# Urban Areas and Climate Change: Review of Current Issues and Trends

**Issues Paper for the 2011 Global Report on Human Settlements**

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## Executive Summary

This document is a Concept and Issues Paper which will serve as basis to the 2011 UN-Habitat Report on Human Settlements *Urban Areas and Climate Change: Review of Current Issues and Trends.*

Climate change has become one of the most challenging global environmental issues facing humanity. Global warming is created by such societal activities as the combustion of fossil fuels and land use changes, but with wide ranging consequences to our natural world and to human settlements all around the world. While it is a profound global issue, in all of its manifestations and components, global warming is a deeply local issue as well. It is in this context, that urban centers of different sizes – especially cities – play a crucial role in the climate change arena. Urban households, industries and infrastructures are key sources of greenhouse gases. Urban areas concentrate populations, economic activities and built environments, thus increasing their risk from floods, heat waves, and other climate and weather hazards that climate change is expected to aggravate. Many of our urban centers are in the very areas (e.g. coasts) that will make them more vulnerable to adverse climate change events. But beyond the obvious risks and vulnerabilities that climate change will bring to our urban areas, these same urban centers will, by necessity, play a pivotal role in our mitigation and adaptation efforts as well. Urban centers are hubs of development, sources of innovations and policy responses to reduce the emissions of heat trapping gases and adapt to the impacts of climate change. It is this combination, within urban areas, of increased vulnerabilities along with increased opportunities that can incubate important synergies and resources for creating innovative adaptation and mitigation strategies.

This paper will contribute to the wealth of information already available on climate change by going beyond context specific urban case studies and to an understanding of the common ingredients that can help urban centers become better prepared and more resilient to respond changes in climate. It extracts ideas and findings from policy and academic writings on the multiple interactions between urban centers and climate change. It provides an overview of the current state of knowledge and practice and looks, not only at what is known, but also at existing gaps in our knowledge and new directions for work in this area. The paper justifies a report on urban areas and climate change that will help create a conceptual framework to explore and understand the multiple relationships between urban centers and global warming (chapter 2). Chapter 3 provides an overview of the extent of global warming and its urban implications. It describes the main risks to and vulnerabilities of urban centers, and provides some reasons as to why some paths of urbanization relate to increased vulnerability to climate change.

By virtue of the fact that cities are hubs of development, they may also be key drivers of global warming. Chapter 4 explores how large a contribution to global warming urban areas are making. Chapter 5 explores how cities are responding to both the mitigation and adaptation challenges. It explores the opportunities and constraints to these responses, looking at both the synergies and trade offs among mitigation and adaptation actions and development goals.

Urban areas have many linkages with climate change. Urban centers are ***drivers*** of global warming because they concentrate industries, transportation, households and many of the emitters of greenhouse gases (GHG); they are ***affected*** by climate change; and they are sources of ***responses*** i.e., of initiatives, policies and actions aimed at reducing emissions and adapting to climate change.

Urban areas will be faced with increases in the frequency and intensity of heavy rain, storms, droughts, heat-waves and other extreme weather events. The urban centers that will be more at risk are those where these events are already widespread. However, with the expected increase in frequency and intensity of those extremes, risks for these already threatened areas will increase still more. Not of lesser importance, changes in mean temperatures, precipitation levels and sea level will lead to impacts on energy demand, reduction of the draining capacity of sewage systems and long-term increases in vulnerabilities of low-lying coastal cities respectively. A frightening, but not yet fully explored, implication of climate change relates to the possible effects of abrupt changes in temperature and weather patterns.

Climate impacts are not only related to ***exposure,*** but also to ***adaptive capacity***. Urban settlements with a long history of investment in housing, urban infrastructure and services (such as in many high-income countries), and public emergency response (such as in Cuba), as well as those with economic/financial losses much reduced by insurance, will be relatively more resilient to cope with the impacts of climate change. Yet, these urban areas can still be overwhelmed by the increased intensity of storms and by a disparity of vulnerability based largely on access to insurance and income level as seen in the US Katrina experience. These dangers are compounded for urban centers facing ***adaptation deficits***. The main problem for these cities is the lack of provision for adequate roads, piped water supplies and other infrastructures and services that can be depended on in the event of severe weather. Without considering any of the future impacts of global warming, the populations and infrastructures of those urban settlements already show adaptive deficits within the current range of climate variability

While urban areas are hotspots for climate risks, they are also the ***sources of options*** to increase our capacity to cope with climate hazards. There is no doubt that urban areas can be dangerous places to live and work; their populations can be very vulnerable to extreme weather events or other hazards with the potential to become disasters. However, the same concentration of people, infrastructures and economic activities in urban centers that may create weaknesses in the face of climate change hazards gives them strengths by making it possible for them to create economies of scale or proximity or for the creation of many of the measures that may reduce risks from extreme weather events. Furthermore, when provided with policies focused on enhancing sustainability and moving from disaster response to disaster preparedness, urban settlements can increase their effectiveness at coping with climate hazards.

There is no doubt that urban centers play a part as ***drivers of global warming***. However, we are faced with many uncertainties on just how big the urban contribution to global GHG emission is. Existing data lead us to conclude that just as urban centers have

registered different levels and paths of development, they have also shown varying levels of emissions throughout their development cycles. We can not provide definitive answers as to the why it is so, because existing data on emissions levels cover very few cities and have not been gathered applying similar or comparable criteria. We can only say that three factors are relevant ***determinants of carbon emissions***, namely a) ***population***, b) ***affluence*** as measured by GDP per capita, c) and ***technology***, which, among other things, helps reduce energy consumption and carbon emissions by unit of GDP or GNP. We also know that it can be misleading to concentrate on urban emissions per capita, as there are very large differentials between different populations within the same urban centers. Socioecomic ***equity*** is, therefore, clearly another key dimension of carbon emissions by cities. The quality of ***governance structures*** is equally important to explain why some cities have larger carbon footprints than others. Independently of level of affluence, when compared to a city that is poorly managed, a well managed city with a good public transportation system, whose population has access to water and sanitation, to adequate health services, and to a good quality of life, is likely to have fewer problems at dealing with both its carbon footprint and its adaptation challenges.

Existing studies also suggest that the ***weight of different sectors*** in the total emissions of an urban center also *relates to such factors as*: a) **its economic base**, i.e. to whether it is mainly **industrial or service oriented**; b) **its form**, i.e. how dense it is, and the location patterns of its settlements, economic activities, and infrastructure; and c) **the lay out and structure of its transportation systems**, effecting the extent of automobile infrastructure compared to transit.

Although a framework of international negotiations among nation-states remains a crucial mechanism to address climate change, the last decades have witnessed a great increase of ***city-based initiatives and efforts to respond*** to our climate challenge. Case studies illustrate that the two sides of climate change (mitigation and adaptation) have only become a local priority when the local range and extent of projected climate change effects have been understood by local actors, or when it has been linked to issues already in the local agenda such as energy or air quality (as for example in US cities and in Mexico City respectively). Yet, many of our existing actions and responses do not necessarily address climate concerns, or if they do, they focus on only a tiny aspect (e.g., mitigation technologies) of the whole issue (which would necessarily include the linkages of mitigation and adaptation with development). Many initiatives have focused mainly on mitigation with very little or no consideration of adaptation.

Diverse institutional factors have come into play to facilitate or – to the contrary – constrain the effectiveness of policy actions. While the presence locally of political champions, financial resources, local government competencies and capacity, a local history of engagement with environmental issues, and political will to address emerging conflicts may facilitate effective action. The lack of financial and human resources, of decision making power and of other components of institutional capacity has hindered the effectiveness of many efforts. Under the recent process of decentralization and devolution, city officials have been charged with climate relevant responsibilities but often without the funding or political power to make effective action possible.

Some urban centers are undertaking actions to promote adaptation through city-wide initiatives to protect their infrastructures, and provide public funds to deal with natural disasters. Yet, ***adaptation actions*** that take climate change into consideration are occurring **only** on a ***limited basis***, and adaptation measures are seldom undertaken in response to climate considerations alone. Adaptation measures, on the contrary, have multiple social and economic drivers and have been implemented as part of broader development and sectoral initiatives rather than being based purely on climate change.

Adaptation is about enhancing resilience or reducing the vulnerabilities of urban populations and infrastructures to observed or expected changes in climate. Similarly to emissions and mitigation, adaptation has many linkages with the way an urban area develops and is planned and managed. The paths of urban development and urban planning might enhance or, on the contrary, constrain the adaptive capacity of a city's populations, especially of its low-income groups. Adaptive capacity will influence adaptation (the *actual* adjustments made). However, as documented by the 2003 heat-waves in Europe, even relatively high adaptive capacity among urban populations does not necessary translate into measures that reduce vulnerability. Fortunately we have older areas of knowledge and precedent that urban centers can learn from and use in their adaptation efforts. They can, for instance, draw from the longer experience on disaster risk management, which includes not only the stages of disaster response and recovery, but also measures to reduce and prevent disasters. Seven components are important in disaster reduction: strengthening local capacity, land-use planning and management, building codes and disaster resistant construction, protecting critical infrastructures and services, and early warning and, underlying all of these, financing. Of course, to be effective, each of these areas will need to be adjusted according to the predicted impacts and increases in disaster frequency and intensity that will be brought by climate change.

There are both ***synergies and trade-offs*** between actions addressing the mitigation challenge and other policy dimensions (e.g. industrial development, energy, health, air pollution). Policies addressing other environmental problems, such as air pollution, can often be adapted at low or no cost to reduce greenhouse gas emissions and improve the health of populations simultaneously. Trade-offs and synergies also exist between adaptation measures and development. There are good examples of city governments, taking steps to promote development and to reduce vulnerability at the same time. Climate change can and has been already included in the risk management policies and plans of many countries. As a next step, it is important that adaptation and mitigation be evaluated at the same time, taking into account the often explicit trade-offs involved between them when evaluating development plans.

***Both adaptation and mitigation are equally important to address climate change***. Adaptation measures can decrease vulnerability to climate hazards, thus reducing the impacts, while mitigation helps slow the rate of climate change and hence delays the date of impact and its magnitude. Most of the benefits of mitigation are not realized immediately, but rather after some decades; therefore, adaptation is required to address current and near-future impacts. Yet without mitigation, eventually the increasing magnitude of climate change impacts would significantly diminish the effectiveness of

adaptation. While mitigation and adaptation are usually addressed in different policy and institutional contexts, and policies are implemented at different spatial and temporal scales, what is important now is to bridge the gap and view the pair as two sides of the same coin. One without the other will render a coin of little value. Therefore, both mitigation and adaptation will be necessary to assure the continuation of our urban areas, our global community and our species with the impending impacts of climate change. Much further research will be needed, however, on the linkages and feedbacks between urban areas and climate change to fill existing gaps in our knowledge in this area.

## 1. Introduction

Climate change has become one of the most challenging global issues facing humanity. This is an issue created by human induced driving forces such as the combustion of fossil fuels, but with wide ranging consequences to our natural world and to human settlements all around the world. The range of effects has included a warming of sea water temperatures that has given us warning signs such as the collapse of the ice shelves such as Larsen A (1995) and Larsen B (2002) in Antarctica propelling a dangerous sea level rise that now threatens many urban centers along the coasts. At the same time our increasingly warm seas threaten, along with pollution and other anthropogenic or human-related drivers, the very existence of coral reef ecosystems around the world. These changes to our natural world gravely threaten the health and quality of life of many urban dwellers that inhabit our coastal zones. Human responses have likewise been varied in scale, ranging, for instance, from a country's commitment to curb emissions to an individual's decision to take public transportation rather than driving to work. Responses to global warming can, and must, operate at different temporal and spatial scales (Kates and Wilbanks 2003).

While it is a profound global issue, in all of its manifestations and components, global warming is a deeply local issue as well. It is in this context, that urban centers of different sizes – especially cities – play a crucial role in the climate change arena (see definitions of cities and urban centers in Box 1). Urban households, industries and infrastructures within them are key sources of greenhouse gases. Urban areas concentrate populations, economic activities and built environments, thus increasing their risk from floods, heat waves, and other climate and weather hazards that climate change is expected to aggravate. Many of our urban centers are in the very areas that will make them more vulnerable to adverse climate change events. For instance, born of times when cultures and industries needed access to waterways as strategic military ports and as the primary trade routes of our earliest civilizations, population growth has continued in urban areas along coasts as the aesthetic appeal of living near the sea continues to draw new residents and fuel an expansive coastal real estate market. Many of our large cities still lie in coastal zones and these areas have come to have some of the highest population densities among cities, where rises in sea level, predicted to result from climate change, threaten to wreak havoc on coastal populations and infrastructures.

But beyond the obvious risks and vulnerabilities that climate change will bring to our urban areas, these same urban centers may play a pivotal role in our mitigation and adaptation efforts as well. Urban centers are hubs of development, sources of innovations and policy responses to reduce the emissions of heat trapping gases and adapt to the impacts of climate change. It is this combination, within urban areas, of increased vulnerabilities along with increased opportunities that can incubate important synergies and resources for creating innovative adaptation and mitigation strategies. Born of pure necessity, the emerging strategies may give our urban centers the power and possibility to become the loci of change that we will need in order to solve this burgeoning global issue.

Notwithstanding their importance, however, the relationship between urban areas and climate change has been relatively less explored than other areas of research on global warming. This paper is one of the pioneering steps to respond to this challenge. It is based on the assumption that to fully understand both the threats and opportunities presented by urbanization in the context of climate change, it will be necessary to achieve a better integrated understanding of the dynamics and interactions between urbanization and the climate system. As we gain this understanding, we must also fully explore and maximize the effectiveness and efficiency of strategies to mitigate and adapt to climate change in order to pursue more sustainable and resilient development paths both within our urban areas and across the globe.

This paper extracts ideas and findings from policy and academic writings on the multiple interactions between urban centers and climate change. It provides an overview of the current state of knowledge and practice and looks, not only at what is known, but also at existing gaps in our knowledge and new directions for work in this area. The paper offers a justification for a report on urban areas and climate change as well as a conceptual framework to explore and understand the multiple relationships between urban centers and global warming (chapter 2). Chapter 3 provides an overview of the extent of global warming and its urban implications. It describes the main risks to and vulnerabilities of urban centers, and provides some reasons as to why some paths of urbanization relate to increased vulnerability to climate change.

By virtue of the fact that cities are hubs of development, they may also be key drivers of global warming. Chapter 4 explores how large a contribution to global warming urban areas are making. It describes the urban activities and sectors contributing to global warming; it explores not only the underlying drivers of cities' emissions trajectories, but also other factors (such as cities' economic bases) explaining the weight of different sectors in total emissions.

The year 1997 is an important milestone in the climate change arena. Not only were the Kyoto negotiations completed, but there was also a great expansion of public awareness of climate change issues. Changes in the way urban actors responded to climate change threats were made possible by the creation of such programs as Cities for Climate Change Protection (CCP), the Climate Alliance and the Energie-Cités. Since then, a growing movement of cities and local communities seeking to place climate change in the local agenda has occurred. Chapter 5 explores how cities are responding to both the mitigation and adaptation challenges. It explores the opportunities and constraints to these responses, looking at both the synergies and trade offs among mitigation and adaptation actions and development goals.

## 2. Urban areas and climate change

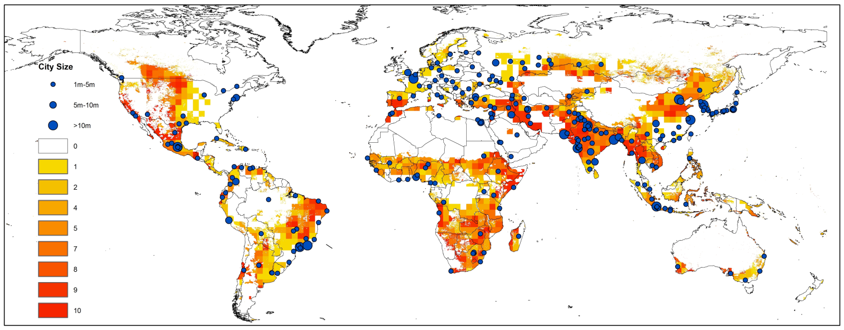
Why should we write a report on climate change, which is global in nature, and urban areas, the most local of the human systems? Many of the studies on the linkages between urban centers and climate change are local in nature, and result from efforts by a loose collection of individual researchers or small research centers, lacking coherence and structure. As a result, it is difficult to harmonize or compare assumptions, tools and research practices within and across different urban centers, thus constraining effective communication and evaluation of results. This paper will contribute to the wealth of information already available on climate change by going beyond context specific urban case studies and understanding common ingredients that can help urban centers become better prepared and more resilient to respond changes in climate. In this section we will provide the justification for a report that focuses on cities and climate change and a conceptual framework to address the multiple linkages between urban centers and global warming.

### 2.1 Why urban centers and climate change?

Urban centers, the most local of the human systems on Earth, will need to pay attention to a global issue such as climate change and to take their place as key players in the climate change arena for many reasons. As illustrated in Figure 1, urban dwellers and their livelihoods, property, quality of life and future prosperity are threatened by the risks from storms, flooding, landslides, heat waves and drought: adverse events which climate change is expected to aggravate. While large population densities in urban areas create increased vulnerability, they also create the potential for city-scale changes in behavior that can mitigate human impacts on climate. Given the failure of international negotiations to achieve the needed consensus on cutting greenhouse gas emissions, our increasingly urban world needs to adapt. The reader can also see in Figure 1 that many of the urban centers with higher risks are located in low- and middle-income countries.

Figure 1:

**Cities in Relation to Current Climate Related Hazards**




Source: A. de Sherbinin, based on Figure 1 of de Sherbinin et al. (2007). Original source data include: For cities: CIESIN (2006), Global Rural-Urban Mapping Project (GRUMP), alpha version (available from http://sedac.ciesin.columbia.edu/gpw/). For hazards: Dilley, Maxx, Robert S Chen, Uwe Deichmann, Arthur L Lerner-Lam and Margaret Arnold (2005), Natural Disaster Hotspots: A Global Risk Analysis, World Bank, Washington DC, 132 pages (available from http://www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html).
Note: The urban areas included in this figure have populations greater than one million. The hazard risk represents a cumulative score based on risk of cyclones, flooding, landslides and drought. "O" denotes "low risk" and "10" denots "high risk".

Urban enterprises, vehicles and populations are key sources of greenhouse gases. For instance, many cities exceed the annual average figure of 2.5 tonnes of $CO2$ per capita suggested by Time for Change (cited by Dodman 2008) as a sustainable annual average (see section 4). However, as noted previously, cities are centers of diverse kinds of innovations that may contribute to reducing or mitigating emissions, adapting to climate change, and making them more sustainable and resilient. Mechanisms for that purpose include changes in transportation, land use patterns, and the production and consumption patterns of urban residents. The economies of scale, proximity and concentration of enterprises in cities make it cheaper and easier to provide the actions and services necessary to minimize both emissions and climate hazards (Dodman 2008).

Most reports on climate change to date have focused on national and global scales. Yet actions to mitigate and to adapt to climate change will take place at the local level as well. These changes may take on an even greater sense of urgency and an earlier

realization within our urban centers  because, urban their inhabitants are ground-zero both for the effects of climate change and mitigation and adaptation strategies aimed at lessening the impacts of global warming. Beyond this, however, cities are the economic and cultural hubs for countries and for the world. The corporate offices of mass media outlets, book publishers and movie studios operate within cities.  Innovations and cultural changes within cities are transmitted outward by media propagation and affect behavior in rural areas as well.

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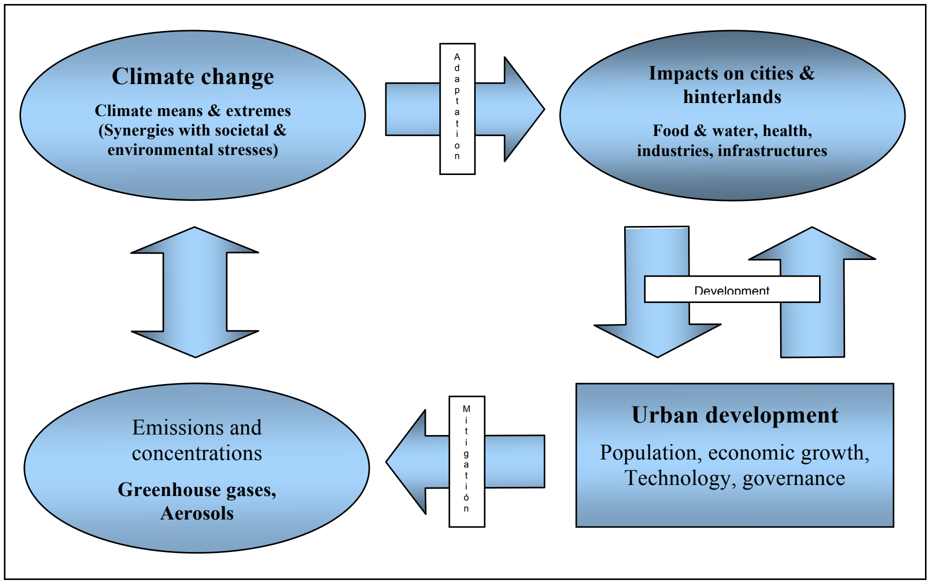
## 2.2 Linkages between cities and climate change

In short, urban areas have many linkages with climate change: urban centers concentrate industries, transportation, households and many of the emitters of greenhouse gases (GHG); they are affected by climate change; and they are sources of initiatives, policies and actions aimed at reducing emissions and adapting to climate change (see Figure 2). In the next sections we will describe some concepts to analyze the interactions between urban centers and global warming, but, before we do, we must emphasize that a report on climate change and urban areas will allow targeted changes in urban and national policies based upon a pulling together our best information to date from the physical and social sciences.  These changes can help set a direction for mitigation and adaptation strategies that will help promote response capacity in urban areas (see Box 1); however, they will also ultimately promote global understanding of the ways in which mitigation and adaptation at the local level help to create synergies of mitigation and adaptation with development at the national and global levels.

**Figure 2: Urban centers and climate change, an integrated framework**




Own based on IPCC (2001)

If we view the Earth's greenhouse effect and its consequences as a dynamic causal chain between cities and climate change (Kates and Wilbanks 2003), the links include lifestyles, demographic dynamics and other *driving forces* of urban activities and infrastructures that produce greenhouse gases. These greenhouse gases, then, not only change the dynamics of the carbon cycle, but also generate changes in the Earth's radiation budget (see Box 1) that induces climate change. The impacts of climate change on urban centers and the resources and ecosystems they depend on result not only from their exposure, but also from their adaptive capacity; there is a necessary feedback loop that conditions adaptation. This feedback may take the form of nature's response to human forcing of the environment, the adverse effects of climate change, or of scientific projections of those events and governmental or civil responses to those projections. The experience and expectation of the effects of climate change encourage a set of human responses to curb emissions, prevent climate change and to cope with any changes that do occur.

Cities are already exposed to the types of climate hazards (e.g. urban heat-island) that global warming is expected to aggravate (Wilbanks and Romero Lankao et al. 2007); however, to fully understand the urban impacts of global warming, it is necessary to focus not only on exposure, but also on vulnerability/adaptive capacity and actual adaptation actions. When we assess the vulnerability of urban populations (see Box 1), it becomes apparent that adaptive capacity, is as key a determinant of impacts as is exposure. Adaptation refers to actions to reduce vulnerability (see Box 1).

The capacity to cope or adapt is influenced by individual/household resources (e.g. asset-bases and knowledge) and by such local resources as the quality and inclusiveness of

community organizations that provide or manage safety nets and other short and longer term responses. Adaptive capacity in urban contexts is also determined by the extent and quality of infrastructure and public services and by the entitlement of populations to those resources and services. The factors that contribute to vulnerability are largely conditioned by the level and type of development within a particular urban area and by an individual or group's access to that development (Wilbanks and Romero Lankao et al. 2007). This is because development has a profound influence on household incomes, education and access to information, on people's exposure to environmental hazards in their homes and workplaces, and on the quality and extent of provision for infrastructure and services.

