Part IV

Cross-cutting issues

8

The role of urban land in climate change

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This chapter should be cited as:
Blanco, H., P. McCarney, S. Parnell, M. Schmidt, K. C. Seto, 2011: The role of urban land in climate change. *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network*, C. Rosenzweig, W.D. Solecki, S.A. Hammer, S. Mehrotra, Eds., Cambridge University Press, Cambridge, UK, 217–248.

8.1 Introduction

Recent IPCC reports have addressed the issue of urban land under the topic of industry, settlement, and society (IPCC, 2007). Since reviews of human settlements from the perspective of climate change have been primarily focused on climate change mitigation, topics of land cover and use, urbanization, land planning and management, land markets, property rights, and fiscal and legal issues, which will be key to responding to impacts of climate change, have not received extensive coverage. We argue in this chapter that it is important to focus on urban land as a sector or as the overarching framework in order to recognize the challenges of government coordination and integration necessary to address climate change. In incorporating urban land in climate change adaptation and mitigation efforts one would be able to include a fundamental set of strategies, such as policies concerning land conversion, land tenure, and urban land markets that have not been fully addressed.

This chapter provides an introduction to the role of urban land in climate change, discusses the potential for urban planning and management to address climate change challenges, and reviews current planning efforts focused on climate change. It is organized into several sections. This introductory section develops several key concepts, such as recent trends in urbanization, and discusses their relation to urban land and climate change. The second section focuses on urban form, impacts on ecosystems, including the urban heat island effect, and discusses the vulnerability of informal and slum settlements to climate change. The third section provides an introduction to the urban land management system, including legal aspects, the urban planning system, and urban land regulation. This is followed by a brief review of climate change risk. Two sections then focus on how urban planning can address mitigation and adaptation challenges, by reviewing current efforts and next steps. The two final sections identify policy issues and research needs requiring attention to fully enable the use of urban planning and management to mitigate and adapt to climate change.

8.1.1 Defining urban land

A recognized, global definition of urban land or urban areas has not been established. The United Nations, when it reports on urbanization or cities, uses countries' self-reports, with varying definitions. Urbanized land is typically defined as land in state-recognized cities (municipalities or local authorities), as land in agglomerations with threshold populations of from 1,000 to 5,000 persons, and in some countries in terms of density per unit area, the number of persons per square kilometer ranging from 386 in the United States, 1,500 in the People's Republic of China to 4,000 in Japan (UN Population Division, 2008). Metropolitan areas, a concept that is defined by an integrated labor market and travel patterns rather than density, include at least one central city, and other urban areas, as well as surrounding rural land. In this report, we most often will use the term cities and urban areas interchangeably to refer to areas with urban densities, and metropolitan areas to refer to areas that incorporate fringe rural lands. Definitional issues are important not only because they determine the extent and rate of urbanization, but also because they are integral to the conceptualization of issues and problems. For example, the phenomenon of increasing metropolitanization involves population, land, and political jurisdictions or governance. A key aspect of metropolitanization is the conversion of rural lands to urban uses. Expansion of urban areas increases energy needs for travel within the area, and involves the substitution of natural vegetation by impervious surfaces, which destroys carbon sinks, and intensifies flooding and heat island effects, among other local environmental risks.

