLOBAL AVERAGE TEMPERATURE INCREASE**



Reproduced with permission from IPCC 2007b.

## Regional Impacts of Climate Change

Climate change impacts will vary by region. All regions will experience some impacts as global temperatures increase (see Table A.2).

**TABLE A.1 RECORDED CHANGES**

| Climate Variable        | Type of Recorded Change  |
|-------------------------|--|
| Surface air temperature | Average increase of 0.6°C over the 20th century (~50% occurred between 1980-2000).             |
| Glaciers                | Retreating on average for a few centuries, increase of ~0.75°C/century.                        |
| Sea-level change        | Rise of ~15 cm total over 20th century (~50% due to ocean water warming).                      |
| Sea ice                 | Decrease by ~10-15% over past 50 years (Arctic sea thickness decreased ~40% over same period). |
| Ocean temperature       | Top 300 m has warmed 0.18°C over past 50 years.  |

Source: Dessler and Parson 2006.

| TABLE A.2 POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE DIFFERENT REGIONS OF THE WORLD |  |
|---|--|
| Region  | Potential Impacts  |
| Africa  | <p>Increased water stress for 75–250 million people by 2020.</p> <p>Agricultural production and access to food is projected to be severely compromised in many countries and regions of Africa.</p> <p>Threats to low-lying coastal areas posed by sea-level rise.</p> <p>Further degradation of mangroves and coral reefs projected and additional consequences for fisheries and tourism.</p> <p>Decreased fisheries resources in large lakes, which could be exacerbated by overfishing.</p>  |
| Asia  | <p>Increases in flooding, rock avalanches, and water resource disruption because of glacier melt from Himalayas.</p> <p>Decreased freshwater availability in large river basins of Central, South, East, and South-East Asia, which, in conjunction with population growth and increased demand, could adversely affect more than a billion people by the 2050s.</p> <p>Increased flooding of coastal areas in South, East, and South-East Asia.</p> <p>Ongoing risk of hunger resulting from regional variations in crop productivity, combined with rapid population growth and urbanization, in several developing countries.</p> <p>Morbidity and mortality because of diarrhea associated with flooding and droughts.</p>   |
| Australia and New Zealand   | <p>Intensified water security problems in southern and eastern Australia and parts of New Zealand by 2030.</p> <p>Significant loss of biodiversity in ecologically rich sites by 2020, including the Great Barrier Reef and Queensland Wet Tropics.</p> <p>Increased risk from sea-level rise, more severe and more frequent storms, and coastal flooding in the Cairns region and southeast Queensland (Australia), Northland to Bay of Plenty (New Zealand), and other coastal communities with ongoing development and population growth by 2050.</p> <p>Some initial agricultural benefits in western and southern New Zealand, such as longer growing seasons, less frost, and increased rainfall.</p> <p>Decreased yields from agriculture and forestry by 2030 because of increased drought and fire, in much of southern and eastern Australia and parts of eastern New Zealand.</p> |
| Europe  | <p>Increased risk of inland flash floods.</p> <p>More frequent coastal flooding and increased erosion because of storms and sea-level rise.</p> <p>South: More health-threatening heat waves and wildfires, reduced water availability and hydropower potential, endangered crop production, reduced summer tourism.</p> <p>Central and East: More health-threatening heat waves, reduced summer rainfall, reduced forest productivity, more peatland fires.</p> <p>North: Initial mixed effects, including benefits such as reduced heating demand, increased crop yields, and increased forest growth; as climate change continues, negative impacts likely to outweigh benefits.</p>  |