There can be no doubt that urban centers make a large contribution to global warming. Since the industrial revolution, urban centers have concentrated industries, construction, transportation, households and other activities directly and indirectly involved in the extraction and use of fossil fuels and in the production of construction materials such as cement, thereby releasing the largest quantities of GHG compared to other sources. Other sources, in order of importance, as they occur both inside and outside cities but serve urban development, are deforestation and other land cover changes, agriculture, industrial production, waste disposal, and refrigeration and air conditioning. Yet, as we will discuss in chapter 3, we lack accurate figures on just how large a contribution of heat trapping gases urban centers actually make. Urban activities responsible for greenhouse gases are impelled by drivers such as population, affluence and technology, as well as by values, lifestyles, policies and other institutional, cultural, ecological and economic determinants to be discussed in chapter 3.

Diverse actions are being undertaking at local, state, national and international levels to respond to global warming. Curbing of GHG is the major focus of mitigation requiring measurement at millions of point sources within urban areas. Not of lesser importance, however, are proposed mitigation responses such as the capture of carbon through reforestation, afforestation and stimulation of photosynthesis as well as actions to remove GHG from the atmosphere (carbon sequestration) and to change the Earth's radiation balance (geoengeeniring). To encourage their undertaking, all these actions will demand the creation of international agreements, national policies, corporate decisions and other structures above the local level. Adaptation actions to cope with climate change, however, will mainly take place at the urban and other local levels, yet they will also require the leverage of global, national and state policies, of public support along with basic changes in people's attitudes (Kates and Wilbanks 2003). In this way, global, national, and city level adaptation and mitigation responses and interests are intricately tied together. It is only through gaining a thorough knowledge of the linkages between urban areas and climate change and their larger context within national and global systems that we may hope to create the cohesive response to global warming that we will need in order to stand our best chance of finding solutions that will work.

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**Box 1: Definitions of terms**

**Adaptation (to human induced) climate change** refers to those actions to reduce the vulnerability of a city, its various populations (e.g. children, the poor) or overall population, to the negative impacts of climate variability and change due to emission of

greenhouse gases. Also necessary to adaptation within the context of the city are actions to protect its infrastructure and buildings and the resources and services it depends on such as food and water supply, Adaptation to climate variability is composed of actions to reduce vulnerability to short term climate shocks (with or without climate change). Often adaptation to climate change will also result in adaptation to climate variability as a co-benefit. While individual adaptation, such as the use of air conditioning, is possible, it can undermine collective resilience by contributing to increased GHG emissions, or compromise collective adaptive capacity by allowing more people to live in urban centers located in dry or otherwise vulnerable areas.

**Adaptive capacity** or adaptability is the ability of a system (e.g. a city), a population (e.g. low income groups), a household or an individual to a) adjust to *climate change* (including *climate variability* and extremes), b) reduce or moderate potential damages, c) take advantage of opportunities, or d) cope with the consequences. Adaptive capacity is the opposite of vulnerability (see below). Elements of adaptive capacity include knowledge, institutional capacity and financial and technological resources. Low-income populations in a city will tend to have lower adaptive capacity than the rich/high income populations as they lack access to adequate and stable income sources and to an appropriate and stable asset base (i.e. ownership or right to use land, savings and stores, literacy and educational attainment). They also frequently have poor quality, insecure, hazardous and overcrowded housing, a key factor increasing health threats such as water borne diseases, and indoor air pollution along with other complicating factors such as inadequate provision of public infrastructure and basic services such as safe and sufficient water and sanitation or health care. They have very limited or no safety nets (e.g. governmental health services and support when emergencies occur) that allow people to mitigate risks. In urban neighborhoods characterized by social violence and lack of cohesion, the amount, variety and quality of community interactions, which can act as another source of safety nets, can often be restricted, keeping social capital low. There is a wide range in adaptive capacities between various city and national governments. The amount of adaptive capacity available within these systems is directly related to the resources available to them, the information base used to guide action, the infrastructure in place within them and the quality of their institutions and governance systems.

**Adaptation deficit**: Lack of adaptive capacity to deal with the problems associated with climate variability. Many cities, and at least some of their populations, already show adaptive deficits within the current range of climate variability without regard to any future climate change impacts. In many such cities, and most smaller urban centers, the main problem is the lack of provision for infrastructure (all weather roads, piped water supplies, sewers, drains, electricity, etc.) and the lack of capacity to address this. This is one of the central issues in regard to adaptation because most discussions on this issue focus on adjustments to infrastructure – but you cannot climate-proof infrastructure that is not there. Funding for 'adaptation' has little value if there is no local capacity to design, implement and maintain the needed adaptation.

**Adaptation in situ**: Actions that enable vulnerable populations to successfully adapt to

climate change (and climate variability) while remaining in their current locations, including adaptations made by or supported by local governments. In most instances, vulnerable urban populations would give priority to in-situ adaptation because their current home and location was chosen for its access to income-earning opportunities or familial connections.

**Autonomous adaptation**: Adaptations that occur without any specific planning (e.g. by companies or individuals)

**Climate change risk**: Additional risks to people and their livelihoods/investments (e.g. buildings, infrastructure, etc) due to the potential impacts of climate change. These risks can be direct, as in larger and/or more frequent floods, or more intense and/or frequent storms or heat-waves. They may also be less direct as climate change negatively affects livelihoods or food supplies (and prices) or access to water needed for domestic consumption or livelihoods. Certain groups may face increased risks from measures taken elsewhere in response to climate change. These include adaptation measures (for instance, measures to protect particular areas of a city from flooding which increase flood-risks 'downstream') and mitigation measures (for instance, emphasis on new hydropower schemes that displace large numbers of people).

**City:** The Merriam Webster defines a city as an inhabited place of greater size, population, or importance than a town or village. According to Satterthwaite (2007) "the terms "city" and "urban centre" are often used interchangeably – but they are not the same. The percentage of people living in cities is considerably lower than the proportion living in urban centers, as a significant proportion of the urban population lives in urban centers that are too small to be called cities". Thousands of settlements around the world are classified by their national governments as urban. Yet they lack the economic, administrative or political status that would normally be considered as criteria for classification as a city.
Rather than universally agreed criteria, local and national criteria are applied to define a "city's" boundaries. In virtually all nations, official definitions ensure that urban centers include all settlements with 20,000 or more inhabitants. However "governments differ in what smaller settlements they include as urban centers – from those that include as urban all settlements with a few hundred inhabitants, to those that only include settlements with 20,000 or more inhabitants. This limits the accuracy of international comparisons of urbanization levels because most nations have a large part of their populations living in settlements with populations in this range of 500 to 20,000 inhabitants" (Satterthwaite 2007).

**Development paths** can be defined as integrated trajectories of interaction between human and natural systems over time at a particular scale. They are conditioned by a complex array of technological, economic, social, institutional and cultural characteristics that define a unique pathway of development. Such technological and socio-economic development pathways may be represented and analyzed using integrated scenarios.

**Greenhouse gases** are those gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, absorbing and emitting radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, atmosphere, and clouds. The accumulation of greenhouse gases causes the *greenhouse effect whereby a shift in the emission and absorption properties of the Earth's atmosphere brings about a gradual warming of the Earth.* The primary greenhouse gases in the Earth's atmosphere are water vapor (H2O), *carbon dioxide* (CO2), nitrous oxide (N2O), methane (CH4) and *ozone* (O3). Besides CO2, N2O, and CH4, the *Kyoto Protocol* includes as GHG sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

**Limits to adaptation** result from the fact that adaptation can reduce the adverse impacts of climate change considerably; yet it cannot reduce them to zero. Adaptation actions can not protect cities from certain impacts of climate change; for instance coastal zones inundated by sea level rise. The less successful mitigation actions are, the more limits are imposed to adaptation.

**Mainstreaming**: Although consensus on a definition of mainstreaming does not yet exist, the term is widely used, many times interchangeably with integration. Mainstreaming refers to the integration of both mitigation and adaptation objectives, strategies, policies, measures or operations such that they become part of the national and regional development policies, processes and budgets at all levels and stages.

**Mal-adaptation**s: Actions or investments that increase vulnerability to climate change impacts rather than reduce it. This can be the result of transferring vulnerability from one social group or place to another; it can also result from shifting risk to future generations and/or to ecosystem and ecosystem services. In many cities, investments being made are in fact maladaptive rather than adaptive. Identifying and removing mal-adaptations is often the first task to be addressed even before making new adaptations.

**Mitigation** is defined by IPCC as a human intervention to reduce greenhouse gas emissions, thereby reducing the anthropogenic forcing of the *climate system*; it includes strategies to reduce *greenhouse gas sources* and emissions and enhancing *greenhouse gas sinks*.

**Mitigation and adaptation linkages**: The intent of mitigation is to avoid the negative impacts of climate change in the long run (at least any increased impacts due to greenhouse gases not yet emitted). While adaptation can reduce unavoidable climate change impacts in the near term (but cannot reduce them to zero), failure to mitigate will lead eventually to failure of adaptation. Therefore, adaptation and mitigation are complementary strategies that need to be pursued in a coordinated and synergistic way.

**Planned adaptation** is planning in anticipation of potential climate change. Generally, government agencies have key roles in providing the information about current and likely future risks and providing frameworks that support individual, household, community and private sector adaptation. However, it is possible that some governments will not fulfill this role and civil society organizations might need to be the initiators and

supporters of planned adaptation in these cases.

**“Radiative forcing”** has been employed by IPCC to “denote an externally imposed perturbation in the radiative energy budget of the Earth's climate system. The Earth Radiation Budget is the balance between incoming energy from the sun and the outgoing longwave (thermal) and reflected shortwave energy from the Earth. Such a perturbation can be brought about by changes in the concentrations of $CO_2$, aerosols and other greenhouse gases in the atmosphere, or by changes in the solar irradiance incident upon the planet. This imbalance in the radiation budget has the potential to lead to changes in temperature and other climate parameters and thus result in a new equilibrium state of the climate system.

**Resilience** refers to the capacity to maintain core structures and functions in the face of climate threats and impacts, especially for vulnerable populations. It is a product of governments, enterprises, populations and individuals with strong adaptive capacity. It frequently requires a capacity to anticipate climate change and plan needed adaptations. The resilience of a city, its populations and economic sectors to climate change and variability interacts with its resilience to other dynamic pressures including economic change, conflict and violence.

**Response capacity** describes the ability of societies and their demographic and economic groups to manage both the generation of greenhouse gases and the associated consequences. Response capacity is given by a broad pool of resources, many of which are related to a group or country’s level of socio-technical and economic development, which may be translated into either adaptive or mitigative capacity. Institutional settings and capacities as well as belief systems, cultural values and other socio-cultural dimensions, which are often not addressed to the same extent as economic elements, can also affect response capacity (Klein and Huq et al. 2007).

**Urbanization** is, in statistical terms, an increasing proportion of a population living in settlements defined as urban centers. The immediate cause of most urbanization is the net movement of people from rural to urban areas. Extensive urban-to-rural migration flows may also take place, but urbanization takes place when there is more rural-to-urban than urban-to rural migration. Growth in urban population is defined as an increase in the proportion of the population living in urban areas).

**Vulnerability** is the degree to which a city, its populations, economic sectors and infrastructures are susceptible to the adverse affects that the increase in *climate means* and extremes *resulting from climate change is expected to generate*. Vulnerability is a function of both exposure and sensitivity. The first refers to the character, magnitude, and rate of climate change and variability to which a city is exposed. *Sensitivity*, on the other hand, refers to a city’s adaptive capacity, with lower adaptive capacity equating to greater sensitivity.

Sources: Satterthwaite et al. (2007), IPCC (2007), Satterthwaite and IPCC (2007a).

## 2.3 Key actors in the climate change arena

In this section we present the actors with stakes in city relevant efforts to both curb GHG emissions (mitigation) and adapt to climate change. The actors include international multilateral and bilateral organizations, the different tiers of government, grassroots groups, private enterprises, non-governmental organizations and individuals to be described later in this section. It has been found that when viewed in sectoral terms different actors would be involved in the implementation of mitigation from those involved in adaptation actions. The former frequently includes the energy, transportation, forestry and agriculture sectors. Actors involved in adaptation represent a large variety of interests, including agriculture, tourism and recreation, energy, human health, water supply, coastal management, urban planning and nature conservation (Klein and Huq et al. 2007).

Note that in many countries the policies and actions to mitigate and adapt to climate change are increasingly taking place in the context of a transition from government to governance, as the roles of the public, private and social sectors are restructured (Bulkeley and Betsill 2003, see Table 1). This is resulting in new *geographies of governance*, given by a redistribution of state-functions upwards to international and transnational organizations and institutions; downwards to states, regions, urban areas and *cities*; and outwards to NGOs, civil organizations and other non state actors.

Rather than weakening the power of the nation-state, these processes are leading to redistributions of functions and responsibilities (e.g. decentralization, privatization of urban services and infrastructures), and to multilevel structures of governance (Bulkeley and Betsill 2001; Lemos, M. and Oliveira, J.L.F. 2004, Wilder and Romero Lankao 2006) *where urban areas are playing a vital role*. Not only are they responsible for the provision of services previously in the hands of national governments (decentralization and devolution); they are also involved in initiatives seeking to implement solutions to global warming – e.g., C40, Climate Alliance (see Box 3). Structural adjustment programs of the 1980s and 1990s often included decentralization and offloading of national responsibilities for service provision to local authorities and private enterprises (Wilder and Romero Lankao 2006). The problem is that in many cases, the additional burdens of service provision did not come with sufficient resources. This has undermined the institutional capacity of local authorities and, hence, the resilience of urban centers.

**Table 1: From government to governance**

| | Old government | New governance |
|---|---|---|
| Location of power | The state, private sector | The state, civil society, private sector |
| Exercise of power | Hierarchy and authority | Networks and partnerships |
| Actors | The public sector | Public, private and voluntary sectors |

| | | |
|---|---|---|
| Role of the state | Providing, commanding, controlling | Steering, enabling, facilitating, bargaining |

Source: slightly adapted from (Bulkeley and Betsill 2003: 17)

Which are the organizations and institutions operating at the international level? The most important international institutions or regimes are the United Nations Framework Convention on Climate Change (UNFCCC) the Intergovernmental Panel on Climate Change (IPCC) and the "The Kyoto Protocol". They have served to establish climate change as a legitimate global concern (Bulkeley and Betsill 2003). The Protocol sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions to an average of five per cent against 1990 levels over the five-year period 2008-2012. This is based on the principle of "common but differentiated responsibilities". The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. 180 countries have ratified the treaty to date. As can be seen Box 2, it also has a fund to help low- income countries adapt to the impacts of climate change. The goal of IPCC is to "assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change, its potential impacts and options for adaptation and mitigation". IPCC assessments and technical reports are collective, deliberative processes by which experts review the state of scientific knowledge, and synthesize it with a view to providing information of relevance to policy or decision makers involved in UNFCCC.

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Box 2: The Kyoto Protocol

Under the protocol, countries must meet their mitigation targets primarily through national measures. However, the Kyoto Protocol offers them an additional means of meeting their targets by way of three market-based mechanisms:
a) Emissions trading or "the carbon market" (Article 17), according to which Annex B nation-states (those with binding commitments) that exceed their allowed emissions can offset them by buying "credits" from countries that stay below their allowed emissions; b) the clean development mechanism (CDM, Article 6) allows private actors in high-income countries to invest in mitigation actions in other countries, and obtain credit for the "emission reduction units"; and c) joint implementation (JI, Articles 12) allows Annex B countries to comply with their reduction targets by investing in mitigation activities in middle- and low-income countries. An open question is whether a potential exists for urban settlements to tap into this carbon market (see section 5.3).

These mechanisms help countries – also known as Parties – meet their emission targets in a cost-effective way. Under the Protocol, countries' actual emissions have to be monitored and precise records have to be kept of the trades carried out. The UN Climate Change Secretariat, based in Bonn, Germany, keeps an international transaction log to verify that transactions are consistent with the rules of the Protocol. Reporting is done by Parties by way of submitting annual emission inventories and national reports under the Protocol at regular intervals. A compliance system ensures that Parties are meeting their

commitments and assists them if they have problems doing so.

The Kyoto Protocol seeks also to assist countries in adapting to the adverse effects of climate change. It facilitates the development and deployment of techniques that can help increase resilience to the impacts of climate change. It has an Adaptation Fund to finance adaptation projects and programs in developing countries that are Parties to the Protocol. The Fund is financed mainly with a share of proceeds from CDM project activities.

Source UNFCCC http://unfccc.int/kyoto_protocol/items/2830.php Viewed on July 28 2008

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Many UN organizations are contributing by collecting and disseminating information and building national capacity for both mitigation and adaptation (e.g. IPCC, UN-Habitat, the Natural Disasters Unit of the Bureau for Crisis Prevention and Recovery: UN-BCPR). UN organizations are also participating in the management of climate change (e.g. UNFCCC). The World Bank, the Global Environment Facility (GEF) and many Regional Development Banks, (e.g. the InterAmerican Development Bank, the Asian Development Bank) are also addressing climate change together with international organizations and NGOs.

The international climate change regime and its organizations have provided a forum in which, through interactions and negotiations between different actors, the interests of countries around climate change have been defined and contested. National governments have the primary responsibility for signing international agreements, curbing GHG emissions and coping with climate hazards. It is also within their sphere of responsibility to encourage their local administrations to take appropriate steps to enhance urban planning, and mobilize the necessary support from the public and private sectors to curb GHG emissions and adapt to climate change. That said, national mitigation strategies as well as adaptation and disaster management plans often omit urban areas (Bulkeley and Betsill 2003, Pelling 2005, Satterthwaite et al. 2007).

National states are unable to meet their international commitments for addressing both mitigation and adaptation without local action. Not only because green house gas emissions originate in activities, individual behavior, and processes embedded in cities, urban centers and other local places, but also because many impacts of climate change are locally felt. Many local governments have authority over land use planning and waste management, and can play a key function in making sure new developments are not located in risk prone areas. Local governments can influence transportation choices through policies aimed at constructing bike and walking paths and public transportation systems rather than building roads and supplying parking spaces.

Subnational levels of government (for example state, provincial, and local) are increasingly involved in mitigation and adaptation actions. Not only are urban centers involved through many interactions with their national governments, or through the fact that the capacity for local government to build resiliency is greatly determined by its

organizational structure and relationship to the national government, but also because of the increased involvement of urban centers in transnational interactions through which multi-level governance takes form (Bulkeley and Betsill 2003). Examples of this kind of interactions are the Cities for Climate Protection Program and the C40 (see Box 3).

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Box 3: Multilevel-governance of climate change

Cities are increasingly involved in transnational and subnational networks which represent a form of environmental governance, "multilevel-governance", happening across multiple scales (Bulkeley and Betsill 2003), namely the Cities for Climate Protection (CCP), the C40, Climate Alliance.

ICLEI is the International Council for Local Environmental Initiatives. Local governments participating in ICLEI's *Cities for Climate Protection* (CCP) Campaign commit to undertake and complete five performance milestones, namely a) conduct an energy/emissions inventory and forecast, b) establish an emissions target, c) develop and obtain approval for the Local Action Plan, d) implement policies and measures, and e) monitor and verify results. See ICLEI 2006: April 20 2006 www.icle.org).

The Large Cities Climate Leadership Group, also known as the **C40 Cities** (and originally as the C20 Cities) is a group of cities as diverse as Chicago, Cairo, Mumbai and Sydney committed to both reducing urban carbon emissions and adapting to climate change. It believes it has an important role to play because cities contain around 50% of the world's population, and consume a high share of the world's energy.

The Climate Alliance is an alliance of European cities and municipalities that have developed a partnership with indigenous rainforest communities. Its aim is to preserve the global climate through a two-fold mechanism: reduction of greenhouse gas emissions by high-income countries and conservation of forests in middle- and low-income countries.

Created in 2001, the Majors Alliance on Climate Change Protection in the US seeks to foster local action to reduce greenhouse gas emissions. It was created as a reaction to the refusal of the U.S Federal Government to sign the Kyoto protocol and concerns about the impacts of climate change on cities. As of the end of 2007, it had 700 members representing small, medium and large urban areas.

For more information on other initiatives see Dawson et al. (2007 Appendix A)

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Local actors such as individuals, households and community-based organizations (CBOs) play a role as emitters and in the success or failure of mitigation efforts; in facilitating the integration of climate-risk reduction; in emergency response and development planning. Through their local knowledge, CBOs, for instance, can be a vehicle for more inclusive

urban governance. Grassroots should not be idealized. It should be kept in mind that their extensive involvement in many efforts is difficult (Pelling 2005). Sometimes, local associations are closely related to the state, or hold private or sectarian interests that distort local action. Change is perhaps most difficult in settlements within countries that have experienced strong centralized control. As documented in Guyana and Vietnam (Pelling 1998), the attempt by the international community to modify urban governance through the funding of community sponsored development projects runs the danger that local elites or state agents capture the benefits of grassroots funding.

NGOs are plentiful in large cities but tend to be less common or even absent from smaller urban settlements. Local NGOs are well placed to produce, accumulate and transfer knowledge. As partners in development projects aimed at reducing emissions, capturing carbon and reducing risk they are cost effective, increase transparency and accountability to beneficiaries and strengthen inclusive governance. However, by increasing their accountability to upper levels of governance, NGOs can lose their flexibility and contesting power. This can distance them from grassroots partners reducing inclusiveness and horizontal accountability (Pelling 2005). NGOs can add sustainability and resilience to urban systems by providing a channel for feedback between the grassroots and urban government or international civil society actors (Pelling 2005).

The private sector has received great attention as an important player in efforts aimed at curbing GHG emissions, i.e., in producing more efficient vehicles and utilities, creating technologies to use alternative energy resources, and constructing controlled waste water treatment plants (see IPCC 2007, and Table 4 below). However, the private sector has been subject to comparatively little attention in the analyses of adaptation to climate change. This is beginning to change as privatization policies have led to the shrinking of the state and a greater role for commercial interests. Be that as it may, as yet few private sector actors have engaged with disaster mitigation or vulnerability reduction in the city. The role of private security firms and privatized health care during emergency periods requires greater study with potentially profound implications for governance in urban risk management and disaster response (Pelling 2005).

## 3. Global warming and its impacts on urban centers

In its Fourth Assessment Reports the Intergovernmental Panel on Climate Change (IPCC) draws many conclusions relevant to the understanding of the relationships between urban centers and climate change. First it is unequivocal that the Earth's climate is warming. This is evident from observations of phenomena such as increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level. Not only that, there has been an increase in the frequency and severity of storms, precipitation, droughts and other weather extremes (see Box 4). Since the dawn of the industrial era, concentrations of carbon dioxide and methane have increased at a rate that is "very likely to have been unprecedented in more than 10,000 years," and urban centers have played a key, though not yet fully understood, role in this process.

**Box 4: IPCC Findings on Recent Climate Change**

**Rising Temperatures**

• Eleven of the last 12 years rank among the 12 hottest years on record since 1850, when sufficient worldwide temperature measurements began).

• Over the last 50 years, "cold days, cold nights, and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent."

Increasingly Severe Weather

• The intensity of tropical cyclones (hurricanes) in the North Atlantic has increased over the past 30 years, which correlates with increases in tropical sea surface temperatures.

• Storms with heavy precipitation have increased in frequency over most land areas. Between 1900 and 2005, long-term trends show significantly increased precipitation in eastern parts of North and South America, northern Europe, and northern and central Asia.

• Between 1900 and 2005, the African Sahel, the Mediterranean, southern Africa, and parts of southern Asia have become drier, adding stress to water resources in these regions.

• Droughts have become longer and more intense, and have affected larger areas since the 1970s, especially in the tropics and subtropics.

**Rising Sea Levels**

• Since 1961, the world's oceans have been absorbing more than 80 percent of the heat added to the climate, causing ocean water to expand and contributing to rising sea levels. Between 1993 and 2003 ocean expansion was the largest contributor to sea level rise.

• Melting glaciers and losses from the Greenland and Antarctic ice sheets have also contributed to recent sea level rise.

**Melting and Thawing**

• Since 1900 the Northern Hemisphere has lost seven percent of the maximum area covered by seasonally frozen ground.

• Mountain glaciers and snow cover have declined worldwide.

• Satellite data since 1978 show that the extent of Arctic sea ice during the summer has shrunk by more than 20 percent.