Beyond metropolitanization, two other interconnected urbanizing trends complicate the study of cities and climate change, the growth of megacities (cities over 10 million), and the convergence of metropolitan areas into mega-scale urban *megalopolis* regions (Gottmann, 1961; Gottmann and Harper, 1990), and more recently identified as *megapolitan areas* (Lang and Dhavale, 2005; Lang and Knox 2009)[1] and *mega-city-regions* (Hall, 2009). Gottmann (1961) used the merging of the metropolitan areas of Boston, New York, Philadelphia, Baltimore, and Washington, DC, or the Boswash urban corridor as a first example. Although Gottmann was at first ambivalent about whether the term referred to a physical or morphological merging of metropolitan areas, this type of conurbation of metropolitan areas, more commonly referred to as mega-city-regions, is now understood as a functional, rather than a physical, or administrative concept.[2,3] Urban space in these urban regions is defined by the "space of flows" (Castells, 1989), of people, goods, or information on a regular basis. The term mega-city-regions was first applied to East Asia regions, such as the Pearl River Delta in southern China, which include several metropolitan areas, typically with populations of ten million or more. Mega-city-regions are currently found throughout most parts of the world. Some examples include the Greater La Plata–Buenos Aires metropolitan region in Argentina, Mumbai–Pune mega-region in India, the Suez–-Cairo–Alexandria urban region, and the Randstad in the west of the Netherlands.[4] The mega-city-region of central Mexico, with close to 30 million people, includes the metropolitan areas of Mexico City, Puebla, Cuernavaca, Toluca, and Pachuca, and 173 municipalities in five states.

The increase and expansion of these mega-city-regions will aggravate urban land management challenges across the world. These regions cross local and provincial political boundaries where the jurisdiction for urban land management typically lies,

1 Studies in the USA have identified ten megapolitan areas that house 197 million people (Lang and Knox, 2009).
2 The term mega-city-region was first applied to urbanized regions of Eastern Asia including the Pearl River Delta, the Yangtze River Delta, the Tokaido (Tokyo-Osaka) corridor, and Greater Jakarta (Lin and Ma, 1994; McGee and Robinson, 1995; Hall, 2009).
3 In the US census, Consolidated Metropolitan Statistical Areas (CMSA), composed of several Metropolitan Statistical Areas (MSAs) are similar to the concept of mega-city-regions.
4 See Hall and Pain (2006) for a study of European examples.

and thus make planning, management, and public finance more difficult to coordinate across these vast regions.

8.1.2 Cities: their natural setting, urban form, and built environment

Urban places by definition are human-dominated and constructed landscapes; however, their natural characteristics, and the management of the ecosystem services on which cities depend, are essential to their definition (Spirn, 1985; Hough, 1995; McHarg, 1995;Alberti, 2008). Furthermore, the formation of cities, their location and characteristics are heavily influenced by the economic and technological context of a people. These, in turn, are dependent on environmental features. Agricultural economies and the early cities that owed their formation to agricultural surpluses relied on water sources for urban uses, crops, and for goods transportation. For example, the alluvial basin between the Tigris and Euphrates rivers in contemporary Iraq and the Nile Delta are often cited as some of the earliest known urban concentrations dating back to at least 5000 BC (Benevolo, 1980; Kotkin, 2005) As trade increased, many major cities, such as Guangzhou with a population of over 200,000 by AD 1200, developed near and along coastlines (Ma, 1971). In a similar way, early industrialization relying on steam power gave economic advantage to coastal cities and cities along navigable waterways. Waves of European colonization of the Americas, India, Asia, Africa, and Australia, and increasing intercontinental trade from the late 1400s through the 1800s, during an era where intercontinental travel was primarily accomplished by sea, led to the establishment and increasing prominence of coastal cities in these continents, such as Boston, New York, Veracruz, Havana, Rio de Janeiro, Buenos Aires, Cairo, Cape Town, Bombay, Madras, Calcutta, Goa, Singapore, Macao, Jakarta, Adelaide, Melbourne, and Sydney (Southall, 1998).

While economic and technological factors have favored the location of cities in certain environmental settings, the geomorphology of a city and the soil conditions also affect a city's vulnerability to natural hazards, such as flooding and landslides, and can constrain urban expansion. Surface and groundwater features of an urban area are often sources of water supply and partly determine a city's drainage options. Urban coastal areas are faced with erosion and storm surges, as well as salt water intrusion into creeks and rivers. Cities in arid and semi-arid areas are subject to flooding, and special sediment problems, including desertification. The proximity or extension of urban areas into rural or undeveloped lands can increase vulnerability to wildfires. As discussed, cities are often located on or close to prime agricultural land, and urban expansion destroys these resources. As cities expand to create metropolitan regions, forested areas, which serve as carbon sinks, are degraded and destroyed. These ecological aspects of urban land use and change can constrain or expand options cities have to mitigate and adapt to climate change.