*continued next page*

| TABLE A.2 POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE DIFFERENT REGIONS OF THE WORLD |  |
|---|--|
| Region  | Potential Impacts  |
| Latin America   | <p>Gradual replacement of tropical forest by savanna in eastern Amazonia because of higher temperatures and reduced soil moisture.</p> <p>Risk of significant biodiversity loss. Adverse effects on coral reefs. Species extinctions in many tropical areas. Shifts in the location of southeast Pacific fish stocks.</p> <p>Loss of arable land in drier areas because of increased salinity and desertification.</p> <p>Decreased yields of some important crops and reduced livestock productivity. Increased soybean yields in temperate zones.</p> <p>Increased risk of flooding in low-lying areas because of sea-level rise.</p> <p>Stress on water availability because of precipitation changes and disappearing glaciers.</p>  |
| North America   | <p>Western mountains: Decreased snowpack, more winter flooding, and reduced summer flows.</p> <p>Increasing impacts on forests due to pests, diseases, and fire, with an extended period of high fire risk and large increases in area burned.</p> <p>In early decades of the century, during moderate climate change, 5–20% increase in total agricultural yields, with important regional variations; major challenges for crops with limited access to water or those near the warm end of their suitable range.</p> <p>Increased intensity, duration, and number of heat waves in cities historically prone to them; the elderly, whose proportion of the U.S. population is increasing, are most at risk.</p> <p>Coastal areas: Increased stress on people and property because of climate change impacts interacting with development and pollution.</p> |
| Polar Regions   | <p>Thinning and reduced extent of glaciers and ice sheets. Changes in the extent of Arctic sea ice and deeper seasonal thawing of permafrost.</p> <p>Detrimental effects on migratory birds, mammals, higher predators, and other species because of changes in natural ecosystems.</p> <p>Negative impacts on Arctic society include threats to traditional ways of life. Positive impacts on Arctic society may include reduced heating costs and more navigable sea routes.</p>   |
| Small Islands   | <p>Threats to vital infrastructure, settlements, and facilities because of sea-level rise.</p> <p>Reduced water resources on many small islands by mid-century, jeopardizing access to fresh water during dry periods.</p> <p>Fisheries impacts and reduced tourism value because of beach erosion, coral bleaching, and other deteriorating coastal conditions.</p> <p>Invasion by nonnative species with higher temperatures, especially on middle and high-latitude islands.</p>  |

Source: IPCC 2007b.

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# Glossary

**Adaptation** refers to initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects (IPCC 2007a).

**Adaptive capacity** refers to the whole of capabilities, resources, and institutions of a country or region to implement effective adaptation measures (IPCC 2007a).

**Climate change** is a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (UNFCCC 1992).

**Climate change impact** refers to the effects of existing or forecasted changes in climate on natural and human systems (IPCC 2007a).

**Climate change mitigation** means implementing policies to reduce greenhouse gas emissions and enhance sinks (IPCC 2007a).

**Climate variability** refers to variations in the average climate beyond that of individual weather events (IPCC 2007a).

**Disaster risk reduction** is the broad development and application of policies, strategies, and practices to minimize vulnerabilities and disaster risk through society, through prevention, mitigation, and preparedness (Twigg 2004).

**Exposure** refers to the nature and degree to which a system is exposed to significant climatic variations (IPCC 2001).

**Green infrastructure** is the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, forest preserves, and native plant vegetation that naturally manages storm water, reduces flooding risk, and improves water quality (Center for Neighborhood Technology 2011).

**Magnitude** refers to the scale (for example, the geographic area or number of people affected) and intensity (for example, the degree of damage caused) of an impact (IPCC 2007b).

**Maladaptation** is any change in natural or human systems that inadvertently increases vulnerability to climatic stimuli, or an adaptation that does not succeed in reducing vulnerability but increases it instead (IPCC 2001).

**Natural hazards** comprise such phenomena as the following: earthquakes; volcanic activity; landslides; tsunamis; tropical cyclones and other severe storms; tornadoes and high winds; river floods and coastal flooding; wildfires and associated haze; drought; sand/dust storms; and infestations (ISDR 2001).

**Resilience** is the ability of a system to absorb disturbances while retaining the same basic structure and ways of functioning; it is the capacity to self-organize and adapt to stress and change (IPCC 2007a).

**Risk** is the combination of the probability of an event and its consequences (IPCC 2007c).

**Sensitivity** refers to the degree to which a built, natural, or human system is directly or indirectly affected by changes in climate conditions (for

example, temperature and precipitation) or specific climate change impacts (for example, sea-level rise or increased water temperature). If a system is likely to be affected as a result of projected climate change, it should be considered sensitive to climate change (Snover and others 2007).

**Vulnerability** is the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, as well as the system's sensitivity and adaptive capacity (IPCC 2007a).

## Glossary References

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## FURTHER RESOURCES

Other documents that may be useful references for definitions include the following:

*Preparing for Climate Change: A Guidebook for Local, Regional and State Governments* (Snover and others 2007, available online at <http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf>).

*On Better Terms*, a UN-ISDR comparative glossary of disaster risk reduction and climate change adaptation terms (UN ISDR 2006, available online at [http://www.preventionweb.net/files/3854\\_Onbetterterms1.pdf](http://www.preventionweb.net/files/3854_Onbetterterms1.pdf)).

UN-HABITAT's *Planning for Climate Change* handbook (UN-HABITAT forthcoming).

*Adapting Urban Water Systems to Climate Change* (ICLEI 2011, available online at <http://www.adaptationhandbook.org>).





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The full guide, including an interactive online version, is available at [www.go.worldbank.org/EEBXYRPRO](http://www.go.worldbank.org/EEBXYRPRO) and [www-esd.worldbank.org/citiesccadapation](http://www-esd.worldbank.org/citiesccadapation).

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