Source: IPCC (2007c).

Second, the dramatic rise in energy use, land use changes, and emissions between 1970 and 2004 has resulted from such factors as increased per capita income (up 77 percent) and population (up 69 percent). Not every country has contributed at the same level to global warming. In 2004 for instance, high-income countries accounted for 20 percent of world population and 46 percent of global emissions. Developing countries generated one-fourth the per capita emissions of developed countries. A progressive decoupling of income growth from carbon emissions has taken place through improvements in energy intensity (total energy used per unit of GDP; down 33 percent). Yet, the rate of improvement has not been enough to globally reduce the emissions of heat-trapping gases. In this context, humanity is facing two main challenges: The need to adapt to some degree of continued warming because past emissions will stay in the atmosphere for decades or more. The need to mitigate, i.e., to achieve development paths that involve emissions peaking by 2015 and heat-trapping gas concentrations in the atmosphere stabilizing around the end of the century at about 445 to 490 parts per million by volume (ppm) of CO2-equivalent. This path would allow us to keep equilibrium global average temperature increases within 2 to 2.4 degrees Celsius (°C), above pre-industrial levels, thereby avoiding some of the most damaging and irreversible impacts (IPCC 2007).

### 3.1 Implications of climate change for urban centers

Climate change has a variety of potential implications for urban areas, some of which have already been pointed out by scholars (Bigio 2003, Wilbanks and Romero Lankao et al. 2007, Satterthwaite et al. 2007, Hunt and Watkiss 2007, see Table 2). In terms of *exposure*, a key risk relates to the increase in the frequency and intensity of heavy rain, storms, droughts, heat waves and other extreme weather events. The urban centers more at risk are those where these events are already widespread. However, it is expected that

the frequency and intensity of those extremes will increase. Not of lesser importance are changes in mean temperatures, precipitation levels and sea level which will lead to adverse impacts on energy demand, reduction of the draining capacity of sewage systems and long-term increases in vulnerabilities of low-lying coastal cities respectively (Wilbanks and Romero Lankao 2007 et al. 375). A not yet fully explored implication relates to the possible effects of abrupt climate change.

**Table 2: Projected impacts on urban areas of changes in extreme weather and climate events**

| **Climate phenomena and their likelihood** | **Major projected impacts** |
|---|---|
| Warmer and fewer cold days and nights; and<br>Warmer and more frequent hot days and nights over most land areas<br>*Virtually certain* | Reduced energy demand for heating<br>Increased demand for cooling<br>Declining air quality in cities<br>Reduced disruption to transport due to snow, ice<br>Effects on winter tourism |
| Warm spells/heat waves<br>Frequency increases over most land areas<br>*Very likely* | Reduction in quality of life for people in warm areas without air conditioning;<br>Impacts on elderly, very young and poor; |
| Heavy precipitation events: frequency increases over most areas<br>*Very likely* | Disruption of settlements, commerce, transport and societies due to flooding<br>Pressures on infrastructures, potentials for use of rain in hydropower generation<br>Loss of property |
| Areas affected by drought increases<br>*Likely* | Water shortages for households, industries and services<br>Reduced hydropower generation potentials<br>Potential for population migration |
| Intense tropical cyclone activity increases<br>*Likely* | Disruption by flood and high winds;<br>Disruption of public water supply<br>Withdrawal of risk coverage in vulnerable areas by private insurer (at least in high income countries)<br>Potentials for population migration |
| Increased incidence of extreme high sea level (excludes tsunamis) likely | Costs of coastal protection *versus* costs of land-use relocation;<br>Decreased freshwater availability due to salt –water intrusion<br>Potential for movement of population and infrastructure (also see tropical cyclones) |

Source (IPCC 2007a)

Even in the presence of underlying risks, urban settlements with a long history of investment in housing, urban infrastructure and services (such as in many high-income countries), and public emergency response (such as Cuba), as well as those with

economic/financial losses much reduced by insurance, are relatively more resilient to cope with the impacts of climate change. Yet, in high-income countries, where buildings and infrastructure are built to withstand extreme and very unlikely weather events (such as a once in one hundred years flood), urban areas can still be overwhelmed by the increased intensity of storms. These dangers are compounded for urban centers facing adaptation deficits. The main problem for these cities is the lack of provision for adequate roads, piped water supplies and other infrastructures and services that can be depended on in the event of severe weather. Without considering any future impacts of global warming, the populations and infrastructures of those urban settlements already show adaptive deficits within the current range of climate variability (see Box 1).

The reader needs to keep in mind that climate change is not the only risk facing urban centers. Its significance (positive or negative) lies in its interactions with other societal and environmental sources of change and stress. Thus the impacts of climate change should be considered in such a multi-cause context. Such phenomena as unmet resource requirements, congestion, poverty, economic inequity, social tensions, and insecurity can be serious enough in some urban settlements that any significant additional stress could be the trigger for serious disruptive events and impacts. Governance structures that are inadequate even in the absence of climate change are not likely to perform well with the introduction of additional stressors. Institutional and jurisdictional fragmentation, limited revenue streams for public-sector roles, and fixed and inflexible patterns of land use do not take the same form in every city, nor are they equally severe everywhere. Yet they will constrain any ability to cope with the additional stress of climate change. Of no less importance are other environmental stresses that may form a complex of risk factors that will be difficult for local governments to overcome. For example, climate change, a city's building conditions, and poor sanitation and waste treatment could coalesce to affect the local quality of life and economic activity of many cities of the world such as Mumbai, Rio de Janeiro and Shanghai (de Sherbinin et al. 2007) and Mexico City (Romero Lankao 2006).

### 3.2 Main climate risks and vulnerabilities

The main climate risks facing urban centers and their underlying vulnerabilities will be described in the following sections.

#### 3.2.1 Sea- level rise and other risks to coastal areas

According to IPCC coastal areas are projected to be "exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas" (Parry, Canziani and Palutikof et al. 2007: 12). Estimates for sea level rise vary from 18 to 59 cm up to the end of the 21st century, this along with predicted changes in the frequency and/or intensity of storms, associated surges and other extremes. Direct effects of sea level rise include increased storm flooding and damage, inundations, coastal erosion, increased salinity in estuaries and coastal aquifers, rising coastal water tables and obstructed drainage. Potential indirect impacts also exist, e.g., changes in the functions of coastal

ecosystems and changes in the distribution of bottom sediments. Since ecosystems such as wetlands, mangrove swamps and coral reefs form natural protections for coastal areas, changes to or loss of these ecosystems will compound the dangers faced by urban coastal areas. It is also worth remembering that such ecosystems have been destroyed by such processes as urban growth on coastal areas even before the issue of global warming was raised in the global agenda (Nicholls and Wong 2007; see below in this section and Box 4*)*. The effects of climate change threaten to compound this damage and reduce these natural protections still further, but as urban areas attempt to replace these natural protections with human-engineered ones, economic resources will be strained. Protections are usually added to protect commercial interests and real property of the wealthier classes. Added to this, artificial shore protections have been shown to increase erosion in adjacent areas and could make the problem worse in areas with the most vulnerable populations.. No human designed system has yet been designed that can do as good a job as the natural systems that we are now impacting and will continue to be impacted by climate change..

It is hard to precisely estimate how many urban dwellers are at risk from sea-level rise and the associated events that climate change will bring. One reason for this is the existence of many definitions of coastal areas. Some define coasts as "the strip of land that extends from the coastline inland to the first major change in the terrain features, which are not influenced by the coastal processes" (*http://www.encora.eu/coastalwiki/* 2008). Others define coastal areas as the territory within 100 miles of the coast (see Cutter et al. 2007: footnote 7) McGranahan, et al. (2007) published the first detailed analysis on the number and proportion of urban populations living in the low-elevation coastal zone (LECZ), defined as the continuous area along the coast that is less than 10 meters above sea level. According to this, LECZ covers 2 percent of the world's land area but includes 13 percent of its urban population (about 360 million people). Asia has the largest share of urban people in LECZ (18%), followed by Australia and New Zealand (13%), Small Island States (13%) and Africa (12%). Low-income and lower-middle income countries have a higher proportion of their urban population in this zone (28%) than high-income countries (12%). Regardless of what definition of the coastal zone we choose to accept, it is easy to see that a significant proportion of the population living on our coasts will be at risk with the combined affects of sea level rise and the increased frequency and intensity of storms that is predicted to be a byproduct of climate change. These risks will be greatest within the low-elevation coastal zones.

**Paty Romero Lankao 11/28/08 10:19 AM**
**Comment:** The comment is not right. Most of the data presented here refer to urban areas.

**Inge Jensen 10/22/08 12:38 PM**
**Comment:** Any estimation of how large a share of these are living in urban areas?
Again, the report is to focus on cities…

The impacts of sea level rise are compounded by the fact that economic activities and populations continue to move to low-elevation coastal zones (McGranahan, et al. 2007, Nicholls et al. 2007). Such mega deltas as the Ganges Brahmaputra in India and the Nile in Africa are associated with significant and expanding urban areas (Nicholls et al. 2007). China offers another example of how increasing trade and market-driven movements, often supported by government incentives, are still attracting people to coastal provinces, which experienced a net in-migration of about 17 million people between 1995 and 2000, creating pressures in an already crowded coastal zone (McGranahan, et al. 2007). Major urban settlements along the very low-lying coasts from northeast Brazil to Venezuela in northeast South America are equally faced by risks. So are many Caribbean states and

urban areas along the Northern coast of South America, where between 20 and 50% of the population resides within the LECZ – e.g. Georgetown located below high-water sea level.

Sea level rise interacts with and potentially exacerbates ongoing environmental change and environmental pressures in cities. In areas such as the Gulf Coast of the United States, for example, land subsidence is expected to add to apparent sea level rise (see Box 4). For New York City, sea level rise will accelerate the inundation of coastal wetlands, threaten vital infrastructure and water supplies, augment summertime energy demand, and affect public health (Rosenzweig and Solecki,2001a; Kinney et. al. 2006; Knowlton *et al.* 2004). The concurrent impacts of climate change on cities' building conditions, and poor sanitation and waste treatment on the settlements of Mumbai, Rio de Janeiro and Shangai could have further impacts on the local quality of life and economic activity (de Sherbinin et al. 2007).

Highly urbanized coasts in South East Asia (e.g. Yangon in Myanmar), in India, and in the Caribbean and Central America (Cancun, Santo Domingo, Tegucigalpa) are at risk of predicted increases in hurricane force. For instance, highly urbanized areas in East India and Bangladesh, where cyclone formation frequency is about five times that of the Arabian Sea, are expected to experience a 10 to 20 percent increase in cyclone intensity. As shown by the 1999 Orissa super cyclone, this will result in extremely high vulnerability in this region.[2]

Different vulnerabilities to the impacts of sea level rise exist, not only between, but also within, urban areas. Local factors, such as location in risk-prone and low-lying areas, income, and access to drainage and to protection structures are important in determining the underlying vulnerability of a population. As with many poor groups in coastal cities, slums in Mumbai illustrate how, even without sea level rise many areas are already recurrently flooded, precisely because they are located in low-lying coastal areas and along river-banks (de Sherbinin et al. 2007)

### 3.2.2 Water resources and systems

According to IPCC (2007a) runoff and water availability are projected to have a regionally differentiated behavior by 2050: increases by 10-20% at higher latitudes and in some areas in the wet tropics (e.g. populous areas in tropical E and SE Asia); decreases by 10-30% over areas in the mid-latitudes and dry tropics, some of which are presently water-stressed. Increases in the frequency and severity of floods and droughts as well as declines in water quantities stored in glaciers and snow cover are also expected.

All these changes will have profound consequences for cities in terms of both water resources and water systems. With profound implications for the availability of water

[2] Orissa killed over 10,000 people, devastated buildings, lifeline infrastructure and economic assets across 10 coastal and 6 inland districts, which included a number of towns and cities due to a mixture of devastating storm surge, cyclonic winds and coastal flooding (see Satterthwaite et al. 2007).

resources, during the last century, mean precipitation in all four seasons of the year has tended to decrease in all the world's main arid and semi-arid regions: northern Chile, the Brazilian northeast and northern Mexico, west Africa and Ethiopia, the drier parts of southern Africa, and western China (Folland et al. quoted in Wilbanks and Romero Lankao et al. 2007). If these trends continue, water resource limitations will become more severe in precisely those parts of the world where they are already most likely to be critical (Rhode, (1999) quoted in Wilbanks and Romero Lankao et al. 2007). Yet it is also likely that together with reduced annual average rainfall, greater extremes in individual rainfall events will mean that overall flood hazard may not be reduced, even in these regions (see below).

Many water basins will get less precipitation constraining the availability of freshwater sources for urban centers. These will be especially hard for growing cities and large cities that already face serious problems to obtain sufficient freshwater supplies - e.g., urban centers along the U.S. Mexican border and Mexico City; in central, south, east and southeast Asia; and in Africa (Parry, Canziani and Palutikof *et al.* 2007, Muller 2007 quoted in Satterthwaite et al. 2007), already suffering water scarcity or water stress – especially affecting poorer groups. The cities of these countries already face governance failures to manage water resources and services, independent of climate change. For example, around half of Africa's and Asia's urban populations lack provision for water and sanitation to a standard that is healthy and convenient. For Latin America and the Caribbean, more than a quarter lack such provision (UN-Habitat 2003). Therefore, any action to increase the adaptive capacity of urban water supplies in those cities has to be done keeping in mind the massive deficiencies in provision and the very large backlog in basic infrastructure that needs to be addressed.

Climate variability and change affects urban water supply and sewage systems in different ways (Wilbanks and Romero-Lankao et al. 2007). Increased temperatures can affect water demand for drinking, for cooling systems and for garden watering. Regional water supplies can be reduced through changes in precipitation patterns, reductions in river flows, falling ground water tables and, in coastal areas, saline intrusion in rivers and ground water. For example, detected declines in glacier volumes in parts of Asia and Latin America will reduce river flows at key times of the year. For cities located in the Andean valleys and the Himalaya-Hindu-Kush region this will mean substantial impacts on water flows (and also reductions in hydro-electric generation, Magrin and Gay et al. 2007, Vergara 2005).

Water supplies are designed to have a life of many years, so as to respond to future growth in demand and to variations in seasonal and day-long demand. Thus, if appropriately designed and if working effectively, most water supply systems are quite able to cope with the relatively small changes in mean temperature and precipitation that are expected for many decades (Wilbanks and Romero Lankao et al. 2007). However, different phenomena might coalesce to negatively affect the coping capacity of urban water systems. These phenomena include:

a) The increased competition for freshwater resources between urban enterprises and

consumers on the one hand and agriculture on the other, with agriculture still the largest water user within virtually all national economies.

b) The fact that many major urban centers (e.g. Los Angeles and Mexico City) have imported freshwater from increasingly distant watersheds, as local surface and groundwater sources no longer meet the demand for water, or as they become depleted or polluted. Many coastal cities have depleted their local groundwater supplies to the point where saline intrusion limits freshwater supplies (UN-Habitat 2006).

c) The dramatic impacts on water supplies likely to occur under extremes of weather (e.g. heavier rainfall or rainfall that is more prolonged than in the past) that could result from climate change, particularly *drought* and *flooding*.

*Droughts* have diverse implications for urban water systems and especially for the urban poor: they constrain water availability; they might result, through complex causal chains, in infectious diseases, respiratory diseases and other health problems. For instance, the drought affecting the western and central part of the Amazon region, especially Bolivia, Peru, and Brazil in 2005 resulted in waterborne infections due to low water levels leading to pathogen concentration in surface water. There were also respiratory problems due to heavy smoke from forest fires (Confalonieri and Menne et al. 2007).

*Floods* are already one of the most frequent natural disasters often overwhelming the physical infrastructure, human resilience and social organization of Dhaka, Mumbai, Jakarta, Caracas, and many other cities around the world. Some of these disasters are reported in the news and form part of the official statistics generated by national governments and international organizations[3]. Yet for every flood large enough to get noticed internationally, there are hundreds that do not get reported, but kill and seriously injure many people and destroy or damage many people's homes and assets (see Satterthwaite et al. 2007).

Cities always present some risk of flooding when precipitation occurs, because buildings, roads, and infrastructure prevent rainfall from infiltrating into the soil – and so produce more run-off. Heavy and/or prolonged rainfall generates very large volumes of surface water which can easily overwhelm drainage systems in many cities. This does not pose a problem to well governed cities, because they generally have good drainage systems together with parks and other complementary measures to protect from flooding. However in poorly governed cities (e.g. Mombasa, Alam and Golam Rabbani 2007) or cities where drainage does not cover all neighborhoods (e.g. Mexico City, Rio de Janeiro and Mumbai (Romero Lankao 2006, de Sherbinin et al. 2007), the affects of excess runoff can be devastating. The ineffectiveness and/insufficiency of their drainage systems

[3] E.g. Events such as the December 1999 flash floods and landslides in Caracas killing nearly 30,000, or the floods resulting from hurricane Stan hitting Southeast Mexico and Centro America in 2005 (more than 1,500 deaths) and Mitch hitting Centro America in 1998 (around 18,000 deaths). The floods in Mozambique in 2000 which included heavy floods in Maputo and other urban centres (see Annex Box 6), the floods in Algiers in 2001 (around 900 people killed, 45,000 affected); heavy rains in East Africa in 2002 that brought floods and mudslides forcing tens of thousands to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda and the very serious floods in Port Harcourt (Nigeria) and in Addis Ababa (Ethiopia) in 2006.

is further compounded by inadequate solid waste management; with inappropriately disposed of solid waste often clogging any drainage they do have; or by the fact that their buildings and infrastructure are constructed in such a way that they actually obstruct natural drainage channels.

Higher than average and more extreme rainfall events associated with climate change are, and will be, related not only to flood hazards, but also to increased landslides and mudflows, and in alpine areas, to avalanches. Although landslides and mudflows are a primary trigger for local disasters, they are usually localized. This results in an underestimation of the impact of these events. Both floods and landslides are influenced by such factors as land use practices in surrounding watersheds, as well as by solid-waste management, land-use and drain maintenance within the city. Urban areas are faced with two options. The first is to reduce the future occurrence of these risks in the face of climate change by appropriate management and governance. The second option is to do nothing, in which case climate change will add additional flood hazard onto drainage systems that are unable to cope with current rainfall.

Water supply, drainage and treatment infrastructures are frequently the first to be affected by floods. Electrical switchgear and pump motors are particularly at risk. In severe riverine floods with high flow velocities, pipelines may also be damaged (Wilbanks and Romero-Lankao et al. 2007). Note that, for the most part, the urban centers in sub-Saharan Africa, Asia and Latin America have no sewers; if they do exist they serve only a very small proportion of the population (UN-Habitat 2003), Therefore as pointed out by IPCC, the main significance of floods for sanitation is that sanitation infrastructures such as pit latrines or septic tanks (or the lack of them) can become sources of the contamination of urban flood water with fecal material, presenting a substantial threat of enteric disease (Ahern et al. 2005 quoted in Wilbanks and Romero Lankao 2007).

### 3.2.3 Health risks

A range of health-related risks is expected to arise from climate change, besides the physical hazards from floods (Confalonieri and Menne 2007). It is expected that heat stress and respiratory distress from extreme temperatures will coalesce as air quality decreases. Water- and vector-borne diseases will result from changes in temperature, precipitation, and/or humidity. Less direct risks are expected as well as climate change negatively affecting livelihoods, food supplies or access to water and other natural resources.

Many urban centers around the world will likely experience increased heat stress in summers and reduced cold-weather stresses in winter. Few studies have been undertaken on the impacts of heat stress in Africa or Latin America. Studies undertaken in North America, Asia and Europe found that heat waves are associated with two main health problems: marked short-term increases in mortality; increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone (Confalonieri and Menne et al. 2007). Projections of climate change impacts in New York City, for instance, show significant increases in respiratory-related diseases and hospitalization

(Rosenzweig and Solecki 2001a). The European heat wave of 2003 claimed 20,000 lives, mostly amongst the poor and isolated elderly. In Andhra Pradesh, India more than 1,000 were killed in a heat wave. These were mostly laborers working outside in high temperatures in smaller urban settlements.[4]

For larger, more dense cities, the temperatures in central 'heat-islands' can be several degrees higher than in surrounding areas. The heat-island effect results from cycles of absorption of solar energy during the day and later re-radiation of that absorbed heat by physical structures that have been built or paved within our urban areas; and (to a much lesser extent) from the heat generation of energy usage such as the exhaust of large cooling systems. The causes of heat islands are complex, as is the interaction between atmospheric processes at different scales. It has been found that urban heat-islands can affect the health, labour productivity, and leisure activities of urban dwellers. Heat-islands are also related to economic effects, such as the additional cost of climate control within buildings, and environmental effects, such as the formation of smog in cities and the degradation of green spaces. Last but not least, heat-islands have mitigation implications, i.e., the emission of greenhouse gases increases if additional demand for cooling is met with electricity generated from fossil fuels.

There is some evidence that the combined effects of heat stress (e.g. urban heat-island effects) and air pollution may be greater than the simple additive effects of the two stresses (Patz and Balbus 2003), Among different populations and localities there are different vulnerabilities to the health impacts of climate related extremes and air pollution within urban areas. Local factors, such as climate, topography, heat-island magnitude, income, access to health services and the proportion of elderly people, are important in determining the underlying temperature-mortality relationship in a population (Curriero et al. 2002). Winter mortality and morbidity in high altitude and colder cities depend on the quality of households home heating, the health of the populations, and the conditions of prevention and treatment of winter infections (Carson et al. 2006).

Climate change is also likely to bring an increased burden of diarrhoeal disease to urban settlements. The geographical distribution of some infectious diseases will be altered, as warmer average temperatures permit an expansion of the area in which malaria, dengue fever, filariasis and other 'tropical' diseases can occur (Confalonieri and Menne et al. 2007). Note that many of these health risks are evident for much of the urban population without climate change, and are related to socioeconomic status. Extreme weather events might create new health hazards and cause disruption to public health services, thereby leading to increased disease incidence. Hurricane Mitch in Central America in 1998 resulted in increases in cases of malaria, dengue fever, cholera and leptospirosis (Vergara 2005). The transmission of enteric pathogens, i.e. gastrointestinal organisms spread by contamination of foods mainly of animal origin and among people, is generally higher during the rainy season (Nchito et al. 1998 quoted in Satterthwaite et al. 2007).

### 3.2.4 Industries and the built environment

[4] http://www.heatisonline.org/contentserver/objecthandlers/index.cfm?id=3943&method=full

Industrial sectors situated in urban areas or providing urban areas with the commodities they need to function such as energy supply and demand, mining, and construction are generally thought to be less vulnerable to the impacts of climate change than agriculture, water and other sectors and services dependent on climate. This is in part because their sensitivity to climatic variability and change is viewed as being comparatively lower and in part because industry is seen as having a high capacity to adapt in response to changes in climate.

There are exceptions to this, namely industrial facilities located on coasts, floodplains and other climate-sensitive areas (e.g. petrochemical industries in New Orleans), food processing and other industrial sectors dependent on climate-sensitive inputs, and industrial sectors with long-lived capital assets (Wilbanks and Romero Lankao et al. 2007). Furthermore industrial activities can be vulnerable to the following impacts of climate change:

a) Direct impacts such as temperature and precipitation changes. For instance, weather-related highway accidents translate into annual losses of at least $1 billion annually in Canada, while more than a quarter of air travel delays in the United States are weather-related (Andrey and Mills 2003 quoted in Wilbanks and Romero Lankao et al. 2007). In India 14% of the annual repair and maintenance budget of the newly-built 760 km Konkan Railway is spent repairing damage to track, bridges and cuttings due to rain-induced landslides. This amounts to about US$1 million annually. Notwithstanding preventive targeting of vulnerable stretches of the line, operations must be suspended for an average of 7 days each rainy season because of such damage (Shukla, Kapshe and Garg 2005, cited in Wilbanks and Romero Lankao et al. 2007).

b) Extreme events threatening linkage infrastructures such as bridges, roads, pipelines, or transmission networks. In these cases industry can experience substantial economic losses. Relatively few quantified assessments of these direct impacts exist, suggesting an important role for new research

c) Less direct impacts: Some industries depend on pulp and paper production, on cotton production and on other suppliers dependent on cheap and reliable supplies of forest fiber, cotton and other climate-sensitive inputs, all of which are likely to be affected. However, in the longer term, as the impacts of climate change become more pronounced, regional patterns of comparative advantage for industries with climate-sensitive inputs or outputs could be affected, influencing regional shifts in production (Easterling *et al.* 2004, cited in Wilbanks and Romero Lankao et al. 2007).

d) In some cases, climate change could lead to reductions in the direct vulnerability of industry and infrastructures. For instance, fewer freeze-thaw cycles in temperate regions would lead to less premature deterioration of road and runway pavements (Mills and Andrey 2002, cited in Wilbanks and Romero Lankao et al. 2007).