Although the terms urban form and built environment are often used interchangeably, here we use the term urban form to refer to city-scale or macro-scale patterns, and built environment to refer to micro-scale or structural aspects of cities. A city's urban form, the overall characteristics of a city's existing built environment, e.g., dispersed versus compact settlement form, the extent and pattern of open spaces and impervious surface, and the relationship of its density to destinations and transportation corridors, interacts with natural and other urban characteristics to constrain transportation options, energy use, drainage, and future urbanization. The urban form also can affect the vulnerability of a city to climate change impacts. Because of its potential impact on energy and building materials, the management of urban form is a critical area of intervention for the promotion of climate mitigation and adaptation (see Box 8.1; Boarnet and Crane, 2001; Giuliano and Narayan, 2003; Sorensen and Hess, 2007; Ewing *et al.*, 2008; Grazi and van den Bergh, 2008).

The built environment or structural aspects of cities, streets, buildings, and infrastructure systems contribute significantly to the emission of greenhouse gases, and can also amplify climate change impacts. The structure, orientation, and condition of buildings and streetscapes can increase the need for cooling and heating buildings, which are associated with the level of energy use and can account for a significant proportion of greenhouse gas emissions in a city. The extent of streetscape and the impervious surface of structures can intensify flooding and are direct determinants of the heat island effect. Conventional wastewater and drainage systems impede natural processes of evapotranspiration and can amplify flooding and drought effects.

A city's natural setting, its urban form and built environments are relatively fixed or static factors, but they are subject to future modification through urban planning and management. For example, managing the size and shape of the overall urban form through urban land use planning may provide more significant opportunities for mitigation and adaptation to climate change, and settlement patterns can be modified through redevelopment or the imposition of urban boundaries or by restricting development through land use controls.

8.1.3 Market and public good aspects of land

Urban areas are most often the economic engines of nations, containing major industrial and commercial enterprises, government centers, as well as major residential settlements. Today, in modern market economies, land for these urban uses is a market commodity, often representing a quarter or more of the total value of urban properties (O'Sullivan, 2006). In developed countries, government heavily regulates urban land, less so in developing countries where there are more diffuse and often competing systems of land regulation in place, including traditional authorities and private land barons, as well as the state. The regulation of land and its uses in developed countries typically includes institutional processes for planning, subdivision of undeveloped land, zoning, and building codes for private and public development. Public regulation of urban land in developed countries is balanced by private property rights that facilitate land and real estate markets. In developing countries, where the bulk of urbanization

[ADAPTATION] Box 8.1 Report from Rome, Italy: Discovery of crossroads

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The Rome Forum was the first in a series of forums initiated by the Urban Securities Project of the Earth Institute's Urban Design Lab at Columbia University.[5] The Rome Forum, held in February 2008, aimed to investigate ways in which cities are called to expand their vision in responding to climate change. Thirty researchers from across North America and Europe participated in the forum, including engineers, anthropologists, business and media studies experts, philosophers, political scientists, urban designers, and climate scientists.