Energy use and energy production, the main source of GHG, is one of the industrial sectors that will see great changes due to climate change. In urban areas expected to warm due to climate change, industrial, commercial, and residential buildings will need less heating and increase their cooling demands. Of course, all these changes will vary with the location of the urban center and by season (Wilbanks and Romero Lankao et al. 2007). There are not so many studies on low and middle income countries, but in Europe particularly in the South, there are predicted to be strong increases in cooling (electricity), but reduced heating (energy) demand in winter, particularly in northern Europe. Similar tendencies are found in the US and Japan (Hunt and Watkiss 2007).

The importance of net energy demand at the scale of an urban settlement will be influenced by the structure of energy supply at the regional and national level. The main source of energy for cooling is electricity; coal, oil, gas, biomass, and electricity are generally used for heating. Urban centers with substantial requirements for both cooling and heating could find that net annual electricity demands increase while demands for heating energy sources decline (Wilbanks and Romero Lankao et al. 2007).

Energy *production* is also likely to be affected by climate change, especially in the following circumstances: (a) if extreme weather events such as droughts or hurricanes (remember Katrina, Box 4) become more intense, (b) where regions such as cities along the Andes dependent on water supplies for hydropower and/or thermal power plant cooling face reductions in water supplies, (c) where changed conditions affect facility location decisions, and (d) where conditions change (positively or negatively) for biomass, wind power, or solar energy production.

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Box 5: Hurricane Katrina

In late August 2005, Hurricane Katrina -- a category 5 storm that had weakened to Category 3 before making landfall -- moved large waves and storm surge onto the coast of Louisiana and Mississippi. In New Orleans, the approximately 5 meter surge overtopped and breached sections of the city's 4.5 meter levees, flooding 70 to 80 % of the urban area, and 55 % of the city's properties. The majority of the 1101 people that died in Louisiana related to the floods were from vulnerable groups such as the poor and elderly.

Economic costs across the region were also staggering. For instance, there were 1.75 million private insurance claims, costing in excess of US$40 billion, while total economic costs are projected to be significantly in excess of US$100 billion. In New Orleans alone, flooding of residential structures caused between US$8-10 billion in losses, but US$3-6 billion of these loses was uninsured (Hartwig, 2006, cited by Wilbanks and Romero Lankao et al. 2007).

But even beyond the locations directly affected by the storm, areas that hosted tens of thousands of evacuees by providing shelter, schooling, and human services were also economically impacted by the catastrophe. Storm damage to the oil refineries and

production facilities in the Gulf region raised fuel prices nationwide. Reconstruction costs drove up prices for building construction across the southern U.S. At the same time, because of commitments to provide financial support for hurricane damage recovery, federal government funding for many programs was reduced.

Many lessons can be drawn from the experience of the U.S. Gulf Coast with Hurricane Katrina in 2005, which rather than being a proof of climate change, should be seen as a proof of what the urban impacts of more intensive hurricanes resulting from the disruption of our climate system might be. First, the resilience and sustainability in some densely populated mega deltas of the world will be challenged by climate change, not only in developing countries but also in developed countries. Second, deltas are disaster zones in waiting, vulnerable to floods and storm surges. Under natural conditions, delta lands are built up by river flooding, which washes land with fresh water, sediments and nutrients.

The combination of delta lands and barrier islands form natural protection for the inland areas from large waves and storm surges; however such human factors as construction of dikes and levees, deforestation and alteration of mangroves and other wetlands, and subsidence resulting from water extraction reduce a delta's function as "natural" buffer against storm surges. According to some estimates, the approximate equivalent of one football field per minute of Louisiana wetlands is currently being lost; with the onset of climate change, and a predicted increase in adverse climatic events, this problem could be greatly compounded.

While the problem of wetlands loss in coastal Louisiana has been understood since the 1970s, political processes and economics have stalled the implementation of several plans to address the problem. It can be seen here that in the face of human interactions with the natural world, nature is not everything. Extremely important are investment, governance and policy (or the lack of it). Governments that do not prepare appropriately — either through political inertia and underinvestment as in New Orleans, or stubborn disregard of a military government that allows little room for political and non-governmental organizations (another source of resilience), as in Myanmar in 2008— will continue to see tragic losses and constrain any ability to effectively deal with disasters and rebound.

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As documented by Katrina, transportation and communications infrastructure, buildings and other components of the built environment of a city are especially vulnerable to such extreme events as floods and storms and – to a lesser extent – to heat-waves and drought. Climate change is expected to aggravate all these events.

Increases in temperature and a higher frequency of hot summers are likely to result in an increase in withered rails and bumpy roads, which involve significant disruption and repair costs (London Climate Change Partnership 2004). Less salting and gritting will be required in temperate zones, and railway points will freeze less often. Most adaptation to

these changes can be made gradually in the course of routine maintenance, for instance by the use of more heat resistant grades of road metal when re-surfacing.

Storms are currently the costliest weather events in the cities of high income countries. According to some estimates, it is likely that changing climate risk will coalesce with socio-economic development problems to double worldwide economic losses due to natural disasters every ten years (Hunt and Watkiss 2007). However with the exception of the New York study by Rosenzweig and Solecki (2001a[5]), there are far fewer predictions of storm damage risks specifically at a city level.

Transport infrastructure is more vulnerable to effects of extreme local climatic events than to changes in mean temperatures. Flooding is the greatest, in terms of cost, of all the possible impacts of climate change on transportation. As documented by Kirshen *et al.* (2006b), the cost of delays and lost trips would be relatively small compared with damage to infrastructure and to other property. For instance, 14% of the annual repair and maintenance budget of the newly-built 760 km Konkan Railway in India is spent repairing damage to tracks, bridges and cuttings due to extreme weather events such as rain-induced landslides.

Infrastructure for power transmission and communications is vulnerable to high winds and ice storms when it is built as suspended overhead cables and cell phone transmission masts, but reasonably resilient when buried underground, although burial is significantly more expensive. In low- and middle-income countries, a common cause of death associated with extreme weather events in urban areas is electrocution by fallen power cables (Wilbanks and Romero Lankao et al. 2007). Although such infrastructure can usually be repaired at a fraction of the cost of repairing roads, bridges and railway lines, and in much less time, its disruption can seriously hinder public emergency responses to an extreme event.

Low- and middle-income countries face many deficits in infrastructure management that underlie their vulnerability to climate hazards. The poor quality of infrastructure and the lack of maintenance are key determinants of dams failing, and public hospitals, schools, bridges and highways collapsing during or after extreme weather events. Issues of quality control and accountability exist in the construction and maintenance of infrastructures. For example, lack of transparency in procurement frequently leads to corruption and poor quality work (see for Latin America Charvériat 2000: 85). Decentralization has often transferred responsibility for infrastructure maintenance to local authorities without also transferring the necessary resources and capacities to fulfill this responsibility. The collapse or damage to buildings and infrastructure obviously increases the indirect costs of climate disasters by paralyzing economic activities and increasing reconstruction costs.

### 3.3 The increasingly urban face of climate hazards

[5] Applying historical analogues to derive annualized losses for different storm frequencies, the authors estimate projected damages of approximately 0.1% of Gross Regional Product, annualized, and a probable maximum loss of 10-25% of GRP for one event

Why are more and more people and enterprises moving to urban centers? Why are cities increasingly facing climate risks? In this section we will describe some of the components and underpinnings of the current urbanization era. We will also describe some of the reasons why urban centers are faced with a dichotomy in the climate change arena: on the one hand cities present features making them vulnerable to climate and other hazards, but at the same time they can be sources of processes and innovations that can make them more resilient.

### 3.3.1 An increasingly urban world

Half of the world's population of about 6.4 billion people currently lives in urban areas (see Box 1), compared to less than 15 percent in 1900. Many aspects of urban change in recent decades are unprecedented. The world's urban population increased more than ten-fold during the 20th century. The fastest growing cities are mainly concentrated in the world's largest economies (Satterthwaite 2007). But unlike urbanization in the beginning of the 20th century, mostly confined to countries with the highest levels of per capita income, the most rapid urban change is currently taking place in middle and low income countries, which host nearly three quarters of the world's urban population.[6] In regard to climate change, urban areas house a large proportion of the population and the economic activities most at risk from extreme weather events and sea-level rise – and this proportion is increasing. Here is where a huge structural problem arises. Notwithstanding fast economic growth, the economies of urban areas in low- and middle-income countries have been unable to absorb more than a fraction of the growing labor force. As a result, unemployment and underemployment persist as a structural problem. Even when donors supply capital for infrastructure, the poor – a majority – lack the resources to pay taxes and to cover the costs of the operation and maintenance of that infrastructure. In this context, urban authorities' efforts to deal with climate change and any environmental issue are constantly constrained by lack of capital, resources and planning (Lee 2006).

Other aspects of the rapid urban growth since 1950, are the growth of small and medium cities, the increase in the number of large cities, the historically unprecedented size of the largest cities, the proliferation of slum and squatter settlements, and the extent to which urban centers are exposed to climate hazards (see Figure 1). In the 18th Century, only London and Beijing (then called Peking) had more than a million inhabitants. By 1950, there were 75; by 2000, 380 and most were in low- and middle-income countries. The size of the world's largest cities has also increased dramatically. In 2000, the average size of the world's 100 largest cities was around 6.3 million inhabitants compared to 2.0 million inhabitants in 1950 and 0.7 million in 1900 (Satterthwaite 2007). As illustrated in Figure 1, an overlapping geography exists between urban centers and climate relevant hazards which are now thought of as predominantly urban.

Features of development relevant to adaptive capacity, such as access to resources, location and institutional capacity, are likely to be predominantly urban and to be determined by differences in economic growth and access to assets, which tend to be

[6] As shown by Satterthwaite (2007) rapid urban growth has also taken place in cities of North America (e.g. Las Vegas, Phoenix-Mesa and Orlando).

increasingly unequal**.** It is estimated that one third of the urban population (923.9 million) lives in "overcrowded and unserviced slums, often situated on marginal and dangerous land" (i.e. steep slopes, food plains, and industrial zones), and that 43 percent is from developing countries (UN-Habitat 2003: 5 and 14). It is projected that in the next 30 years "the total number of slum dwellers will increase to about 2 millions, if not firm and concrete action is taken" (UN-Habitat 2003: xxv).

Urban settlements are already exposed to sea level rise, droughts, heat-waves, floods and other processes and hazards that climate change is expected to aggravate (Wilbanks and Romero Lankao et al. 2007). These hazards represent a potential threat. Yet, as already mentioned in chapter 2, a focus on the *exposure* to those perturbations alone is insufficient to understand climate change impacts on urban centers, their populations and economic sectors. Attention needs to focus on the importance of development and one of its dimensions, socioeconomic equity, as key determinants of adaptive capacity. As noted by the UNDP (2007: 3) "whatever the future risks facing cities in the rich world, today the real climate change vulnerabilities linked to storms and floods are to be found … in sprawling urban slums across the developing world".

### 3.3.2 Why can urban development bring increased vulnerability to climate risks?

The concentration in urban centers of people and their homes, as well as of infrastructures, industries and wastes has two implications for the urban impacts of climate change and other stresses. On the one hand, urban areas can be dangerous places to live and work; their populations can be very vulnerable to extreme weather events or other hazards with the potential to become disasters. For instance urban concentration can generate risk when residential and industrial areas lack space for evacuation and emergency vehicle access, when high-income populations are lured by low-lying coastal zones, or when lower-income groups, lacking the means to access safer land, settle on sites at risk from floods or landslides. Urban settlements can increase the risk of 'concatenated hazards' (Allan Lavell cited in Satterthwaite et al. 2007). This means that a primary hazard (heavy storm) leads to secondary hazard (e.g. floods creating water-supply contamination). It is possible that the impacts of climate hazards such as heat waves will overlap with pollution events and compound one another making urban disaster risk management even more complex. On the other hand, the same concentration of people, infrastructures and economic activities in urban centers also means economies of scale or proximity for many of the measures that reduce risks from extreme weather events. Economies manifest themselves in the per capita cost of better watershed management, warning systems and other measures to prevent and lessen the risks when a disaster threatens or occurs. Furthermore, when provided with policies focused on enhancing sustainability and moving from disaster response to disaster preparedness, urban settlements can increase their effectiveness at coping with climate hazards.

Urban development can relate to increased vulnerability to climate risks for several reasons. First, many cities have developed without consideration of the risks that climate change will carry with it. Most large cities have been built on sites that were originally chosen for trade or military advantage (e.g. Shanghai, New York, Buenos Aires). In the majority of cases, this has meant that they were located on the coasts or near the mouths of major rivers where trade by sea with other coastal cities or by rivers with the interior hinterlands could best be accomplished. These urban centers then became the hubs of trade for their countries and, as such, greatly increased their wealth.

As this wealth continued to build, further development was fueled and these areas became engines of economic growth for their countries, attracting more capital from private sector investment and labor migration from rural areas and immigration from other countries. The movement to urban centers continues today and these areas have become magnets of industry and labor without regard to the many environmental risks that are endemic to these areas and the mounting hazards that are predicted to be brought with climate change.

Urbanization is taking place at unprecedented rates, especially in small and medium cities (see section 3.3.1). As migration has accelerated, the abilities of urban centers to accommodate there populations has been put under increasing pressure, especially in middle and low income countries. Certain urban characteristics have relevance for understanding risks from climate and weather hazards (Satterthwaite et al. 2007):

a) Urban centers are growing onto land with agricultural potential, with land costs often pricing most or all low income groups out of 'official' land-for-housing markets. As a result large sections of the urban population acquire land and build housing outside of the official system of land use controls and building standards that is supposed to reduce risks and stop settlements on land at risk from floods, storms and industrial hazards.

b) Related to the above and especially in urban centers of middle- and low- income countries, large sections of the population are living in housing constructed informally – with no attention to health and safety standards needed by these populations. (It is common in cities for large sections of the low-income population to rent or to live in modest accommodations for large groups of people, often whole households living in one room or many adults sharing a single room).

c) High density populations increase the concentrations of their solid and liquid wastes: This is a particular problem if no sewers/drains and waste collection services remove these. Many provisions for disaster avoidance (e.g., thicker walls), disaster response (access for emergency vehicles), or reducing disaster impacts (readily available open spaces not at risk from falling buildings) are not possible in crowded low-income settlements.

d) Large, impermeable surfaces and concentrations of buildings which disrupt natural drainage channels and accelerate run-off. As the ad hoc collections of poor people often living in squatter settlements often make no allowance for

considerations like drainage, the resulting damage from floods can be much more catastrophic than it is in wealthier planned communities.

e) Patterns of urban form and buildings that do not take current and future hazard into account. This generates increased scales and levels of risk from floods, landslides, fires, industrial accidents.

f) Industrialization, inadequate planning and poor design generating secondary or technological risks.

g) Changes in the region around urban centers that cause or exacerbate risks. Examples of these are deforestation and poor watershed management, which often pose a particular problem for local governments as the forest or watershed areas are situated outside their jurisdiction.

h) City governments and urban economies unable to cope with sudden movements of people into a city in response to crises elsewhere. These movements can be linked to extreme weather events nearby as happened with Hurricane Mitch in 1998 or to conflicts as in Colombia with guerrillas and paramilitary groups since the 1960.

### 3.3.3 Why are some sectors of the population more vulnerable?

As was emphasized above, not all demographic segments of the urban population are equally affected by the hazards climate change is predicted to aggravate. Wealthy individuals and households have more resources to reduce risks, i.e., safer housing, more stable jobs, safer locations to live, and better means of protecting their wealth (e.g. insurance of assets that are at risk). Wealthier groups often have more influence on public expenditures. In many urban areas, middle- and upper-income groups have been the main beneficiaries of government investment in infrastructure and services. If government does not provide these, higher income groups have the means to develop their own provisions for water, sanitation and electricity, or to move to private developments which provide these. Wealthier groups in short, have higher adaptive capacity.

The populations most at risk from climate change are those living in affected areas who: a) are very young, already sick or elderly; b) lack the capacity to avoid the direct or indirect impacts by having such means as good quality houses and drainage systems that prevent flooding, by moving to places with less risk, or by changing jobs if climate-change threatens their livelihoods; c) are least able to cope with the illness, injury, premature death or loss of income, livelihood or property caused by these hazards (Wilbanks and Romero Lankao et al. 2007; Satterthwaite et al. 2007). Impacts will also differ according to gender, as gender gaps exist in access to such determinants of adaptive capacity as access to resources, including credit, services, information and technology affect adaptive capacity (Klinenberg 2002 and Cannon 2002 cited in Wilbanks and Romero Lankao et al. 2007).

Especially in middle- and low-income countries the urban poor, for instance, live on

flood plains, unstable slopes, over river basins and other riskiest areas (Hardoy et al. 2004). Many poor populations face additional risks: they live in informal settlements, work within the informal economy; and are constantly faced with the possibility that governments may forcibly move them off land sites deemed to be vulnerable to weather risks but away from their means of livelihood (Satterthwaite et al. 2007). They may also be moved simply because other actors want the land they occupy for more "profitable" uses. Furthermore, poorer groups are affected most by the combination of greater exposure to other urban hazards (sanitary conditions, lack of hazard-removing infrastructure). They have less state provision to help them cope, less legal and less insurance protection. Low-income groups also have far fewer possibilities to move to less dangerous sites. This should not lead us to conclude that the poor are passive recipients of all of the risks of climate change and other hazards. As will be illustrated in section 5, they have developed mechanisms to adapt. It just means that structural issues as those referred here pose limits to their coping mechanisms.

3.3.4 Migration and climate change

In 1990, the Intergovernmental Panel on Climate Change (IPCC) noted that the greatest single impact of climate change could be on human migration especially to urban centers —with millions of people displaced by shoreline erosion, coastal flooding and agricultural disruption (IOM 2008). Since then various analysts have tried to put numbers on future flows of what came to be called "climate refugees. Yet it has been difficult to establish a predictive line of causation between climate change and migration (IOM 2008). This is so because finding the primary causes of migration is highly problematic, not least because individual migrants may have multiple motivations, and be displaced by multiple factors (Black, 2001 cited in Wilbanks and Romero Lankao et al 2007). For instance, studies of displacement within Bangladesh, and to neighbouring India, have drawn obvious links to increased flood hazard as a result of climate change. However, such migration also needs to be placed in the context of changing economic opportunities in the two countries and in the emerging megacity of Dhaka, the encouragement of migration by some politicians in India, rising aspirations of the rural poor in Bangladesh, and rules on land inheritance and on ongoing process of land alienation in Bangladesh (Abrar and Azad, 2004 cited in Wilbanks and Romero Lankao et al 2007).

The example shows that temporary migration as a strategy to cope or adapt with climate hazards is already apparent in many areas (see also IOM 2008). However, it also illustrates that the relationship between migration and climate change is not straightforward. Furthermore, the ability to migrate is related to mobility and access to financial and social resources. "In other, words, the people most vulnerable to climate change are not necessarily the ones most likely to migrate" (IOM 2008: 9).

In this context, estimates or predictions of the number of people who may become environmental migrants are at best guesswork, and at worst, dangerous, since

a) migrations from areas impacted by climate hazards are not one-way and permanent, but multi-directional and often temporary or episodic;

**b)** the reasons for migration are often multiple and complex, and do not relate straightforwardly to climate variability and change;

**c)** In many cases migration is a longstanding recurrent response to *seasonal* variability in environmental conditions. Especially migration to urban centers and other countries, represents a strategy to *accumulate* wealth or to seek a route out of poverty, a strategy with benefits for both the receiving and original country or urban area;

**d)** There are few reliable censuses or surveys in many key parts of the world on which to base such estimates (e.g. Africa); and

**e)** There is a lack of agreement on what an environmental migrant is anyway (Unruh *et al.* 2004 cited in Wilbanks and Romero Lankao et al 2007).

Some might argue that rising ethnic conflicts will lead to migration that can be linked to competition over natural resources, as these resources become increasingly scarce as a result of climate change. However, many other intervening and contributing causes of inter- and intra-group conflict need to be taken into account. For example, major environmentally-influenced conflicts in Africa have more to do with relative abundance of resources – oil, diamonds, cobalt, and gold for example, than with scarcity (Fairhead, 2004 cited in Wilbanks and Romero Lankao et al 2007). This allows little confidence in the prediction of such conflicts as a result of climate change

## 4. Cities as drivers of global warming

Cities have often been blamed for causing air water and water pollution, and currently for causing global warming. Yet, do we have any consistent measure of cities' contribution to global GHG emissions? The next sections will address the questions of how much we actually know about how cities generate GHG and impact the atmosphere. We will also look at whether, within our current knowledge, we understand the societal and environmental drivers of the different trajectories of emissions by cities?

### 4.1 How big is the contribution of urban centers to global warming?

To understand how urban centers generate GHG, it is necessary to find a representative measure of carbon emissions (Molina and Molina 2002). Different issues need to be considered here. First, there is a paucity of data limiting the scope of any study exploring how big urban contribution to global emissions is. The second relates to the activities generating those emissions. Most of the total pollution comes from the combustion of fossil fuels (coal, oils and natural gas) for heating and electricity generation for consumption by commercial and residential buildings, for running motor vehicles and in industrial processes. Other sources are households consuming fuels in heaters and cookers, or indirectly in air conditioning. It is also usual to find carbon emissions resulting from land use changes and aggravated by poor land management and many unpaved roads. Landfill sites taking urban wastes are another key source of methane. The manufacturing process used in the production of cement needed for the development of our urban areas can also account for as much as 5% of global emissions of GHG. Finally, many activities undertaken outside the boundaries of urban centers such as agriculture and cattle, aimed at satisfying urban requirements of food, raw materials, forest products and construction materials as well as electricity generation in rural areas but largely for urban use also contribute to carbon emissions.

Paty Romero Lankao 12/10/08 9:41 AM
**Comment:** Thawing is one of the consequences of climate change. I am not aware of any way in which urban centers might contribute directly to it. At the most they contribute indirectly by overwhelming the absorbing capacity of terrestrial carbon pools such as the tundras

Inge Jensen 10/22/08 4:00 PM
**Comment:** What about GHG emissions from thawing of tundra frost? Some numbers may put these into some kind of overall perspective

Second, GHG emissions are formed through different processes, and have a residence time before being absorbed by the atmosphere, or the oceans ranging from 3 to 4 years (CO2), to 8-10 years (Methane) and even 50 to 100 years (Chlorofluorcarbons, see Molina et al 2002: 12). Third, the impacts of urban emissions range from destruction of ecosystems to photochemical smog, and from acidifying emissions to global warming (Molina and Molina 2002; Hardoy et al. 2004). All these impacts impair the health of populations and ecosystems in direct and indirect ways (Molina and Molina 2002).

Last but not least, many scholars, practitioners and policy makers claim that cities are sources of most of the world's greenhouse gas emissions as put forward by the William Clinton Foundation:

> "Large cities take up only 2 percent of the Earth's land mass, but they are responsible for about 75 percent of the heat-trapping greenhouse gases that are released into our atmosphere"

However, too few cities exist for which there are detailed greenhouse gases inventories to validate this claim (See Table 3).

**Table 3: Total and per capita emissions at the city level**

| City | Total GHG Emissions | GHG Emissions Per Capita |
|---|---|---|
| (date of study) | (million tonnes $CO_2$ equivalent)* | (tonnes of $CO_2$ equivalent) |
| European cities | | |
| Barcelona (1996) | 5.1 | 3.4 |
| London (2006) | 44.3 | 6.18 |
| Oxford (2004) | 0.99 | 6.9 |
| Stokholm (2005) | n.a. | 4 |
| North American cities | | |
| Toronto (2001) | 37.1 | 8.2 |
| Austin (2006) | n.a. | 20.7 |
| New York City (2005) | 58.3 | 7.1 |
| Los Angeles (2006) | 234 | 15.2 |
| San Diego (2005) | 2.9 | 12.3 |
| District of Columbia (2005) | 11.3 | 19.7 |
| Latin American cities | | |
| Rio de Janeiro (1998) | 12.8 | 2.3 |
| Mexico City (2000) | 64.8 | 3.6 |
| São Paulo (2003) | 15.7 | 1.5 |
| Asian cities | | |
| Baguio (2002) | 0.2 | 0.7 |
| Beijing (1998) | n/a | 6.9 |
| Chiang Mai (2002) | 0.5 | 0.7 |
| Dhaka (1999) | 1.8 | 1.7 |
| Delhi (2000) | | 1.5 |
| Kolkata (2000) | | 1.1 |
| Seoul (1998) | n/a | 3.8 |
| Shanghai (1998) | n/a | 8.1 |
| Tokyo (1998) | n/a | 4.8 |
| South African cities | | |

| | | |
|---|---|---|
| Cape Town (metro, 2004) | 19.7 | 6.4 |
| Johannesburg (metro, 2004) | 19.9 | 5.6 |
| Durban (metro, 2004) | 18.4 | 5.6 |
| N. Mandela (metro, 2004) | 4.8 | 4.7 |

Sources: Dodman (2008); Romero Lankao (2007a) and UN-Habitat (2007).

It is not clear how accurate existing figures on GHG emissions by cities are (Satterthwaite 2008, Dodman 2008). The IPCC provides a methodological framework to assess all the greenhouse gases emitted from four main sectors: energy; industrial processes and product use; agriculture, forestry and other land use; and waste (IPCC 2007). The methodology seems to be broadly used at the urban level, yet no international framework exists requiring measurements of urban emissions. However there are different criteria to measure and inventory those emissions, and the choice by researchers to use of one or the other can greatly skew the final calculations on how big cities' contributions to GHG emissions are (Satterthwaite 2008).

For instance, if allocated to the generating activities and assigned to certain types of settlements – production-based approach to allocating emissions – then urban centers possibly emit between 30 and 40 per cent of all anthropogenic greenhouse gases (Satterthwaite 2008: Table 1). Of course some assumptions were made by the author to arrive at these figures. For example that the energy was produced within cities' boundaries, or that land use changes cannot be assigned to cities. However, several caveats need to be considered here. Much carbon dioxide emitted by transportation, such as in aviation or sea freight, can not be assigned to urban centers (see Satterthwaite 2008). Other elements of per capita GHG emissions make calculation of the total impact of urban centers difficult. In many cities the production of electricity by fossil fuel combustion takes place outside the city limits (Satterthwaite 2008). The production-based approach has moral implications as well (Dodman 2008): it distracts attention and blame from the high consumption lifestyles that together with the production systems profiting from them drive unsustainable levels of carbon emissions.

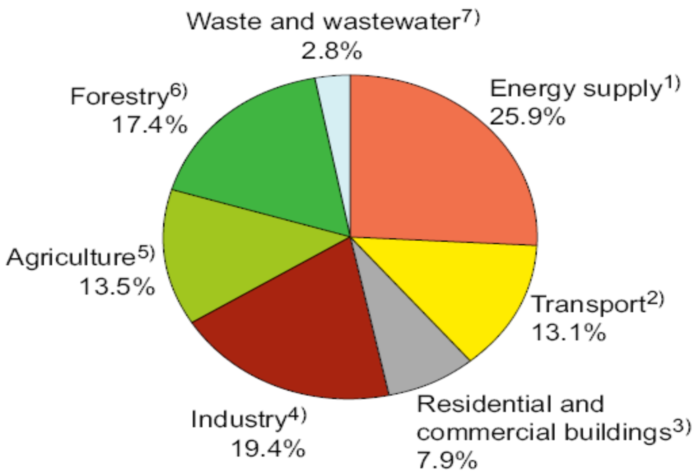
The proportion of GHG generated in cities would be higher if emissions were assigned to the consumers, i.e. to the location of those whose traveling or demand for goods, services or waste disposal was what ultimately produced the greenhouse gas emissions. According to Satterthwaite (2008) the figures on cities' contribution to global GHG emissions would rise to almost half of the total. That percentage would also include emissions from agriculture and deforestation. *But again there are no precise figures of how high cities' contribution to global warming would be.*

**4.2 Evaluating urban impact on GHG emissions**

A key element in the assessment of emissions by cities is the identification of the main direct sources of these emissions. The problem again is that with the exception of some cities for which this information is available (Table 3), most data on GHG emissions are provided at the global and national level. Internationally the main emitter is energy

supply (25.9%), followed by industry (19.4%), forestry (17.4%), agriculture (13.5%), and transportation (13.1%). (See Figure 3 from IPCC 2007b).

**Figure 3: GHG emissions by sector in 2004**




Source: IPCC (2007b)
Note: According to IPCC (2007b), 1) energy excludes refineries, coke ovens etc., which are included in industry; 2) transportation includes international transport (bunkers), and excludes fisheries, off-road agricultural and forestry vehicles and machinery; 3) residential and commercial includes traditional biomass use. Emissions here are also reported on the basis of end-use allocation (including the sector's share in emissions caused by centralized electricity generation) so that any mitigation achievements in the sector resulting from lower electricity use are credited to the sector; 4) industry includes refineries, coke ovens, and cement production. Emissions are also reported on the basis of end-use allocation (including the sector's share in emissions caused by centralized electricity generation) so that any mitigation achievements in the sector resulting from lower electricity use are credited to the sector; 5) agriculture includes agricultural waste burning and savannah burning (non-CO2). CO2 emissions and/or removals from agricultural soils are not estimated in this database; 6) Forestry data include CO2 emissions from deforestation, CO2 emissions from decay (decomposition) of above-ground biomass that remains after logging and deforestation, and CO2 from peat fires and decay of drained peat soils; and 7) waste and waste water includes landfill CH4, wastewater CH4 and N2O, and CO2 from waste incineration (fossil carbon only).

Existing scholarship suggests that the weight of different sectors in the total emissions of a city relates, not only to underlying drivers to be addressed in the next section, but also to such factors as: a) the economic base of a city, i.e. to whether it is mainly industrial or service oriented; b) its form, i.e. how dense it is, and the location patterns of its settlements, economic activities, and infrastructure; c) the lay out and structure of its transportation systems, i.e. the extent of automobile infrastructure compared to transit.

Regarding the economic base of a city, in Beijing and Shanghai industry contributes 77% and 83% of the total emissions respectively (Dhakal 2004). This reflects the fact that China has become the main manufacturer of commodities for the world allowing western consumers and industries to dodge taking responsibility for their own carbon emissions as a percentage of the amount that their consumer driven impact on the market has created the need for the high industrial output in China. Industrial emissions of GHG in cities elsewhere are much lower: 28.6 per cent in Mexico City, 7 per cent in London, 9.7 per cent in São Paolo, and 10 per cent in Tokyo and New York (Romero Lankao et al 2005 and Dodman 2008). This reveals a transition to service-based urban economies as well as a different pattern of international localization of industrial activities. A pattern determined by differences in profitability, costs and environmental legislation among cities (see Satterthwaite 2007)

Changes in the localization patterns of economic activities and population are affecting urban form as well. These are related to a two-sided pattern of localization with new forms of both decentralization and centralization occurring simultaneously. New branches and segments and top level management and control functions are falling outside and within cities' cores respectively (Sassen 2002). Southeast Asia for instance is witnessing the formation of such "urban corridors" connecting cities across the region from Seoul to Tokyo. Also known as the BESETO corridor (Beijing, Seoul and Tokyo), it connects 77 cities of over 200,000 inhabitants each stretching an area of 1,500 km (Cohen 2004). Buenos Aires, Santiago and Mexico City experienced during the last two decades a region-based or polycentric urban expansion of first and second-order urban localities sprawling along major highways and functionally linked to the main city (Aguilar and Ward. 2003; De Mattos 1999). A similar trend is experienced across US regions, where growth is occurring unevenly within regions, and between central cities and suburbs. The northeast, the Great Lakes, Southern California and Florida are part of the 10 mega-regions emerging as development hubs (RPA 2006) In short, a regional or polycentric path of urban development is taking place.

The polycentric pathway of urbanization is associated with carbon relevant consequences. According to the Regional Plan Association (2006: 9), traffic congestion has worsened in the urban cores of the 10 US mega-regions. "In major metropolitan areas in the US, a commute that used to take 30 minutes now takes 44.4 minutes during the peak rush hour", a 46 percent increase since 1982. As illustrated by Mexico City (Romero Lankao 2007), passengers commuting distance increased from 3.5 km to 5.6km by bus between 1987 and 2000 while commuting speeds decreased from 16.8 to 16.7km/h in the same time period. As a result overall travel times increased from 0.21 hours to 0.34 hours. Freight transportation showed can probably be assumed to have shown a similar pattern of increased travel times. As shown by Newman and Kenworthy (1999), more sprawled patterns of urban growth are related to variations in car use, gasoline consumption, and by this, to more emissions. Gasoline use in New York outer suburbs for instance was 5 times larger than in its core area.

Paty Romero Lankao 11/29/08 11:30 AM
**Comment:** I agree but I don't have those figures

Inge Jensen 10/22/08 4:12 PM
**Comment:** A comparison with rural areas seems appropriate here. How large is the relative gasoline consumption there?

Although emissions from the transportation systems in urban areas and corridors represent a fast growing source of greenhouse gases both in developed and developing countries, transportation is growing at different rates in different urban areas and is manifested by different modes and layouts dependent on historical paths of development (Newman and Kenworthy 1999; Barter 2004). Large cities within Europe and Asia (Japan) industrialized before the middle of the 20th Century and tended to have extensive public transport before motorization started in earnest. They have tended towards a more transit orientated model, and have followed a different path from USA and North America, where motorization was embraced without limit, notwithstanding some cities kept older systems to serve older city centers (See box 6).

Cities that industrialized by the middle of the 20th Century and afterwards (e.g. Chinese urban centers) were frequently not able – or not willing – to invest in extensive public transport systems. They usually adopted buses, minibuses and jitneys, and embraced motorization in diverse ways. Many of these cities have high density, low and ineffective road provision, and high dependence on road-based public transportation and on non motorized transport (Barter 2004). These features have made them prone to higher levels of motorization and very vulnerable to traffic congestion and pollution.

**Box 6: Transportation and the shape of a city**

Transportation priorities define three types of cities: walking, transit and automobile orientated urban centers.

Walking is used as a primary mode of transportation in the medieval core areas of European cities, or in large sections of urban centers in low- and middle-income countries. They have very high densities, mixed land uses, and many destinations which can be reached on foot. They are thus rarely more than 5 km across.

During the second half of the 19th Century, the spatial growth outward of many cities was enhanced as the tram and the train permitted faster travel between more distant points, creating the transit city encompassing an area of twenty to thirty kilometers. Those urban centers were to be found not only in Europe, but also in North America (e.g. Los Angeles, New York, Boston) and Latin America (e.g. Mexico City, Buenos Aires). The transit era is still visible in European cities and in Asian urban centers such as Tokyo. Although in recent decades they started to sprawl around corridors based on automobile travel. Different was the case in other urban areas such as Los Angeles, where the transit era only lasted until 1930. The Pacific Electric Rail, one of the most extensive and efficient systems in the world, was sold to a consortium, National Cities Lines, created by General Motors and Standard Oil. After this acquisition there were no investments in those systems. Instead, since the 1950s, a great expansion of investments in roads led to the development of a car oriented city.

After Second World War the automobile, supplemented by the bus, increasingly

became the transportation technology that formed the city, first in the urban centers of North America and Australia, but then in the sprawling areas and in corridors connecting satellites to the core areas of cities all around the world. The birth of the Auto City made feasible the existence of low density housing and of zoning separating residential and business centers.

Source: Newman and Kenworthy (1999)

Barter (2004) refers to another transportation development path present in Singapore, Hong Kong and Japanese cities, emphasizing alternatives to private motor vehicles. Policies aimed at slowing down motorization have been crucial to allow public transportation to build up, even as incomes increased.

Evaluating urban impact on global greenhouse gasses (GHG) emissions is, therefore, a complex undertaking. While it is common sense that dense urban populations are large producers of GHG with the simple idea that more people equate to more output of GHG, a look at per capita output of GHG shows that population density actually pushes the per capita output of GHG down. Dense traffic and congested thoroughfares function as a deterrent to private automobile use and often push people towards other forms of transportation. The concentration of population within an urban tax base helps promote the availability capital to build urban infrastructural elements such as mass transit systems. This infrastructure complements the movement away from private automobile use; hence, dense urban areas are often characterized by an increased use of public transportation. Access to goods, services and cultural attractions is also close at hand for many urban dwellers and can often be reached via walking or bicycle. The decrease in the use of private automobiles creates a downward pressure on per capita GHG emissions. Yet, if not accompanied by measures to strengthen the use of an efficient public transportation, higher densities are related to higher health impacts (Marshall et al 2005).

It is therefore important not only to recognize the upward pressure that cities may exert on climate change but the downward pressure they may exert as well. Well designed urban centers may hold one of the central keys to mitigation strategies. Local efforts to reduce contributions to global GHG may gain a great boost by zoning for mixed-use land developments (Brown et al. 2008) creating urban districts where populations are able to maintain physical, economic and cultural needs without the need to travel great distances and where housing needs may be met within energy saving compact dwellings that share walls for heating.

The temptation for local authorities within these areas may be to increase tax revenue by offering single or select vendors access to the populations in given areas at a premium tax charge by local districts, creating near monopolies for enclave merchants. This should be avoided at all costs as it could move these areas into being perceived as "company towns" that benefit a few enterprises at the expense of those that live and work there. This would create pressure away from the compact use of these communities and toward a wider travel to gain access to goods and services not controlled by the central district and would work against the savings in production in GHG that these communities may offer. It is important, therefore, to guard against a central control of the zoning management of these areas and allow broad based community involvement and real and

effective stakeholder involvement in community development and zoning decisions. To the residents of these areas, the development should feel ad-hoc and free from overburdensome central control. To be dynamic and alive, these areas must feel free to develop organically to meet not only the current needs and cultural awareness's of their residents but those unplanned and unimagined needs and cultural movements of the future.

### 4.3 What societal and environmental factors underlie the trajectories of emissions by cities?

Just as urban centers register different levels and paths of development, cities do not contribute at the same level to global warming. Some scholars point to the fact that urban centers in low-income countries have lower levels of emissions per capita than cities in high-income countries (e.g. Romero Lankao 2007, Satterthwaite 2008). In fact carbon emissions per capita in cities from high-income countries such as Texas and the District of Columbia are 19-20 fold as high compared with those in Sao Paolo, Delhi and Kolkata (see Table 3). Yet, other wealthy cities such as Stockholm and Barcelona have lower levels of emissions per capita than the four South African cities included in Table 3. Why is this so?

We can not provide definitive answers to this question, because existing data on emissions levels cover very few cities and have not been gathered applying similar or comparable criteria. As a result, it is difficult to apply such statistical tools as regressions or correlations to explore the role of affluence, population dynamics, climate and other drivers in explaining the levels of carbon emissions by urban centers. However we can offer some hints using both theoretical papers and empirical findings from case studies.

Scholars tend to agree on the relevance of three factors as determinants of carbon emissions, namely a) population, b) affluence as measured by GDP per capita, c) and technology, as measured by both energy intensity and carbon intensity) of the energy system[7] (Nakicenovic 2004, Brown et al 2008). Numerous articles use the IPAT identity to assess the weight of those drivers. *I* is a measure of atmospheric and other environmental impacts, *P* is population, *A* is affluence and *T* is technology (Ehrlich and Holdren 1971). Dietz and Rosa (1994) and York et al (2003a, 2003b) have also proposed that the IPAT identity would be more useful if recast in such a way as to allow random errors in the estimation of parameters and permit systematic hypothesis testing (see Romero Lankao et al forthcoming).

In the future, this data analysis method promises to yield information on the complex interplay and interrelation of the multiple drivers of climate change within cities, but first we must have more complete and consistent data on GHG emissions within cities. The

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[7] Energy intensity is defined as the energy consumption relative to total output as measured by GDP or GNP (E/GDP). Carbon intensity is the relative amount of carbon emitted per unit of energy or fuels consumed (C/E), and it depends on the characteristics of the fuels. According to the London Department of Transport (2008), when using coal, 112 grams of $CO_2$ are produced per Megajoule of energy, while the figures are 86 when using diesel, 85 when using gasoline and 62 when using gas. A decreased carbon intensity of the energy system is also used here as an indicator of relative environmental quality.

problem we face, then, is that we lack information on the impact (emissions of green house gases) across a wide spectrum of urban areas. Therefore, we can not measure the weight of different drivers on cities' emissions to test competing hypotheses. Instead, in this section, we will describe these drivers and hypotheses, together with such factors as climate, consumption patterns and governance structures considered equally important by scholars (Kates and Wilbanks 2003).

Climate indeed functions as an important context in which social factors drive such environmental impacts such as global warming. A city located in high latitudes, for instance, might consume more energy to heat its buildings and houses than one situated towards the tropics; and vice versa, an urban center located in the tropics might consume more energy for air conditioning (Wilbanks and Romero Lankao et al. 2007). Weather undoubtedly plays a role in cities' footprints, but does not act alone. Brown et al (2008) found, for instance, that many relatively colder urban areas in the Northeast of US have larger residential footprints because they rely on carbon-intensive home heating fuels such as fuel oil. Warm areas in the South, likewise, have large residential footprints because they rely on carbon-intensive air conditioning. The characteristics of the fuels – their carbon intensity – are hence key factors. For instance, the carbon intensity of coal is almost two fold higher than the carbon intensity of natural gas (see footnote 6). And a city as Stockholm relying on hydropower to generate its electricity has of course a much lower carbon footprint than one relying on fossil fuels, but hydropower schemes may have large environmental and social impacts because large areas have been flooded displacing both people and wildlife habitats.

As emphasized by human ecologists, the size, growth, structure and density of population are key determinants of cities' carbon emissions and other environmental impacts (Walker and Salt 2006). Spatially compact and mixed-use urban developments have different benefits in terms of carbon emissions:

a) Reduced costs for heating and cooling resulting from smaller homes and shared walls in multi-unit dwellings. For instance, households in buildings with five or more units consume 38 per cent of the energy of households in single-family homes (Brown et al 2008: 12)

b) The use of energy systems covering a broader area (e.g. district) for cooling, heating and power generation as well as lesser line losses related to electricity transmission and distribution. The use of microgrids to meet local requirements of electricity can create efficiencies in storage and distribution (Brown et al 2008: 11).

c) Reduced average daily vehicle-kilometers traveled in freight deliveries and by private motor vehicles per capita (VKT). Population density increases accessibility to such destinations as stores, employment centers and theaters (Newman and Kenworthy 1999). It has been found that with all other variables constant except density, "the household in a neighborhood, with 1,000 fewer units per square mile drives almost 1,200 miles more and consumes 65 more gallons of fuel per year over its peer household in a higher density neighborhood" (Brown et al 2008: 12).

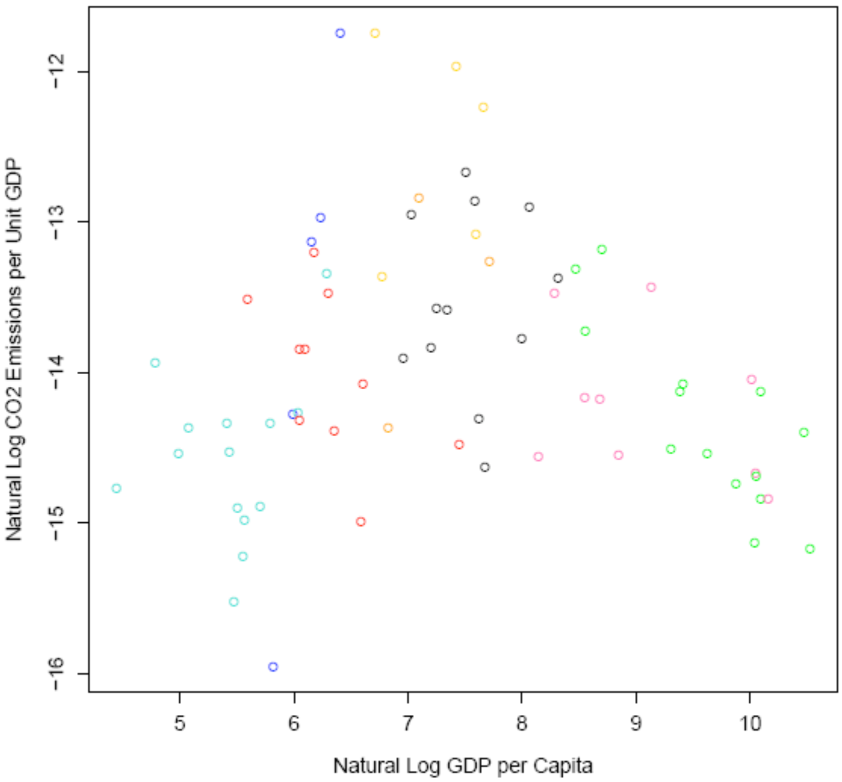
d) Public transit and non-motorized modes of private transportation such as walking and cycling show a higher usage in urban settings. It is also more common to find certain disincentives to driving (e.g. congestion delays and limited parking availability) in densely populated areas (Marshall et al. 2005).

Urban density however, is not again the only explaining factor. Studies on urban transportation have found that besides higher levels of mixed land-use, transit accessibility, pedestrian friendliness and attitudes and preferences also influence driving behavior (Handy et al. 2005). Furthermore, urban density poses a dilemma: while "tailpipe emissions and fossil-fuel consumption are greatly increased with urban sprawl", levels of human exposure to emissions of other pollutants (e.g., NOx) might actually increase with density if no measures are undertaken to reduce atmospheric emissions (Marshall et al. 2005: 284).

Affluence has been repeatedly acknowledged as another significant driver of carbon emissions and other environmental impacts. Yet there remain two visions on how economic development influences carbon emissions. According to proponents of ecological modernization, environmental problems such as global warming are addressed by development leading to modernization (EM), i.e. via the deployment and application of more sophisticated technologies driven by market mechanisms (Murphy 2000). With this kind of development there is a structural change – or shift – to less carbon intensive societies. Structural change occurs at the macro-economic level, through the development of new and less carbon intensive technologies whose use is induced by market mechanisms (Gibbs 2000). For instance, and as showed by Brown et al (2008), the mix of fuels and the technologies used in electricity generation influences the residential carbon emissions of a city. Washington D.C. uses high carbon sources like coal to generate electricity, while Seattle draws its energy primarily from carbon-free hydropower. As a result, in 2005, Washington D.C.'s carbon footprint from the use of residential electricity was 10 times larger than that of Seattle. This means that although both cities are similarly affluent, differences in their carbon impacts can be attributed to the source of energy used to generate electricity; and that coal has a low efficiency compared to hydropower. It is also a measure of the local resources available for the production of electricity. Development often follows the path of least resistance with regard to resource usage.

As an economy develops (modernizes), sectors such as the agricultural and fisheries segments of the economy are replaced by manufacturing industries, and further by service industries. (Gibbs 2000). Precisely because economic growth endogenously reduces environmental stress, the environmental impacts of economic growth increase in early stages of development, but stabilize and then decline as economies mature. The process is depicted by an inverted-U shape curve, also known as the Environmental Kuznets Curve. Indeed Roberts and Grimes (1997) found that the relation between national carbon intensity and level of economic development has changed from essentially linear in 1965 to essentially curvilinear in 1990. While Romero Lankao et al accepted confirmed that the tendency to an essentially curvilinear relation is still valid for the year 2003 (See Figure 4). A linear relation means that a one unit increase in GDP essentially translates to a similar increase in emissions, while in a curvilinear relation a one unit increase relates to a smaller than one unit increase in emissions.