The Forum reached consensus on the following points:

1. On adaptation, cities should enhance the value of their neighborhood residential identity and their social networks and not just geographical or political boundaries. At this scale is easier to fast-track implementation of adaptation decisions at the city scale.
2. A crucial consideration is incorporating health impacts of climate change into the cycle of decision-making (co-factoring short, medium, and long-term implications), while stressing the importance of achieving social, economic, and environmental benefits.
3. A common language for intervention is needed related to goals, methods, and terminology. Urban institutions that until now have worked in isolated modes should not perceive a more integrated approach as an undue interference and loss of power within their specialized realms.
4. Environmental injustice is a key concern to avoid uneven physical dislocation and social turmoil. To achieve this goal, local knowledge as well as scientific findings should be considered.
5. Given the projected social dimensions of climate change, personal responses are important since there can be a sense of dislocation that accompanies such transformations. Social adaptation may be best addressed through "understanding by doing," where the process of taking action, either personal or collective, is continuously assessed and modified following results and discoveries.
6. At the local urban scale, the aim is to proceed from public awareness to personal action. On the city government level, political leadership is needed to clearly set forth decisions with adequate implementation and monitoring. The re-emergence of the "city-state" will be a crucial complement to national and global climate change initiatives.
7. From a communication point of view, climate change challenges are well understood when cast in a context that touches the individual directly, indicating either new economic possibilities, or threatening public well-being such as increased illnesses due to temperature change or decreased food availability due to drought/flooding.
8. Effective public communication is crucial to insure understanding and changes in attitudes. Valid communication is delivered through both statements and congruent actions. Lack of communication transmits uncertainty, and is likely to contribute to public skepticism of climate change.
9. The climate change challenges associated with the economic, social, and political systems of cities are embedded in the urban infrastructure: energy, transportation, water, waste, and food.
10. The process required to establish an appropriate assessment and response system for evaluating climate risks needs to be streamlined. Adaptation is still not fully understood by the private sector as a mainstream risk issue. More information on climate impacts is needed in the public media.
11. Overall, it is important to recognize the complexity of interactions among the natural, technological, and human components in designing for urban-scale climate change responses. We call for accelerating the process of transformation of society into one more respectful of the Earth's planetary processes and resources.

The Rome Forum proceedings are available as: R. Plunz and M. P. Sutto (Eds.) (2010), *Urban Climate Change Crossroads*. Farnham, UK: Ashgate Publishing Ltd.

in the first half of the twenty-first century is forecast to occur, the management of urban land is more problematic, since much urbanization occurs informally, without the protection of property rights or of adequate urban infrastructures and services, and without effective institutions for land management. Nations fall along a broad continuum that marks the extent of reliance on private property versus public management of urban land. Over the past two or three decades, there has been a shift to stronger private property rights and market orientation. Market-oriented approaches to the management of urban land are likely to make large-scale interventions in the interests of climate change mitigation or adaptation more complex, and likely more expensive.

8.1.4 Urban land and infrastructure

In the developed world, urban land is land supplied with urban infrastructure and other urban services (Kelly, 2004). Without appropriate transportation, water systems, waste disposal, and energy supplies, land cannot be properly developed to sustain urban densities with high levels of public health and wellbeing. Public health, administration, police and fire services are also crucial to ensure the safety and security of urban populations. Urban infrastructure and services in developed countries have been typically supplied by the public sector and comprehensive community planning involves both land use and infrastructure

5 The Rome Forum was a collaboration between the Urban Design Lab (UDL), the Urban Climate Change Research Network (UCCRN), the Fondazione Adriano Olivetti, and the Camera di Commercio Ambiente e Territorio of Rome.

planning. In developing countries, newly urbanizing areas typically lack urban infrastructure and services, both at the household level, e.g., electricity, running water, as well as at the neighborhood level, sidewalks, garbage disposal, parks. One of the most difficult aspects of climate mitigation for cities of the developing world is the lack of connection between land use planning and infrastructure provision. Thus, in the informal sections of cities (which in Africa account for as much as 80 percent of settlements) it is very difficult to use the land use management system to regulate building bulk or household infrastructure standards and make the requisite improvements required to accommodate increasing extremes associated with climate change (Parnell *et al.*, 2009).