**Figure 4: Carbon Intensity (kt per unit GDP) and Economic Development (2003)**




Source: Romero Lankao et al (2008).

In contrast to the EM theory, for the proponents of urban transitions theory, affluence, as measured by GDP per capita, is also an important driver of atmospheric emissions and other environmental impacts. While EM theory states, that further development and modernization are the source of solutions to environmental impacts, urban transitions scholars suggest that there are affluence dependent sets of urban environmental transitions or shifting loci of environmental burdens based on levels of development and affluence in given urban area(Satterthwaite 1997, McGranahan et al. 2001; Bai 2003). Urban populations and economic activities in low-income cities tend to have more localized, immediate and health threatening environmental issues belonging to a “brown” agenda (e.g. indoor air pollution and ambient concentrations of sulphur dioxide). Middle-income cities are likely to have shifted to cleaner fuels. Yet industrialization and motorization are likely to have added a new set of atmospheric problems to these cities belonging to a “grey” agenda, with environmental problems of impacts at the city-wide

and regional level. Affluent or high income cities and urban populations are faced with "green" agenda issues, including non-point source pollution and consumption related burdens (e.g., $CO_2$ emissions), which have global and intergenerational impact.

Affluence holds empirical and political relevance for two reasons. While the "environmental burdens of urban poverty primary affect the poor living in the immediate locality, the environmental burdens of affluence can affect both rich and poor people around the globe" (McGranahan et al. 2001: 15, see also Satterthwaite 1997). The second reason, relevant for the debate around climate change impacts on cities, and which can be derived both from the most recent report by Working Group II on the Intergovernmental Panel on Climate Change (IPCC) and from its chapter on urban settlements (Parry, Canziani and Palutikof *et al.* 2007; Wilbanks and Romero Lankao et al. 2007), refers to the fact that the urban dwellers most at risk from environmental threats, the poor, seem also to be most at risk from floods, heat waves, storms and other climate related threats (see also Satterthwaite et al. 2007).

It can be misleading to concentrate on urban emissions per capita, as there are very large differentials within urban centers. Socioeconomic equity is, therefore, key dimension affecting carbon emissions by cities. We lack information to provide an accurate picture on the role of equity in determining different levels of emissions among demographic sectors of an urban area. Yet we can use some examples to draw preliminary conclusions. The per capita emissions of Dharavi, the predominantly low-income, high-density, inner-city of Mumbai, are a tiny fraction of the per capita emissions of high-income district of Mumbai, where a high proportion of the population commutes to work by car (Satterthwaite 2008). The transportation sector of Mexico City, which accounts for the highest share (34.7%) of $CO_2$ equivalent emissions, can also illustrate the weight of equity. Private cars only contribute 18% of the city's daily trip segments yet they account for 40.8% of $CO_2$ equivalent emissions, while public transport accounts for 82% of those trip segments yet emits 25.9% of $CO_2$ equivalent emissions (Romero Lankao 2007a). This also supports the idea that a key determinant of carbon dioxide emissions is the consumption patterns of middle- and high-income sectors around the world together with the production systems that benefit from that consumption.

The quality of governance structures is equally important to explain why some cities have larger levels of carbon emissions. Independently of level of affluence, a well managed city with a good public transportation system, whose population has access to water and sanitation, to adequate health services, and to a good quality of life, is likely to have fewer problems in dealing with both its carbon footprints and its adaptation challenges (see next section) than a city that is poorly managed (McGranahan et al. 2001: 14-15).

Governance is deeply interlinked with urban planning, which has recently emerged as a fundamental developmental tool. For it is widely acknowledged that climate change, other environmental issues and equity can not be addressed by "the market", and that the capacity of both government and civil society to manage those issues is far from adequate.

The above does not mean the reemergence of master planning originated in high income countries, which found their way to almost every other part of the world, in the form of comprehensive plans generated with technocratic, top-down methods, and primarily

zoning as their main legal tools. Notwithstanding persisting in many parts of the world, master planning has been criticized for bearing too little relation to the reality of rapidly growing and poor cities. They have been selectively mobilized to achieve particular sectional or political interests, or to influence the land use and development of some parts of cities in ways that may exclude poorer sectors of the population (Watson 2007).

Rather, the above means the emergence of such new planning initiatives as strategic planning, UN Urban Management Programme, and Planning for environmental hazards and risks that resulted from criticism of strategic planning and have some of the following common characteristics (Watson 2007: 52)):

a) strategic rather than comprehensive;
b) flexible rather than end-state and fixed;
c) action and implementation oriented, through links to budgets, projects and city-wide or regional infrastructure;
d) stakeholder or community driven rather than only expert driven;
e) containing objectives reflecting such current urban new concerns as a city's global positioning, environmental protection, and social inclusion;
f) playing an integrative role in policy formulation and in urban management
g) focusing on the planning process, yet with the outcomes highly diverse outcomes (urban modernism, gated communities, compact city models)

The new approaches to urban planning have positive aspects (they are forward looking and inclusive), but are also faced to constraints. They do not, for instance, address the regulatory side of planning and changing the land use management system, which are at the core of such sources of urban vulnerability such as the location of populations in cheaper and – often – risk-prone areas. As stated by Watson (2007: 52) social inclusion can only be realized through changes in the regulatory frameworks and in systems of land rights. Especially in low- and middle- income countries, the new approaches face an important emerging tension. On the one hand, they push for more open, inclusive, flexible planning systems which work with the informal sector rather than trying to eradicate it. But on the other hand, a push exists for stronger controls and state-led development processes, in response to the threats of climate change, environmental hazards, and the spiraling crisis of poverty, crime and disease (see also section 5.2.1).

## 5. Cities responses to climate change

It has been recently recognized that urban areas play a key role in addressing the challenges created by climate change in terms of mitigation and adaptation alike (Sanchez et al 2008). Different initiatives such as the Cities for Climate Protection, the C40 Cities Climate Leadership Group, and the Majors Alliance for Climate Change Protection in US (see Box 3) are examples of current responses. A high proportion of these initiatives has been created in large cities of high income countries and to a lesser extent of middle- and low-income countries. As stated by Sanchez-Rodriguez et al (2008), we still have a lot to learn about the way in which cities have responded to climate change. We do not know, for instance, how many cities around the world have

initiated programs and actions to address climate change; what the nature of those responses is; what actors are getting involved; what the underlying drivers and the institutional constraints/opportunities of the responses are; finally we do not yet know whether there are synergies, conflicts and contradictions among mitigation and adaptation responses, and development goals within and between these cities.

The following section offers a preliminary response to these questions, based on the still fragmented knowledge we have of existing urban mitigation and adaptation responses. In chapter 2, we referred to the main actors in the climate change arena. We pointed to the multi-level nature of climate governance. In this section, we will describe what actions, policies and technologies have been designed to curb emissions, and how cities have responded to the mitigation challenge of climate change (section 5.1). We will explore the role of knowledge in local climate policy, and some factors explaining the huge gap between the rhetoric and reality of local climate policy (section 5.2). We will then describe existing adaptation responses, their constraints, and the role of good governance in enhancing adaptive capacity (section 5.3).

## 5.1 Mitigation, options and constraints

Mitigation seeks to slow and – if possible reverse – the processes of climate change by lowering global GHG emissions, which have increased dramatically during last decades. To stabilize the concentration of GHG in the atmosphere, emissions would need to peak and decline thereafter. The lower the desired stabilization level, the more rapidly the peak and decline would occur. The following table provides a series of mitigation options relevant to cities.

**Table 4: Some examples of mitigation policies, technologies and measures relevant to cities**

| **Sector** | **Mitigation technologies and practices currently commercially available** | **Policies, measures and instruments shown to be environmentally effective** | **Key constraints (-) or opportunities (+)** |
|---|---|---|---|
| Energy supply | Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bio-energy); combined heat and power; early applications of CO2 capture and storage (e.g., storage of removed CO2 from natural gas). | Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels.<br><br>Feed-in tariffs for renewable energy technologies renewable energy obligations; producer subsidies. | (-) Resistance by vested interests may make them difficult to implement.<br><br>(+) May be appropriate to create markets for low emissions technologies. |
| Transport | More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles bio-fuels; modal shifts from road transport to rail and public transport; measures to enhance the use of cycling, walking; land-use and transport planning. | Mandatory fuel economy, bio-fuel blending and $CO_2$ standards for road transport.<br><br>Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing.<br><br>Influence mobility needs through land use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorized forms of transport | (-) Partial coverage of vehicle fleet may limit effectiveness.<br><br>(-) Effectiveness may drop with higher incomes.<br><br>(+) Particularly appropriate for countries that are building up their transportation systems. |

| | | | |
|---|---|---|---|
| Buildings | Efficient lighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases. | Appliance standards and labeling. | (+) Periodic revision of standards needed. |
| | | Building codes and certification. | (-) Attractive for new buildings.<br>(-) Enforcement can be difficult. |
| | | Demand-side management programs. | (+) Need for regulation so that utilities may profit. |
| | Less carbon intensive building materials (e.g. wood[8]), construction and demolition technologies | Public sector leadership programs, including procurement. | (+) Government purchasing can expand demand for energy-efficient products. |
| | | Incentives for energy service companies. | (+) Success factor: Access to third-party financing. |

[8] An analysis of typical forms of building construction (could you provide the reference Inge Jensen?) shows that wood buildings require much less energy and result in lower carbon emissions than buildings of other materials such as brick, aluminum, steel and concrete. It shows that a 17 per cent increase in wood usage in the New Zealand building industry could result in a 20 per cent reduction in carbon emissions from the manufacture of all building materials. Moreover, as wooden buildings themselves store carbon, the increased use of wooden building materials — provided that it is accompanied by corresponding reforestation — would reduce carbon emissions to the atmosphere. Another study has shown that if wood products are used in the production of a single-story house, greenhouse gas emissions would be reduced by 85 per cent compared to a high greenhouse gas emission house (floor: concrete slabs and ceramic tiles; wall frame: brick; roof frame: steel; and windows: aluminum). In general, increased use of wood could reduce $CO_2$ emissions in construction by nearly 50 per cent.

| | | | |
|---|---|---|---|
| Industry | More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-$CO_2$ emissions; and a wide array of process-specific technologies. | Provision of benchmark information; performance standards; subsidies, tax credits | (+) May be appropriate to stimulate technology uptake.<br>(+) Stability of national policy important in view of international competitiveness. |
| | | Tradable permits | (+) Predictable allocation mechanisms and stable price signals important for investment. |
| | | Voluntary agreements | (+) Success factors include clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring.<br>(+) Close cooperation between government and industry. |
| Waste | Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimization. | Financial incentives for improved waste and wastewater management. | (+) May stimulate technology diffusion. |
| | | Renewable energy incentives of obligations. | (+) Local availability of low-cost fuel. |
| | | Waste management regulations | (+) Most effectively applied at national level with enforcement strategies. |

Source: IPCC (2007), World Bank (2008).

Although a framework of international negotiations among nation-states remains a crucial mechanism to address climate change, the last decades have witnessed a great increase of city-based initiatives and efforts to respond to climate change. For instance, after being mainly confined to North American and European countries, the Cities for Climate Protection has programs involving around 700 local governments in Latin America, Asia, and Australia (see Box 3). Yet, although research has helped consolidate our understanding of the role of cities in responding to climate change, very few studies exist on the nature of these mitigation responses in cities of middle- and low-income countries (Betsill and Bulkeley 2007). Existing studies have focused on how climate change is framed by city authorities, on what its priority is and on how much of these efforts has gone beyond the policy discourse on the relevance of local action and become a real and effective climate change policy on the ground.

The way climate change is framed may play a crucial role in the effectiveness of a local climate change policy. It is important to prioritize climate change in relation to economic growth, poverty reduction, political stability, and other societal issues. Pioneering efforts at climate change policy creation in cities from low and middle income countries such as Durban, South Africa have shown that political will is not enough when local authorities need to deal with other “higher priority” matters, such as unemployment, backlogs in housing and high levels of HIV among the population (Roberts 2008: 2). But even in high-income countries such as Sweden (Storbjörk 2007), psychological and cultural barriers reflected in the attitudes of the populous who may believe “it won’t happen here mentality” can work against the political priority of climate change in comparison with other local issues.

Equally important is the fact that a global issue like climate change needs to mean something for the actors involved in policy making at the city level. Existing case studies illustrate that the two-sides of climate change (mitigation and adaptation) have only become a local priority when the range and extent of climate change have been actually understood by local actors (as in Durban, Roberts 2008), or when it has been linked to issues already in the local agenda such as energy or air quality in US cities and in Mexico City respectively (Betsill 2003; Romero Lankao 2007b).

Yet, many of existing actions and responses do not necessarily address climate concerns, or if they do they focus on only a tiny aspect (e.g., mitigation technologies) of the whole issue (including the linkages of mitigation and adaptation with development). Existing actions are, hence, fragmented. Most actions have focused mainly on mitigation. The topic of adaptation to a changing climate is not addressed in most plans (Satterthwaite et al 2007, Betsill and Bulkeley 2007). Nor have the potential consequences of the designed actions on other sectors been addressed. Research has shown that in some cases, the short term reduction targets fall short of achieving long-term reduction goals. In the U.S., for example, cities have adopted long-term goals approximating the 80 percent reductions in GHG emissions by 2050 goal. The problem is that they have also adopted weaker near-term targets that do not establish a realistic path towards this goal (Wheeler 2008). Many

of the measures are voluntary, and their implementation has not yet taken place (Rodriguez et al 2008 and Wheeler 2008).

Diverse institutional factors have come into play to facilitate or – to the contrary – constrain the effectiveness of policy actions. Studies undertaken in Europe, Australia, and US, for instance, have identified following factors influencing the extent to which the rhetoric of climate change policy was translated in effective action among local authorities: presence of local political champions, financial resources, local government competencies and capacity, local history of engagement with environmental issues, and political will to address emerging conflicts (Bulkeley and Betsill 2003: 452). The lack of financial and human resources, of decision making power and of other components of institutional capacity has hindered the effectiveness of many efforts in Durban (Roberts 2008), Johannesburg (Holgate 2007), and Mexico City (Romero Lankao 2007b). Equally important is the fact that under the recent process of decentralization and devolution, city officials have been charged with climate relevant responsibilities. Johannesburg for example is responsible for managing climate change programs and the ICLEI CCP program (Holgate 2007). Yet, they are faced with at least one of the two following challenges:

a) The financial resources and decision making power are centralized making local resources scarce and local policy implementation difficult. For instance, the local authorities in the 16 delegations and 34 municipalities of Mexico City have control of revenues amounting to 0.5% of Mexico's GDP, whereas for other federal countries the figures range from 6.4% (Australia) up to 17.4 % of GDP (Canada)" (OECD (2004: 78 cited in Romero Lankao 2007b). In Peru the national government only transfers 5 per cent of the national budget to the 2000 plus local governments (Diaz Palacios and Miranda 2005).

b) Even when national level funding to promote local action is provided (as in Sweden), the competitive nature of this funding, and the need to provide matching resources, means that local authorities, without the capacity to bid for resources remain outside the climate change loop (Granberg and Elander 2007).

### 5.2 Adaptation, options and constraints

Urban centers have historically implemented coping actions to reduce their sensitivity to weather and climate, for example by controlling the climate in buildings within which people live, shop, and work or by controlling the channels and flows of rivers or the configurations of seacoasts. Adaptations have probably been especially salient in coastal cities (e.g. Amsterdam) vulnerable to storms and flooding, in cities from arid areas (e.g. Tucson, US), and in cities located in and around lake systems (Mexico City). This illustrates that if provided with human resources and access to knowledge, urban centers have a considerable capacity to adapt to known conditions. Yet climate change might pose challenges that overwhelm that capacity, especially for urban areas that are already facing adaptation deficits.

Two mechanisms have been developed to understand and cope with climate hazards:

disaster risk management and adaptation strategies. Disaster risk management has a longer history within the policy making community. It has developed a staged model to understand and manage the way responses to disaster (should) operate. It seeks to understand disaster risk management actions in terms of their place in the disaster cycle, which includes following processes: prevention (also called mitigation) and preparedness, emergency response, reconstruction and rehabilitation. The emergency phase is defined by efforts to cope with the hazard, with the injured and loss of life. Depending on the scale of the disaster and of the resources demanded, this phase may last from a few days to many weeks. Prevention (also called mitigation) should take place before a disaster event occurs through actions targeted at reducing vulnerability and mitigating the hazards, as well as measures seeking to involve stakeholders in emergency response planning. The restoration period entails a short phase of reestablishment of transportation, utilities and urban services, of return of refugees. Depending on the extent of damage and of existing resources, it also includes the rebuilding of capital stock to pre-disaster levels; it might also embrace elements of memorializing and commemoration. The rehabilitation period may provide opportunities to build prevention and preparedness into enhancing sustainable development (Vale and Campanella 2005; Pelling 2005).

Adaptation has a shorter history mostly related to climate-change research and action. It is defined as the realization of adaptive capacity, understood as the *potential* of a city, its populations and its decision makers to modify cities' features and or people's behavior so as to better cope with existing and anticipated climate stresses (See Box 1). Thus adaptation is about enhancing resilience or reducing cities', infrastructures', and people's vulnerabilities to observed or expected changes in climate (Adger and Agrawala et al. 2007). As with mitigation, adaptation has many linkages with the way a city develops and is planned and managed (see section 4.3). The paths of urban development and urban planning might enhance or, on the contrary, constrain the adaptive capacity of a city's populations, especially of its low-income groups. Adaptive capacity will influence adaptation (the *actual* adjustments made). However, as documented by the 2003 heat waves in Europe, even among urban populations with relatively high adaptive capacity, this does not necessary translate into measures that reduce vulnerability (see Box 7).

Box 7: 2003 European heat-wave

The summer of 2003 was the hottest in Europe since 1500 (Confalonieri and Menne 2007). According to some climatologists it is very likely that human-induced climate change doubled the risk of such an extreme event, which resulted in 35000 deaths. The heat wave affected urban settlements in many ways. It affected the health of the population, especially the elderly. It impacted water supplies, food storage, and energy systems. In France, for instance, electricity became scarce, construction activities had to be modified, and 25-30 percent of food-related establishments found their cooling systems to be inadequate (Wilbanks and Romero Lankao 2007). The impacts resulted from the fact that although the population has relatively higher levels of adaptive capacity (e.g. access to health services), it lacked adequate climate conditioning in buildings. Furthermore, many of the dead were elderly people, left alone while their families were on vacation.

Two lessons can be drawn from this event: Even developed countries may not be well prepared for extreme weather events. Their governments can be unable to deal with complex, relatively sudden environmental challenges (Lagadec 2004 cited in Wilbanks and Romero Lankao 2007).
Source: Wilbanks and Romero Lankao (2007)

Adaptation is strongly determined by the resources available, the knowledge and information base available to guide action, the infrastructure in place, the quality of institutions, governance systems and urban planning, and the financial and technological resources available for adaptation. Most aspects of 'development' influence adaptive capacity because they also influence local knowledge and local capacity to act. Successful development also relates to increased incomes and asset bases for poorer groups; to improved health which in turn increases their capacity to act to reduce their vulnerability. As already noted in section 3.3.3, low-income populations in a city will tend to have lower adaptive capacity than the rich/high income populations.

Different classifications of adaptation practices exist. There are both proactive and reactive actions – i.e. the proactive seasonal climate forecasting aimed at informing affected populations of the imminence of a weather disaster and reactive disaster recovery respectively. We can find autonomous (e.g., voluntary reductions in water use by individuals) and policy driven measures (e.g., investments in infrastructure). Adaptation for cities entails such diverse actions as increasing the resilience of infrastructures, changing the location of settlements, reducing the emission of solid wastes, reducing heat-island effects, providing financial support, and adopting practices that enhance sustainable development (Wilbanks et al 2005). IPCC has developed a list of adaptation policies and actions that include urban areas, but also other levels of involvement (see Table 5).

**Table 5: Selected examples of adaptation opportunities relevant to cities**

| **Sector** | **Adaptation option/ strategy** | **Underlying policy framework** | **Key constraints (-) or opportunities (+) to implementation** |
|---|---|---|---|
| Water | Expanded rainwater harvesting water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency | National water policies and integrated water resources management; water-related hazards management | (-) Financial, human, resources and physical barriers<br>(+) integrated water resources management; synergies with other sectors. |

| | | | |
|---|---|---|---|
| Infrastructure & settlement (including coastal zones) | Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea-level rise and flooding; protection of existing natural barriers | Standards and regulations that integrate climate change considerations into design; land use policies; building codes; insurance | (-) Financial and technological barriers<br>(+) Availability of relocation space, integrated policies and managements, synergies with sustainable development goals |
| Human health | Heat-health action plans, emergency medical services, improved climate-sensitive disease surveillance and control, safe water and improved sanitation | Public health policies that recognize climate risk; strengthened health services; regional and international cooperation | (-) Limits to human tolerance (vulnerable groups)<br>(-) Knowledge limitations<br>(-) Financial capacity<br>(+) Upgraded health services<br>(+) Improved quality of life |
| Tourism | Diversification of tourism attractions and revenues, shifting ski slopes to higher altitudes and glaciers | Integrated planning (e.g., carrying capacity; linkages with other sectors); financial incentives, e.g., subsidies and tax credits | (+) Appeal/marketing of new attractions<br>(-) Financial and logistical challenges<br>(-) Potential adverse impact on other sectors (e.g., artificial snow-making may increase energy use)<br>(+) Revenues from new attractions<br>(+) Involvement of wider group of stakeholders |

| | | | |
|---|---|---|---|
| Transport | Realignment/relocation; design standards and planning for roads, rail, and other infrastructure to cope with warming and drainage | Integrating climate change considerations into national transport policy; investment in R&D for special situations, (e.g., permafrost areas) | (-) Financial and technological barriers<br>(-) Availability of less vulnerable routes<br>(+) Improved technologies<br>(+) Integration with key sectors (e.g., energy) |
| Energy | Strengthening of overhead transmission and distribution infrastructure, underground cabling for utilities, energy efficiency, use of renewable resources, reduced dependence on single sources of energy | National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards | (+) Access to viable alternatives<br>(-) Financial and technological barriers<br>(-) Acceptance of new technologies<br>(+) Stimulation of new technologies<br>(+) Use of local resources |

Sources: IPCC (2007) and World Bank (2008).

Other issues need to be considered when assessing existing adaptations at the city level refers to the multiple-scale nature of adaptation actions (Adger, Arnell and Tompkins 2005). Adaptation can be implemented at different levels, from individuals to systems, from the local to the national level. Individual adaptations may not result in adaptation at the city level. It is even possible that some adaptations by groups or individuals will increase the vulnerability of other peoples and places. For example, flood protection upstream may increase discharge downstream and increase flood damages for places that cannot afford the increased protection. Sea walls and groins built to prevent shore erosion and beach loss may have the affect of causing increased erosion in other areas normally fed by the movement of sediment. The determinants of adaptive capacity might also vary with scale. We could say for instance, that at a national scale, industrialized countries such as the US, the UK and Norway can cope with most kinds of gradual climate change, but as illustrated by Katrina and the heat waves in Europe, focusing on more localized differences can show considerable variability in stresses and capacities to adapt (Wilbanks and Romero Lankao et al. 2007). At a temporal scale the responses to risks include three levels: current variability, observed medium and long-term trends in climate, and anticipatory planning in response to model-based scenarios of long-term climate change. These responses are frequently intertwined, and might form a continuum, but they might also counteract each other, for instance, when current adaptations such as snow-making results in more GHG emissions, thus being at odds with long term mitigation commitments (Adger and Agrawala et al. 2007, Wilbanks and Romero Lankao 2007). To be effective and avoid contradictions, they require locally-relevant information

on climate variability and trends, which is missing in many cases.

The next sections describe examples of existing adaptation actions relevant to cities. They include an analysis of the role of governance and of government actions that by fostering development increase adaptive capacity. They present some examples of city-wide adaptation efforts, and describe what has been done to adapt infrastructures and include mechanisms to enhance financial preparedness to cope with disasters.