The connections between the management of urban land and infrastructure systems can be complex. For example, as discussed in Chapter 5, land subsidence in Mexico City is due to water extraction from underground aquifers at rates greater than the aquifers can replenish themselves. In urban areas, impervious or sealed surfaces reduce the rates of aquifer replenishment. The extent of impervious surface in an urban area, in turn, can be reduced through urban planning strategies to increase greenspace, or through requirements for more permeable surfaces for certain types of uses, such as driveways or urban alleyways. Or, as discussed in Chapter 6 and below, automobile travel is responsible for a significant portion of greenhouse gas emissions in cities of developed countries. Reducing automobile use by providing adequate public transit is a major strategy to lower greenhouse gas emissions. Public transit, in turn, requires sufficient densities to make it viable. This illustrates the interactions and interdependencies between land development and infrastructure systems.

8.2 Urban form, patterns, and impacts

8.2.1 Urban form

The way in which a city expands in physical space – whether new urban development is contiguous to existing urban areas, or whether it is leapfrog development, or whether the city is compact or dispersed, shaped like a circle or an amoeba – has significant impact on energy use, resource consumption, and the ability of a region to adapt to or mitigate against climate change (Ewing *et al.*, 2008).[6] Many of these impacts are exacerbated when new growth takes the form of *urban sprawl* (Alberti, 2005), a term that refers to low-density, dispersed or even decentralized forms of urban expansion (Ewing *et al.*, 2002; Bruegmann, 2005; Flint, 2006). Compact growth can lead to efficient use of resources, whereas expansive development can strain infrastructure and natural resource availability.

Cities that developed prior to the widespread ownership of private automobiles are usually compact (Jackson, 1987). In contrast, cities that developed during the age of the car tend to be more expansive, and along road transportation corridors (Warner, 1978). For example, in car-dependent regions such as the Silicon Valley, USA, transportation infrastructure has led to expansive patterns of urban growth. In contrast, in Bangalore, India, where car ownership is relatively low, urbanization is not highway-oriented and is more compact (Reilly *et al.*, 2009). In turn, expansive patterns of urban development have led to high levels of dependence on private vehicles, which also drives an increase in fossil fuel demand (Newman and Kenworthy, 1999). See Box 8.2 for a discussion of the relation between urban form and travel behavior. These different patterns of urban form, dispersed versus compact, also have a different effect on the extent of impervious surface, and how the urban area interacts with the local and regional environment. Studies of evolving urban form suggest that cities around the world may be following similar patterns of urban growth, although different local and national policies undergird these patterns (Kenworthy, 2003; Marcotullio, 2003; Leichenko and Solecki, 2005; Seto and Fragkias, 2005). For example, cities across China follow similar physical growth trends and urban growth is largely fragmented across vast megaregions and often driven by foreign investment (Seto *et al.*, 2002; Zheng *et al.*, 2009). Consequently, managing large-scale patterns of urbanization can be a key strategy to mitigate climate change. See also the transportation chapter (Chapter 6) for a discussion of urban transportation and land use.

In addition to macroscale features of urban form, the siting of buildings, and how they use energy and water have important implications for climate change mitigation and adaptation. Many of these features have been identified and incorporated by green building rating systems, such as the US Green Building Council's rating system, Leadership in Energy and Environmental Design (LEED) in the United States and the UK Building Research Establishment's Environmental Assessment Method (BREEAM). See Chapter 7 for a discussion of building energy use.

8.2.2 Environmental impacts of urbanization

Urban expansion has profound environmental impacts that extend beyond city boundaries including: changes to microclimate, conversion of natural ecosystems, loss of agricultural land, fragmentation of natural habitats, contamination of air, soil and water, increased water use and runoff, reduced biodiversity, and introduction of non-native species (Rees, 1992; Pickett, *et al.*, 1997 El Araby, 2002; Alberti, 2005; Potere and Schneider, 2007). In addition, as urban areas expand, they change regional energy budgets, and generate greater demands for natural resources. Interactions between and among urban land use, policies, and earth system functions cannot be decoupled (Liu *et al.*, 2007; Alberti, 2008).

6 When compared to more compact settlements, impacts of climate change, such as heat waves, droughts, wildfires, and more intense storms, will be more difficult and costly to respond to under urban sprawl conditions. In general, more dispersed urban settlements require larger infrastructure networks and service areas, e.g., public health or emergency services, which is likely to increase the costs of responding to climate impacts.

[MITIGATION] Box 8.2 Links between urban form, travel patterns, energy use, and greenhouse gases

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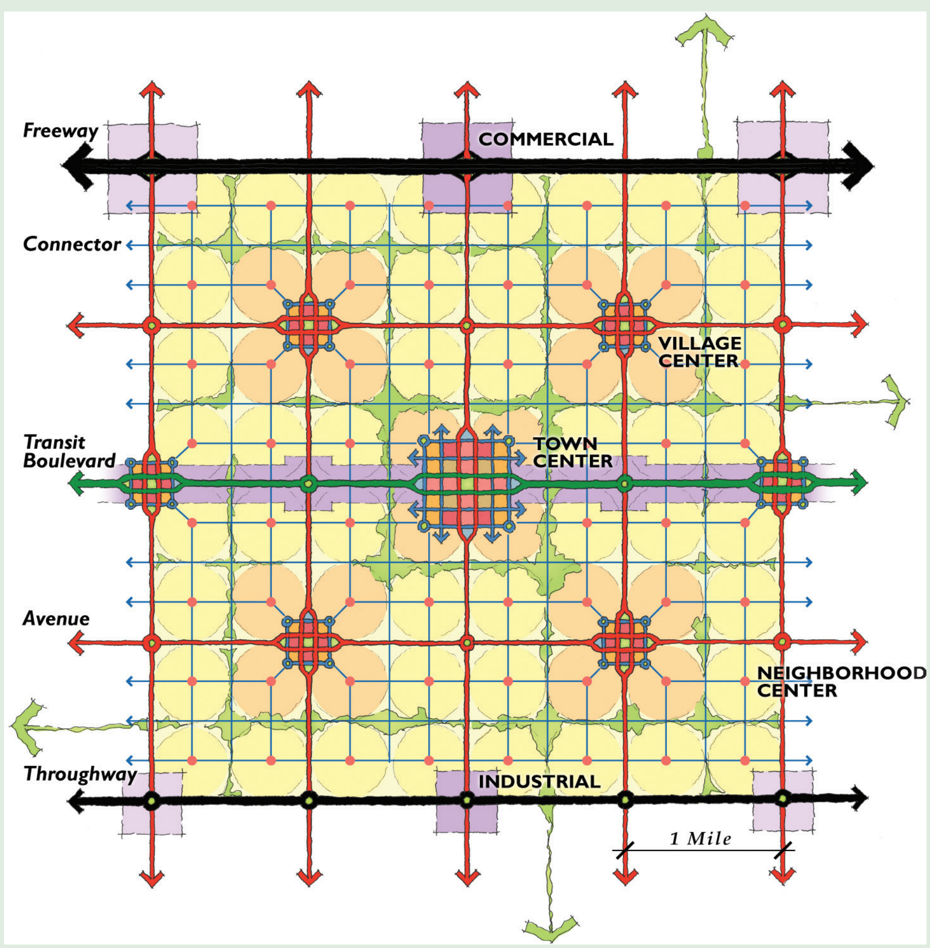
Urban form is a critical factor in explaining patterns of automobile dependence and transportation energy use (Cervero, 1998; Newman and Kenworthy 1989, 1999; Kenworthy and Laube, 1999; Kenworthy, 2003; UN-HABITAT, 2008). According to these studies, the most significant urban form factor affecting travel behavior is urban density. A study of 84 cities around the world (Kenworthy, 2003) demonstrates this linkage. The study shows that higher car and energy use cities, which are the highest greenhouse gas producers, are low in population density, and conversely, that high-density cities have lower car use and lower greenhouse gas emissions due to transportation. The Kenworthy (2003) study also indicates a strong correlation between wealth and density, with lower income cities more than double the density of wealthier cities (109 versus 52 persons/ha). The strongest correlation between urban density and automobile use was among cities in high-income countries, with per capita passenger distance traveled by automobile increasing as densities decrease. This implies that as the wealth of cities in emerging economies and developing countries rises, automobile ownership and usage is likely to increase unless competitive public transit alternatives become available. Consequently, cities which aim to manage traffic congestion, minimize car and energy use, and lower greenhouse gas emissions from transport should address the issue of urban form. To accomplish this, experts recommend a policy of increasing density and mixing appropriate land uses, such as residential and retail, around areas of high public transit accessibility. The centralization of jobs in central business districts and satellite sub-centers built around transit nodes is also recommended, as well as the use of urban containment strategies, such as greenbelts or urban growth boundaries (Kenworthy, 2003). These recommendations are supported by a comprehensive recent study conducted by the US National Research Council (2009). The study examined the empirical evidence on the effects of compact development on motorized travel, energy use, and CO_2 emissions. It found that, "doubling residential density across a metropolitan area might lower household VMT