But before that, we ask the reader to keep in mind the findings of the IPCC Working Group II report (2007) on existing adaptations. Adaptation is occurring in response to observed and anticipated climate change. Such is the case of the design of infrastructure projects such as coastal defense in the Maldives, The Netherlands, and the Qinghai-Tibet Railway. Other examples include prevention of glacial lake outburst flooding in Nepal, the water management project in Australia and government response to heat waves in Canada and some European countries. Yet adaptation is occurring **only** on a limited basis. Adaptation measures are seldom undertaken in response to climate considerations alone. As will be illustrated in the next sections, adaptation measures have multiple social and economic drivers. In other words, they have been implemented as part of broader development and sectoral initiatives.

### 5.2.1 Urban management policies

Governments play a key role in enhancing adaptation (Adger and Agrawala et al. 2007) not only because they watch over land-use management systems that are at the core of such sources of urban vulnerability as the location of populations in risk-prone areas (see section 4.3). But also because in terms of urban development, government's role should be to assure that all urban dwellers have access to infrastructure and services; to guide where settlements develop and where they do not; to regulate industries, transportation and other hazardous activities that can produce disasters; to design land use regulations and zoning to influence land availability; to encourage and foster better quality housing, and safer sites (Satterthwaite et al 2007). Governments can also include climate change considerations into urban planning by making sure that buildings and infrastructure take account of climate-change risks (in ways that do not impose additional costs that are unaffordable for poor groups); by planning and public sector investment decisions that take account of climate change; by ensuring access to appropriate and widely understood information on climate change and its local impacts; by coordinating and supporting strategies and programs to avoid and to prepare for disasters; and by addressing the factors that generate both vulnerability and poverty (Adger and Agrawala et al. 2007, Satterthwaite et al. 2007).

Most cities in high-income countries have many components of urban management that determine their higher adaptive capacity. The majority if not all of their populations have safe, sufficient piped supplies of freshwater, provision for sewers and drains, all-weather roads, electricity and other infrastructure, and services that protect them from environmental hazards. Those populations have health care and emergency services that help them cope when illness or injury occurs. These cities also have resources,

knowledge, infrastructure, institutions, urban planning and governance systems which have allowed them to develop city-wide studies and initiatives to cope with climate change. That might be the reason why, with some exceptions (e.g. Durban and Cape Town South Africa, Dhaka Bangladesh), most city-wide efforts to asses and cope with climate change have been undertaken in cities from high income countries (London, New York, Los Angeles, Hamilton and Wellington, Hunt and Watkiss 2007).

Compared to urban centers from high-income countries, in virtually all urban centers from low-income countries and most from middle-income countries, existing buildings and infrastructure have been built and maintained to much lower standards of resilience. The powers and resources available to local governments are also much smaller (see section 2.2). Such governments are not held accountable through being supervised by elected politicians. There is, in short, a much weaker governance system and, hence, smaller adaptation capacity. Those urban centers hence face development deficits that constraint their capacity to cope with existing weather disasters let alone manage climate variability and change.

In this context, the emergence and dissemination of new governance paradigms at the global level has resulted in at least two kinds of situations. On the one hand, the design of participatory, integrated, and decentralized institutions, such as in South Africa's integrated development planning (Watson 2007), or in Brazil's recent water reform, is likely to build adaptive capacity to climate change by improving availability and access to technology, involving stakeholders, and encouraging sustainable use (Lemos and Oliveira 2004).

On the other hand, decentralization has often resulted in the transfer of responsibility to local authorities, but not the resources and capacities to fulfill their new functions (e.g. maintenance of infrastructure). In many cases, responsibilities such as the public provision of transport, health, water and sanitation services have been practically abandoned by the state, or have been transferred or "decentralized" to the private sector and to local authorities (Wilder and Romero Lankao 2006). These reforms together with an increasingly globalized world have resulted in two paradoxes. The cuts in subsidies on food, health and transportation occurred precisely when the fiscal reform and restructuring of the public sector meant that urban unemployment and inflation were on the increase. A growing competition between cities to attract investments with incentives such as low labor costs or tax breaks tended to increase inequalities between and within cities (Pelling 2003, UN-Habitat 2003). As stated by UN-Habitat (2003: 43) the retreat of the state has been a decisive cause of increases in poverty and inequality during the last 25 years. The reform of the state has resulted in the weakening of such traditional mechanisms for the redirection of income and the social integration of poor sectors, as public infrastructures, public education, public health care systems and central areas for recreation and culture (UN-Habitat 2003). These mechanisms are a key in enhancing poor sectors' adaptive capacity and resilience to climate related and other stresses.

### 5.2.2 Disaster risk management

Cities can draw from the longer experience on disaster risk management, which includes not only the stages of disaster response and recovery, but also (see section 5.2) measures to reduce and prevent disasters. Six components are important in disaster reduction: strengthening local capacity, land-use planning and management, building codes and disaster resistant construction, protecting critical infrastructures and services[9], and early warning and financing (Pelling 2005).

Regarding strengthening of local capacity, the involvement of local actors is a very effective mechanism to reduce disaster risk (see for example Manizales and Ilo in section 5.3). The IPCC WGII noted various examples where disaster preparedness at the community level helped reduce death tolls – for instance through new early warning systems and evacuation procedures (and safe places for evacuation identified). Yet it is important that this involvement be grounded in supporting institutional environments. Moreover, by empowering local actors to confront local causes of risk, we should not offload the state or the private sector from their responsibilities. The focus on participation should not lead us to lose sight of the deeper historical and structural root causes of disaster risk in the national and global political-economy.

Urban development and land-use management plans can not only address social inclusion though changes in the regulatory frameworks and in systems of land rights. They can also help mainstream disaster risk reduction into urban development processes, if they support and incorporate information derived from hazard and vulnerability mapping. For example, risk maps are a key instrument in Cuba, which has one of the best records for urban risk management. The maps have contributed to recommendations for retrofitting, resettlement and urban growth regulation in 107 coastal settlements. A Community-Based Disaster Risk Management in Vietnam, coordinated by the Spanish Red Cross, has benefited 31,000 people in small human settlements. The program applies Hazards, Vulnerabilities and Capacities Assessment tools, including mapping, at the local level. The tools have two purposes: to raise awareness of local causes of risk amongst residents; to encourage the development of flexible action plans for disaster preparedness in each local site (Pelling 2005).

Building codes, standards and regulations seek to ensure construction meets a minimum standard of disaster resilience. However, in the urban centers of many poorer countries, building codes, often imported from industrialized countries, are inappropriate to local conditions and disaster risks. For instance, the high losses of Jamaican homes generated by hurricane Gilbert in 1988 have been blamed on the inappropriateness of their National Building Code inadequately modeled on UK standards. Sometimes codes are up-to-date and appropriate but the mechanisms to ensure compliance and code enforcement are not or there are large areas that are outside of the purview of inspection regimes. This is of particular concern in cities from middle- and low-income countries. Their high percentages of inhabitants forced to reside in informal settlements pose a challenge to

[9] Critical infrastructure includes electricity, natural gas and liquid fuels, potable water and sanitation, telecommunications and transportation systems. Critical services include hospitals and access to health care, polices and maintaining the rule of law, and financial services (Pelling 2005).

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building regulation, as those involved in building these settlements operate outside the formal planning and regulatory systems.

Early warning systems include risk assessment and communication as well as measures to minimize risk. Countries with effective warning systems such as Cuba and Hong Kong illustrate that to be effective early warnings must reach a defined target audience in a timely manner. They must provide unambiguous advice on or automatically activate strategies for minimizing risk, including evacuation. Creation of an early warning system with an effective response requires not only that the sources of information be perceived as authoritative and trustworthy, but that a well managed and often practiced evacuation strategy be in place. Notwithstanding their relevance, few urban centers have early warning systems, or even data on hazards and disasters (Pelling 2005).

Disaster response and recovery require different levels of resources, participation, communication, and partnerships between involved actors (see section 2.2). It demands that attention be paid to the referred dimensions of disaster reduction (strengthening local capacity, land-use planning and management, building codes and disaster resistant construction, protecting critical infrastructures and services, and early warning and financing). Local authorities are well situated to host disaster response efforts, but if they have limited capacity, then the response can end up in the hands of national and international actors. Efficiency can be important determinant of effective responses. However, it is equally important to manage with openness and inclusiveness of stakeholders, otherwise the effectiveness of the response and of post disaster recovery efforts will be constrained.

Scholars point to the fact that large disasters open a window of opportunity to reform urban planning systems and budgets. The reality, however, is that it is often the next development challenge or political agenda that will take precedence over disaster risk reduction. After Hurricane Mitch for instance, there was progress in introducing new legislation but urban concerns were not fully addressed, especially the links between disaster management and urban management, so urban planning did not live up to its potential in risk-reduction (Pelling 2005 cited in Satterthwaite et al. 2007).

### 5.2.3 City-wide climate initiatives

Some cities, especially in high-income countries, have undertaken city-wide initiatives to understand and quantify the impacts of climate change and to explore adaptation options (e.g. London, Boston, New York, Los Angeles, Hamilton and Wellington (Hunt and Watkiss 2007). With the exception of Durban and Dakar, which have had stronger involvement of policy makers and stakeholders, studies in urban centers from middle-income countries have mainly been undertaken by scholars (e.g. De Sherbinin et al 2007 on Shanghai, Mumbai and Rio de Janeiro), and have focused on widely predicted impacts such as sea level rise (e.g. Dossou and Glehouenue 2006, quoted in Satterthwaite et al 2007).

London, New York and Durban (South Africa) offer interesting examples of city-wide

efforts aimed at understanding and coping with the impacts of climate change. They show many of the management ingredients that may enhance adaptive capacity. Their climate programs emerged from national initiatives promoted by the UK and US governments in the first two cases and by the South African government and ICLEI in the third. The three appear as examples of advanced quantitative studies at the urban level in which stakeholder involvement has functioned as source of information on the possible responses to climate change. The three cities show that this type of climate knowledge and analysis can be incorporated into current planning and decision making. They illustrate that two elements, in addition to an assessment of climate hazards, are essential for a successful city-scale program: the creation of a designated lead organization and the involvement of stakeholders (Roberts 2008; Hunt and Watkiss 2007).

Yet, while London and New York started with initial scoping studies and moved to more focused assessments on impacts followed by adaptation options, Durban followed a different path. It started by committing itself to the five performance milestones requested by ICLE as part of the city's mitigation efforts (see Box 3). After realizing that this effort in itself did not help build much internal institutional momentum and knowledge around the issue of climate change(Roberts 2008: 3), local authorities developed the Climate Future for Durban Project focusing on translating global and regional climate science and data into the local predictions of event impacts that would affect the city. By then it became clear that rather than mitigation, adaptation was "likely to be the priority in the further development of the MCPP (Municipality Climate Protection Program)" (Roberts 2008: 4).

With the exception of referred cases, most city-scale initiatives are currently focused on awareness-raising rather than impact assessment or adaptation analysis and action. This might result in missing the opportunity of developing no-regret adaptation options which increase cities' resilience to climate change (Hunt and Watkiss 2007).

### 5.2.4 Infrastructures

Urban infrastructures, which provide human, environmental and economic services typically include flood control, water supply, drainage, wastewater management, solid and hazardous waste management, energy, transportation, constructed facilities for residential, commercial, and industrial activities, communication, and recreation (Kirshen et al 2007). Investment is the main mechanism for adaptation of infrastructures (Wilbanks and Romero Lankao 2007). Within their normal planning, most fields of infrastructure management incorporate, or should incorporate, vulnerabilities to changing trends of supply and demand and risks of disturbances. Yet climate change requires different priorities in infrastructure planning and investment. For instance, increases in reserve margins and other types of redundant capacity, or focus on system designs that permit infrastructural systems to handle more extreme conditions during operation.

While still very limited, some examples exist, mostly from high income countries, on the adaptation of urban infrastructures to climate change. Besides the examples referred to in Table 6 Antwerp, New York and Dutch cities are implementing controls to help deal with

inundated areas. The Dutch, with 60% of their lands below sea level and a long history of engineered responses with a high environmental cost, like holding back the sea using dykes, levees and pumps, are looking to greener approaches like building temporary retention ponds and floating homes, apartment buildings and greenhouses to naturally drain and better coexist with water bodies. In Basel, Linz and Toronto vegetating green roofs are being constructed to address different climate risks (e.g. excessive heat, storm water run-off (LCCP 2004). London (UK) is reviewing its tidal defenses, including the Thames Barrier, to be protected from major flooding resulting from climate change (Wilbanks and Romero Lankao et al. 2007)

To protect climate threatened water supplies, Melbourne is implementing actions to promote a more efficient use of water. Varied tariffs are used to reward lower water use. Drought response plans are applied to introduce staged water restrictions when water levels are low (LCCCP 2004). More conventional adaptation actions are also being implemented. Severn-Trent – one of the nine English water companies – is planning for a new reservoir to maintain the supply to Birmingham, where it has estimated that its output is likely to fall by 180 Megalitres/day (roughly 9% of the total) by 2030 due to climate change. The city of Perth, Australia decided in 2004 to install a desalination plant to supplement the dwindling flows available for water supply. The city of Beira in Mozambique is already extending its 50 km pumping main 13 km farther inland to be certain of fresh water supply.

Other intervention priorities can reduce climate-change related risks especially for urban areas of middle and low-income countries (Revi 2007, quoted in Satterthwaite et al 2007). Technical measures can be introduced to strengthen and retrofit existing buildings. Infrastructure can be also strengthened to integrate into them appropriate climate change-related risk reduction measures. Slums and squatter settlements, as areas of high vulnerability, can be upgraded (see section 5.2.6).

### 5.2 5 Insurance and public financing

The use of insurance as a means of spreading and reducing the losses from climate related events has received increased attention (IPCC 2001, Wilbanks and Romero Lankao 2007). New insurance mechanisms can be designed to help better distribute losses, for example expanded property insurance coverage. Insurance can also work as agent of adaptation through incentives for risk reduction strategies, including better building codes and flood prevention schemes.

In high income countries, the risk-bearing sector is diversified, including banks, government-backed insurance systems, disaster funds, and individuals. The use of private insurance is far lower in low- and middle-income countries (Wilbanks and Romero Lankao 2007). For example, only 150,000 houses out of 16 million (i.e. less than 1%) had disaster insurance coverage in Mexico in 1998. The rate of insurance coverage for the Venezuela floods of 1999 only amounted for 1.4% of total losses. As highlighted by events such as Hurricane Stan that hit Mexico and Guatemala in 2005, individuals bear most of the cost and manage it through the solidarity of family and other social networks, if at all.

There are some examples of public provision of funds to deal with natural disasters. Contingent financing is the main financial instrument - e.g. Fondos Nacionales de Desastre for Mexico, Guatemala and other countries. Most of the contingent financing comes from bilateral or international assistance (e.g. grants, lending). For example, the disaster related assistance of the Inter-American Development Bank reached $1.5 billion between 1996 and 2000; that is 10 times more than it was in the 15 years before on an annual basis (Charvériat 2000: 79). The main problem with this form of financing is the availability of funds and timing of disbursements. International aid following disasters rarely exceeds 4% of the losses incurred. Official development assistance by principal donors decreased by 16% in real terms between1992 and 1996, and a further 7% in 1997 (Charvériat 2000: 79).

Another example of public provision is the Instituto de Resseguros, a kind of public insurance mechanism, which has a monopoly over reinsurance in Brazil. The Institute has recently been transformed into a joint stock company, a majority of the shares of this company is held by the Government. Risks of fire, which include floods, the main hazard in the country, are its major line of business, accounting for 33% of the total retained premium volume (Charvériat 2000: 78).

There may be a potential for public/private partnerships between governments and insurance companies as a mechanism to deal with the failure of purely market driven processes to provide adequate insurance at affordable rates. For example, exploratory insurance schemes have been initiated in India and Ethiopia. The Bangladesh National Adaptation Program of Action (NAPA) included micro-insurance as a priority project. However the experience so far is insufficient to warrant large-scale deployment of insurance as a means of supporting adaptation to climate change in low- and -middle income countries.

Low-income groups in urban areas already employ mechanisms to spread risk and reduce their vulnerability. Community-managed savings groups, taking many forms such as the “tandas” are spreading in Mexico, other Latin American countries and even among the Latino communities within US[10]. These typically allow their members to have access to funds from pooled savings for sudden expenditures (e.g. school fees, medicines) or shocks.. Another well known mechanism is the federations of savings groups, developed by people living in ‘slums’, and active in fifteen countries. The federations are crucial not only in community-managed risk management, but also in many initiatives that enhance the resilience of the urban poor (e.g. improvement of housing, water, sanitation, drainage and other infrastructures (Patel et al 2001; D'Cruz and Satterthwaite 2005).

Micro finance is another instrument to help urban dwellers, especially the poor, cope with climate change and other hazards. The Grameen Bank of Bangladesh is a successful

[10] “Tanda” or “rotating credit association” refers to "an association formed upon a core of participants who agree to make regular contributions to a fund which is given in whole or in part to each contributor in rotation". A tanda is built mostly on trust. See http://www.anthro.uci.edu/html/Programs/Anthro_Money/Tandas.htm

example of this. It uses group lending contracts with joint liability to reduce the problems of 'moral hazard' and 'adverse selection' where households are too poor to offer collateral. It works best when applied to directly increase incomes (micro-enterprise loans) or reduce expenditures. However, micro finance can crumble if everyone experiences the same crisis, so government underwriting is necessary for them to be of any use in the face of climate change related disasters. It also faces the challenge that low-income groups have very limited capacities to save and to pay. Thus all loan schemes have dangers of locking them into debt burdens they find hard or impossible to manage.

### 5.2.6 Community-based adaptation

Community -based adaptation (CBA) to climate change has recently received more attention, although there is uncertainty about its potential. It is unclear, for example, how it fits in with community-based development and disaster planning among other more established development activities. It is also uncertain how different it is from other forms of adaptation and what particular potentials and limitations it will have when applied to urban areas. (Satterthwaite et al 2007).

It can be concluded from existing experience that any CBA includes three important stages. First, it addresses current climate risks within a development context. It then monitors progress and looks outward. Finally, it includes climate change considerations into the assessment of future development options. In this way communities get the opportunity to explore adaptation possibilities under different development approaches. Furthermore they improve their capacity to make choices about their own futures. CBAs need to pay attention to the many political, financial and social barriers hampering this process and to the strategies and mechanisms for addressing those barriers. This will often involve difficult decisions – for instance having to relocate settlements that are vulnerable to severe weather impacts. This makes it all the more important to fully engage communities in choices about where to move, when to move, and how the move should be managed (Satterthwaite et al 2007).

With a 40 year experience, programs to upgrade 'slums' and informal settlements can be seen as the best examples of community-based adaptation. The extent of success is highly varied. But where upgrading has worked, it has certainly reduced poorer groups' vulnerabilities to extreme weather. Many city governments support slum and squatter settlement upgrades, for example, upgrading has been supported by the governments in Sao Paulo, Rio de Janeiro, and Nicaragua as well as in Thailand (Boonyabancha 2005; Stein, 2001). Although upgrading programs focus on addressing 'everyday' hazards and protecting against extreme weather, targeting climate-change is simply an extension of this. Successful examples of upgrading remind us that addressing the causes of vulnerability is the most effective mechanism to enhance the adaptive capacity of poor populations.

### 5.3 Linkages: synergies and trade offs

There are both synergies and trade-offs between actions addressing the mitigation challenge and other policy dimensions (e.g. industrial development, energy, health, air pollution (Barker and Bashmakov et al. 2007). As already mentioned, in many cases climate mitigation is not the priority. It is rather an outcome of efforts driven by economic, security, or local environmental concerns. It is therefore necessary to take advantage of existing synergies between climate protection and other development priorities. For instance, strong synergies exist in the transportation sector between climate change and energy supply and security. Measures replacing oil with domestic biofuels can reduce both emissions and reliance on oil imports. A more decentralized electricity system based on new renewable generation may reduce gas imports. A key question is whether urban settlements have any potential to tap into options such as carbon markets opened by the Kyoto Protocol (see Box 2). For example, could the construction or building materials industries be paid for producing concrete (or other materials) with CO2 capture? Such carbon credit trading could, potentially, be a way to subsidize the construction of adequate low income housing in developing countries. This and other options could open a completely new discussion dealing with synergies between GHG emission control and poverty reduction.

Of course trade-offs may exist. For instance, security arguments may impel countries to increase their dependence on internal reserves of coal rather than relying on natural gas imports (Barker and Bashmakov et al. 2007). Use of biofuels that are dependent on crops such as corn has been linked to food shortages and cost increases as farmers switch food producing croplands to more profitable biofuel crop cultivation. This may also be an unintended effect of government subsidies aimed at increasing production of biofuels but making raising food crops less profitable.

Especially in low- and middle- income countries, policies addressing other environmental problems, such as air pollution, can often be adapted at low or no cost to reduce greenhouse gas emissions and improve the health of the population simultaneously. The burning of fossil fuels is linked to both climate change and air pollution. Thus reductions in the amount of fuel combusted will result in both lower carbon emissions and lower health and environmental impacts from reduced emissions of air pollutants and their precursors. Aware of these co-benefits, organizations such as EPA have applied, in developing countries at the urban and national levels, environmental assessments of the co-benefits of addressing both air pollution and other issues (e.g. economic costs, energy). This has helped introduce policies that address local pollution and GHG emissions together (Barker and Bashmakov et al. 2007). However, attention needs to be given not only to the synergies, but also to the conflicts between these policy domains (see Table 6).

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**Table 6: Selected synergies and conflicts between local pollution control and mitigation of GHG emissions**

| Local action | Synergy | Conflict |
|---|---|---|
| Vehicle fuel efficiency | Reduce both local pollution | Increased $CO_2$ if vehicles' |

| | | |
|---|---|---|
| standards | and $CO_2$ emissions per vehicle-km | travel distances increase or drivers switch to vehicles with larger engines |
| Introducing CNG or propane for motor vehicles | Reduced $NO_x$ and particulates and reduced $CO_2$ | Needs good maintenance and management to avoid increasing emissions of unburnt $CH_4$ or propane |
| Controlling $NO_x$ and suspended particulates released by diesel vehicles | Significant reduction in $CO_2$ and air pollutants | Diesel engines emit less $CO_2$ than gasoline engines, but are often major contributor to $NO_x$ and particulates. |
| Reformulated gasoline | Reductions in smog, Volatile organic compounds and toxic air pollutants | It compromises fuel economy nominally by 1-2%. $CO_2$ emissions might increase |
| Preference for landfills over incinerators | Reductions in $CO_2$ emissions | Increases in methane |

Source: Dhakal (2004: 115-117).

Trade offs and synergies also exist between adaptation measures and development. There are good examples of city governments, such as in Manizales in Colombia and Ilo in Peru, taking steps to promote development – and by this – reduce vulnerability at the same time. The governments implemented actions to avoid rapidly-growing low-income populations settling on dangerous sites. Although neither of these was driven by climate-change concerns, they illustrate how pro-development and pro-poor policies can enhance adaptive capacity.

Manizales faced high rates of population growth, and of social and environmental degradation during the last decades (Velazques 2005). Lacking the resources to buy into the official land market, the poor increasingly settled spontaneously or bought land from illegal developers in many areas at risk from floods and landslides. In the 1990s local authorities, universities, NGOs and communities worked together to develop programs aimed not only at reducing risks, but also at improving the living standards of the poor and at protecting and regenerating fragile ecological areas (Velazques 2005).

The inhabitants of Ilo and seven of the city's democratically elected mayors serving consecutive terms engaged in the process of creating community management committees to collectively improve the living conditions of the population and the quality of the environment through confrontations and negotiations with the state and the Southern Peru Copper Corporation (Palacios and Miranda 2005). All these actions improved the living conditions of the population by making improvements in the provision of water, sanitation, electricity, waste collection and public space. They also reduced air pollution and implemented extensive tree planting and street paving programs. Ilo's population increased fivefold during 1960-2000. Yet, no land invasion or occupation of risk-prone areas by poor groups looking for housing has taken place

because local authorities implemented programs (e.g. acquisition of an urban expansion area) to accommodate Ilo's growth and to support the poor in their efforts to get decent housing conditions (Palacios and Miranda 2003). Notwithstanding the city's successful record of environmental and social management, the actors involved in this fascinating process still face some challenges and paradoxes in environmental and social management. Environmental contamination is still very high, as the four smoke stacks of the Southern Peru Copper Corporation emit 1800 tones of sulphur dioxide daily. Local authorities' capacity to improve the living conditions of the population and the quality of the environment is greatly constrained by a centralized governance structure. The national government for instance only transfers 5 per cent of the national budget to the 2000 plus local governments (Palacios and Miranda 2003).

Climate change can and has already been included in the risk management policies and plans of many countries. For instance, adaptation to current and future climate is now being integrated within the Environmental Impact Assessment (EIA) procedures of several countries in the Caribbean. It has also been extended toward incorporating natural hazard impact assessments in the project preparation and appraisal process, as well as the EIA guidelines, of the Caribbean Development Bank. Like Caribbean countries, Samoa's EIA guidelines also include consideration of climate change. A number of other policy initiatives have also been put in place within OECD countries that take future climate change (particularly sea level rise) into account. For example, there is a requirement for new engineering works in The Netherlands to take 50cm sea level rise into account (Adger and Agrawala et al. 2007).

Synergies and trade offs also exist between mitigation and adaptation measures (Klein and Huq et al. 2007; Wilbanks and Romero Lankao et al. 2007, see Figure 4). For instance, a common adaptation to heat waves is to install air conditioning, which increases electricity demand. Another adaptation option within the ski tourism sector is snow-making. Because of increased energy demand, both measures have consequences for mitigation. As another example, watershed planning is often related to managing climatic risks in using water for urban centers, and can be related to adaptation. However, if hydroelectricity is an option, then the justification for policy decisions in this arena may be mitigation. The implementation of hydroelectric plans may also be buttressed by promises of lower electric rates and more consistent service. All measures related to watershed management, however, will have environmental and social trade-offs such as habitat destruction affecting biodiversity and displacement of human populations occupying areas of proposed reservoirs. This means that both adaptation and mitigation might be evaluated at the same time or even with explicit trade-offs involved between them and in relation to development concerns.

Both adaptation and mitigation are equally important to address climate change. Adaptation measures can decrease vulnerability to climate hazards, thus reducing the impacts, while mitigation helps slow the rate of climate change and hence delay the date of impact and its magnitude. Most of the benefits of mitigation are not realized immediately, but rather after some decades. Therefore adaptation is required to address current and near-future impacts. Yet without mitigation, eventually the increasing

magnitude of climate change would significantly diminish the effectiveness of adaptation. Furthermore, mitigation and adaptation are usually addressed in different policy and institutional contexts, and policies are implemented at different spatial and temporal scales (see Figure 4). Adaptation actions tend to be both more geographically dispersed and smaller in scale than mitigation measures (Klein and Huq et al. 2007), but adaptive capacities refer to a slightly broader and more general set of capabilities than mitigative capacities (see Box 1). This hampers analysis and weakens our ability to evaluate the trade-offs between adaptation and mitigation (IPCC 2007a).

Notwithstanding these minor differences, adaptive and mitigative capacities are driven by similar sets of factors. These draw from a broad pool of resources, many of which are determined by a group or country's level of socio-technical and economic development; socio-political aspirations; risk perception; political will, institutional settings, and socio-cultural dimensions such as belief systems and cultural values (Klein and Huq et al 2007). The term response capacity, applied to describe the ability of humans to manage both the generation of greenhouse gases and the associated consequences, can be used to describe both capacities; it can be viewed as driven by same set of factors referred to above. The concept is new in the literature, however, and as such has yet to be sufficiently investigated.

### 5.4 Research priorities and uncertainties

Many of the studies from which this paper draws are not based on the development and downscaling of scenarios based on global or national assumptions in their use to assess cities' mitigation and adaptation options  A particular challenge is to develop new kinds of scenarios based on particular urban realities.[11] It is not sufficient to improve the capacity to provide more quantitative estimates both of emissions trajectories and impacts and adaptation potentials under the current sets of assumptions included in IPCC Special Report on Emissions Scenarios (SRES), other climate change scenarios and scenarios of greenhouse gas emission stabilization. It is especially important to address urban particularities at time horizons of interest to decision-makers, such as 2020, 2050, and 2080.

Neither are many of the reviewed studies aimed at quantitative analysis of how cities contribute to global warming; or of how climate change impacts urban centers. We lack precise estimations or robust modeling of a) how large a contribution to total emissions urban areas make; b) the main sources of those emissions; and c) the societal and environmental factors underlying different trajectories of emissions by cities. Nor we do

[11] According to Stern and Wilbanks (2008), these new scenarios need to keep in mind "the ways economic development, human population dynamics, investments in physical infrastructure and emergency response capabilities, changes in the demand for water and other resources, land use change, emissions of toxic substances, and other changes combine to alter the populations, places, and sectors that may experience climate-related shocks and thus affect their vulnerabilities". Research is needed to gather and organize data on these social forces and to build methods and models for estimating, analyzing, and projecting human vulnerabilities to climate change.

have studies or assessments of a) the whole set of socioeconomic and institutional constraints/opportunities for the deployment of mitigation measures; b) market and non markets effects of climate change at the city level or a clear consideration of uncertainty and irreversibility (Hunt and Watkiss 2007).

As the IPCC has concluded, it is difficult to estimate the benefits at the city level of damages avoided by different mitigation options or the costs of unavoided climate change impacts on urban settlements. It is difficult to find effects that can be clearly and unequivocally attributed to climate change alone at the city level because climate change is not the only stress facing cities. Most of the economic estimates of the impacts due to climate change are at the national level. Historical experience is of limited value when the potentially impacted systems are themselves changing. Many types of costs – especially to society – are poorly captured by purely monetary measures. In many cases, the best guides to projecting the possible costs of climate change are costs associated with recent extreme weather events of types projected to increase in intensity and/or frequency as climate change progresses (Wilbanks and Romero Lankao et al. 2007).

In the area of research on the vulnerabilities and adaptation potentials of cities, uncertainties dominate lagging behind research on physical and environmental systems, ecological impacts, and mitigation. For instance, uncertainties exist about climate change impacts within specific geographic locations and sectors; uncertainties about potentials, costs, and limits of adaptation in keeping stressful impacts within acceptable limits, especially in developing countries and regions (Parson *et al.* 2003 cited in Wilbanks and Romero Lankao et al. 2007); and uncertainties about possible trends in societal, economic, and technological change with or without climate change. All of these uncertainties undermine efforts to assess potential benefits from investments in adaptation.

What we require now, and without delay, is an improved understanding of indirect second and third order impacts of climate change: a) i.e., beyond the primary effects, such as the collapse of infrastructures caused by hurricanes what secondary effects may trickle down paralyzing economic activities and increasing reconstruction costs; b) What, furthermore, will be the relationships between specific effects in one location and the well-being of other locations, through linkages in inflows/outflows, interregional trade and migration of populations. These are questions which we can not presently answer but that the very survival of our urban centers depend upon. And along with those urban centers go the survival of all of our human cultures and institutions both locally, nationally and globally.

## 5.5. Conclusions

As the local centers of our global human society, urban areas will fulfill a significant role in our responses to the challenges that climate change will bring us. We stand at the threshold of what promises to be a great upheaval of many of our most cherished and deeply held cultural institutions and ways of life and the focal points of all of these changes will be the very areas where they are happening at the local level. Since most of

the Earth's peoples now live in our urban areas, and an accelerating movement of our populations makes this more and more true every day, the primary areas of this localization will be urban. These are the areas where we will feel the pain of the impacts of climate change at the most basic human level. Here we have increased vulnerabilities by virtue of the fact that we have large populations in relatively small areas, circumscribed by economic, cultural, and individual conditions and contingencies. But here we also have the great possibility and hope for human resilience in the face of adversity. All changes, both for good and bad, will be felt at the local level. Our job now is to understand how the changes brought about by global warming will effect and be effected by our actions for mitigation and adaptation at the local, national and global levels. Urban areas, in short, have many linkages with global warming that we are just beginning to understand.

Urban areas have many linkages with climate change: Urban centers are *drivers* of global warming because they concentrate industries, transportation, households and many of the emitters of greenhouse gases (GHG); they are *affected* by climate change; and they are sources of *responses* i.e., of initiatives, policies and actions aimed at reducing emissions and adapting to climate change.

The impacts that urban areas will be faced as a result of climate change with will be based on increases in the frequency and intensity of heavy rain, storms, droughts, heat-waves and other extreme weather events. The urban centers that will be more at risk are those where these events are already widespread. However, with the expected increase in frequency and intensity of those extremes, risks for these already threatened areas will increase still more. Not of lesser importance, changes in mean temperatures, precipitation levels and sea level will lead to impacts on energy demand, reduction of the draining capacity of sewage systems and long-term increases in vulnerabilities of low-lying coastal cities respectively. A frightening, but not yet fully explored, implication of climate change relates to the possible effects of abrupt changes in temperature and weather patterns.

Climate impacts are not only related to ***exposure,*** but also to ***adaptive capacity***. Urban settlements with a long history of investment in housing, urban infrastructure and services (such as in many high-income countries), and public emergency response (such as in Cuba), as well as those with economic/financial losses much reduced by insurance, will be relatively more resilient to cope with the impacts of climate change. Yet, these urban areas can still be overwhelmed by the increased intensity of storms and by a disparity of vulnerability based largely on access to insurance and income level as seen in the US Katrina experience. These dangers are compounded for urban centers facing ***adaptation deficits***. The main problem for these cities is the lack of provision for adequate roads, piped water supplies and other infrastructures and services that can be depended on in the event of severe weather. Without considering any of the future impacts of global warming, the populations and infrastructures of those urban settlements already show adaptive deficits within the current range of climate variability

While urban areas are hotspots for climate risks, they are also the ***sources of option***s to increase our capacity to cope with climate hazards. There is no doubt that urban areas can

be dangerous places to live and work; their populations can be very vulnerable to extreme weather events or other hazards with the potential to become disasters. However, the same concentration of people, infrastructures and economic activities in urban centers that may create weaknesses in the face of climate change hazards gives them strengths by making it possible for them to create economies of scale or proximity or for the creation of many of the measures that may reduce risks from extreme weather events. Furthermore, when provided with policies focused on enhancing sustainability and moving from disaster response to disaster preparedness, urban settlements can increase their effectiveness at coping with climate hazards.

There is no doubt that urban centers play a part as ***drivers of global warming***. However, we are faced with many uncertainties on just how big the urban contribution to global GHG emission is. Existing data lead us to conclude that just as urban centers have registered different levels and paths of development, they have also shown varying levels of emissions throughout their development cycles. We can only say that three factors are relevant ***determinants of carbon emissions***, namely a) ***population***, b) ***affluence*** as measured by GDP per capita, c) and **technology**, which, among other things, helps reduce energy consumption and carbon emissions by unit of GDP or GNP. We also know that it can be misleading to concentrate on urban emissions per capita, as there are very large differentials between different populations within the same urban centers. Socioecomic ***equity*** is, therefore, clearly another key dimension of carbon emissions by cities. The quality of ***governance structures*** is equally important to explain why some cities have larger carbon footprints than others. Independently of level of affluence, when compared to a city that is poorly managed, a well managed city with a good public transportation system, whose population has access to water and sanitation, to adequate health services, and to a good quality of life, is likely to have fewer problems at dealing with both its carbon footprint and its adaptation challenges.

Existing studies also suggest that the ***weight of different sectors*** in the total emissions of an urban center also *relates to such factors as*: a) **its economic base**, i.e. to whether it is mainly **industrial or service oriented**; b) **its form**, i.e. how dense it is, and the location patterns of its settlements, economic activities, and infrastructure; and c) **the lay out and structure of its transportation systems**, effecting the extent of automobile infrastructure compared to transit.

Although a framework of international negotiations among nation-states remains a crucial mechanism to address climate change, the last decades have witnessed a great increase of ***city-based initiatives and efforts to respond*** to our climate challenge. Case studies illustrate that the two sides of climate change (mitigation and adaptation) have only become a local priority when the local range and extent of projected climate change effects have been understood by local actors, or when it has been linked to issues already in the local agenda such as energy or air quality (as for example in US cities and in Mexico City respectively). Yet, many of our existing actions and responses do not necessarily address climate concerns, or if they do, they focus on only a tiny aspect (e.g., mitigation technologies) of the whole issue (which would necessarily include the linkages

of mitigation and adaptation with development). Many initiatives have focused mainly on mitigation with very little or no consideration of adaptation.

Diverse institutional factors have come into play to facilitate or – to the contrary – constrain the effectiveness of policy actions. While the presence locally of political champions, financial resources, local government competencies and capacity, a local history of engagement with environmental issues, and political will to address emerging conflicts may facilitate effective action; the lack of financial and human resources, of decision making power and of other components of institutional capacity has hindered the effectiveness of many efforts. Under the recent process of decentralization and devolution, city officials have been charged with climate relevant responsibilities but often without the funding or political power to make effective action possible.

Some urban centers are undertaking actions to promote adaptation through city-wide initiatives to protect their infrastructures, and provide public funds to deal with natural disasters. Yet, ***adaptation actions*** that take climate change into consideration are occurring **only** on a ***limited basis***, and adaptation measures are seldom undertaken in response to climate considerations alone. Adaptation measures, on the contrary, have multiple social and economic drivers and have been implemented as part of broader development and sectoral initiatives rather than being based purely on climate change.

Adaptation is about enhancing resilience or reducing the vulnerabilties of urban populations and infrastructures to observed or expected changes in climate. Similarly to emissions and mitigation, adaptation has many linkages with the way an urban area develops and is planned and managed. The paths of urban development and urban planning might enhance or, on the contrary, constrain the adaptive capacity of a city's populations, especially of its low-income groups. Adaptive capacity will influence adaptation (the *actual* adjustments made). However, as documented by the 2003 heat-waves in Europe, even relatively high adaptive capacity among urban populations does not necessary translate into measures that reduce vulnerability. Fortunately we have older areas of knowledge and precedent that urban centers can learn from and use in their adaptation efforts. They can, for instance, draw from the longer experience on disaster risk management, which includes not only the stages of disaster response and recovery, but also measures to reduce and prevent disasters. Seven components are critical in disaster reduction: strengthening local capacity, land-use planning and management, building codes and disaster resistant construction, protecting critical infrastructures and services, and early warning and, underlying all of these, financing. Of course, to be effective, each of these areas will need to be adjusted according to the predicted impacts and increases in disaster frequency and intensity that will be brought by climate change.

There are both ***synergies and trade-offs*** between actions addressing the mitigation challenge and other policy dimensions (e.g. industrial development, energy, health, air pollution). Policies addressing other environmental problems, such as air pollution, can often be adapted at low or no cost to reduce greenhouse gas emissions and improve the health of populations simultaneously. Trade-offs and synergies also exist between adaptation measures and development. There are good examples of city governments, taking steps to promote development and reduce vulnerability at the same time. Climate

change can and has been already included in the risk management policies and plans of many countries. As a next step, it is important that adaptation and mitigation be evaluated at the same time, taking into account the often explicit trade-offs involved between them when evaluating development plans.

***Both adaptation and mitigation are equally important to address climate change.*** Adaptation measures can decrease vulnerability to climate hazards, thus reducing the impacts. While mitigation helps slow the rate of climate change and hence delays the date of impact and its magnitude. Most of the benefits of mitigation are not realized immediately, but rather after some decades; therefore, adaptation is required to address current and near-future impacts. Yet without mitigation, eventually the increasing magnitude of climate change impacts would significantly diminish the effectiveness of adaptation. While mitigation and adaptation are usually addressed in different policy and institutional contexts, and policies are implemented at different spatial and temporal scales, what is important now is to bridge the gap and view the pair as two sides of the same coin. One without the other will render a coin of little value. Therefore, both mitigation and adaptation will be needed, however, on the linkages and feedbacks between urban areas and climate change to fill existing gaps in our knowledge in this area.

## 6. Outline

### Part I

### 1. Introduction

Climate change has been publicly perceived as a global issue driven by energy use, land use changes and other human activities inducing transformations in the atmosphere composition and the carbon cycle. This section provides a justification for this report. It includes some of main reasons that a report on cities and climate change is needed to bring together divergent views and information sources from the natural and social sciences to create a cohesive analysis tool that can be used as a guide to policy makers that are engaged with this issue on the urban, national and global fronts. It presents a general framework to address the multiple linkages between urban centers and global warming, and describes some of the main actors in the climate change arena.

Chapter outline

1. Why cities and climate change?
2. Through which mechanisms do cities contribute to climate change? In other words what are the main emitters and underlying drivers of cities' emissions?
3. What are the societal and environmental factors explaining urban impacts on climate change? What are the main climate hazards facing cities and main physical and societal determinants of cities' vulnerabilities;
4. What are the factors constraining or enhancing the effectiveness of cities' adaptation and mitigation responses and how do these fit into national and global perspectives?
5. Who are the main actors in mitigation and adaptation responses? What are the dynamics and institutional contexts in which they operate?
6. Key terminology

### Part II

### 2. Impacts of global warming on urban centers

The Impacts of global warming on urban centers vary remarkably across regions, countries and even within countries. This chapter identifies the tendencies in climate hazards within cities as they fit into patterns of economic activities, infrastructures and groups that are particularly vulnerable to climate change. It describes the recent tendencies in climate events, as presented by IPCC experts. The IPCC posits that climate change will affect cities through rising sea levels, increased hazard from tropical cyclones, flooding, landslides, heat and cold waves, as well as challenges of urban water quality and storage. The section should describe those hazards, as well as the underlying vulnerabilities, explaining how they impact urban centers. It describes the main components and drivers of urbanization. It provides some of the reasons why urban areas can be vulnerable to climate and other hazards, but at the same time can be sources of more effective measures to cope with (adapt to) and mitigate climate change

Chapter outline

1. What are the recent tendencies in climate variability and change, and what knowledge do we have on their regional and temporal dynamics?
2. With what climate risks are cities faced and which underlying vulnerabilities explain the diverse impacts predicted across and within cities? This section should include subsections on
   2.1 Sea level rise and coastal risks
   2.2 Water resources and systems
   2.3 Related health risks
   2.4 Industries, services and the built environment
   2.5 Food security
3. Why has urban development brought increased climate risks to some cities and urban dwellers?

## 3. Cities as drivers of global warming

This chapter identifies how cities contribute to climate change. It presents existing information, data gaps and criteria used to model and measure total and per capita GHG emissions within and across cities. It describes such factors explaining the weight of different sectors on total GHG emissions as the economic base of a city, its form, and the lay out/structure of its transportation system. It presents some of the approach developed to understand the societal and environmental drivers of urban emissions. It provides some predictors and determinants that may explain why some cities emit more carbon than others, namely population, affluence, technology, climate, and institutional settings among others.

Chapter outline

1. How big a contribution do cities make to global emissions?
   1.1 What are the sources of information and data gaps?
   1.2 What are the criteria and tools used to measure emissions? What is their role in the different calculations of total emissions?
2. What are the main sources of emission?
   2.1 Are there city-level data on main emitters at the city level?
   2.2 What is the role of such factors as the economic base of a city, its form, and the layout/structure of its transportation system in the weight of different emitting sectors in total emissions?
3. What are the main underlying drivers of cities' emissions?
   3.1 What theories and tools have been developed to explore those drivers?
   3.2 What is the relevance of three factors as determinants of carbon emissions, namely population, affluence as measured by GDP per capita, and technology, as measured by both energy intensity (E/GDP) and carbon intensity (C/E) of the energy system; what is role of these factors in the emissions trajectories of diverse

cities?
3.3 What is the structure and configuration of the energy systems within cities and how strong is their influence on those cities' emissions?
3.4 What other determinants are relevant? (e.g. climate factors, institutional settings).
3.3 Do these and other factors diverge across cities?

## Part III Urban responses to climate change

### 4. Mitigation responses

This chapter identifies the opportunities and constraints to effective policies, strategies and practices aimed at reducing or mitigating the emission of greenhouse gases. It proposes future policy directions at the local, national and international levels. It examines how cities fit into the picture of national and global climate change mitigation strategies, i.e., how processes operating at the national and global level may constrain and/or enhance a city's ability to mitigate emissions; what is the role of scientific knowledge in local climate policy decisions, and what other factors explain the huge gap between the rhetoric and reality of local climate policy?

Chapter outline

1. What actions, policies and technologies have been designed to curb emissions at the international, national and urban levels?
2. What has been the role of the private sector and the government?
3. What are the technological and market processes at play that might constrain or create possibilities to curb emissions?
4. How have cities responded to the mitigation challenge of climate change?
5. How effective have been those responses, and why? For instance, do cities have the institutional capacity to manage this issue?

### 5. Adaptation responses

This chapter focuses on cities' adaptation options and constraints. It presents two approaches to the analysis and management of these responses: risk management and adaptation strategies. It examines how cities might adapt and, for instance, protect vulnerable populations from increased adverse weather related events that are predicted with climate change.

1. Assessment tools and approaches to coping with climate hazards: risk management and adaptation

2. Existing adaptation options and responses

2.1 Urban management and policies

2.2 Disaster risk management

2.3 City-wide climate initiatives

2.4 Infrastructures

2.5 Insurance and public financing

2.6 Community-based adaptation

## 6. Linkages between responses and development; the way forward

This chapter identifies the multiple relationships between adaptation, mitigation and sustainable development. For instance, it explores the synergies and trade-offs between a) actions addressing the mitigation challenge and other dimensions of policy and development; b) measures targeting adaptation and policies dealing with other such development issues as urban planning and economic growth; and c) policies dealing with mitigation and adaptation. Finally, it describes existing uncertainties and future research priorities.

1. What are the linkages between mitigation responses and other policy dimensions?

2. What are the relationships between adaptation responses and policies dealing with urban planning, and poverty?

3. What are the synergies and trade-offs between adaptation, mitigation and (sustainable) development?

4. What are the current knowledge gaps and uncertainties in area of cities and climate change and what are the research priorities for the future?

## Part IV

**Statistical annex,** which presents key indicators and statistics on urban settlements (as they relate to the theme of the 2011 GRHS) at the regional, national and city levels

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Acronyms

BESETO - Beijing, Seoul and Tokyo Corridor
C/E – Carbon Intensity
C20 – World Cities Climate Change Summit of 20 most prominent cities worldwide
C40 - World Cities Climate Change Summit of 40 most prominent cities worldwide
CBA – Community Based Adaptation
CBOs - Community Based Organizations
CCP - Cities for Climate Change Protection
CDM – Clean Development Mechanism
CH4 - Methane
CIESIN - Center for International Earth Science Information Network
CNG – Compressed Natural Gas
CO2 – Carbon Dioxide
E - East
E/GDP – Energy Intensity
EIA – Energy Information Administration
EPA – Environmental Protection Agency
GDP – Gross Domestic Product
GEF – Global Environment Facility
GHG – Greenhouse Gas
GRHS - Global Report on Human Settlements
GRUMP - Global Rural-Urban Mapping Project
H2O - Water
HFCs - Hydroflourocarbons
HIV – Human Immunodeficiency Virus
ICLEI - International Council for Local Environmental Initiatives
IPAT – Impact = Population x Affluence x Technology
IPCC – Intergovernmental Panel on Climate Change
JI – Joint Implementation
LCCP - London Climate Change Partnership
LECZ – Low Elevation Coastal Zone
N2O – Nitrous Oxide
NAPA - National Adaptation Program of Action
NGOs – National Governmental Organizations
NOx – Nitrogen Oxide
O3 - Ozone
OECD - Organisation for Economic Co-operation and Development
PFCs - Perfluorocarbons
R&D – Research and Development
RPA - Regional Plan Association
UN-BCPR – United Nations Bureau for Crisis Prevention and Recovery
S - South
SE - Southeast
SF6 – Sulphur Hexaflouride
SRES – Special Report on Emissions Scenarios
STIRPAT - STochastic Impacts by Regression on Population, Affluence, and Technology

U.S – United States of America
UK – United Kingdom
UN – United Nations
UNDP – United Nations Development Programme
UNFCCC - United Nations Framework Convention on Climate Change
US – United States of America
USA - United States of America
VKT – Vehicle Kilometers Traveled
WGII – Working Group II of IPCC