Box Figure 8.1: *Schema of transit-oriented development in an urban network.*

Source: Calthorpe, (1993).

[vehicle miles traveled] by about 5 to 12 percent, and perhaps as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures". Density increases, transit improvements, and mixed uses are major tenets of the smart growth movement described in Box 8.3.

In the United States, a major strategy advocated to shape new development and reduce automobile use through transit villages or transit-oriented development (TODs) highlights the role of density, diversity, and design (Bernick and Cervero, 1996). Calthorpe (1993), who initiated the TOD concept (Carlton, 2007) argues that reduction in automobile use and increase in public transit should be pursued as a regional urban form strategy that links TODs. See Box Figure 8.1 for a schematic of such an urban network that incorporates a system of higher density cluster developments with transit links at the center of the clusters. While transit-oriented compact development is the focus of the strategy, the TOD agenda is part of a broader sustainability agenda that also emphasizes a pedestrian orientation, a mix of housing types, preserving environmentally sensitive areas, creating high quality public spaces, as well as fostering development within existing neighborhoods (Dittmar and Ohland, 2004).

Cities have always relied on resources in their immediate and distant areas for their development. The location of the earliest human settlements was in fertile places. Empirical studies show that contemporary patterns of urbanization are also taking place on prime agricultural lands across the continents (Imhoff *et al.*, 1997; Seto *et al.*, 2000; Nizeyaimana *et al.*, 2001; Döös, 2002). Increasingly, urbanization in one place is driving land cover and other environmental changes over longer distances. For example, the developments of the shrimp aquaculture industry in Vietnam and Thailand have been driven largely by urban demand elsewhere (Huitric *et al.*, 2002, Lebel *et al.*, 2002; Seto and Fragkias, 2007). Urban expansion is also likely to take place in the most biologically sensitive regions. A recent study shows that 8 percent of terrestrial vertebrate species on the IUCN Red List are in peril because of urban expansion (McDonald *et al.*, 2008). While we are beginning to understand the local impacts, we have little information on the cumulative effects of urban growth on global environmental processes (Lambin *et al.*, 2001). Urban areas are the primary source regions of many anthropogenic emissions, for instance, yet no global model of climate or biogeochemistry to date adequately represents urbanization.

8.2.2.1 Built environment and its effect on local climate

One major influence of urban spatial development and land conversion to urban uses on the local climate is the shift in the flux between the sensible and latent heat and related increases in thermal radiation. Compared to forest landscape, urban areas experience a radical change in radiation and hydrology. On a global scale, the evapotranspiration of water represents the biggest proportion of radiation conversion. The diagram in Figure 8.1 shows how global radiation is converted on the

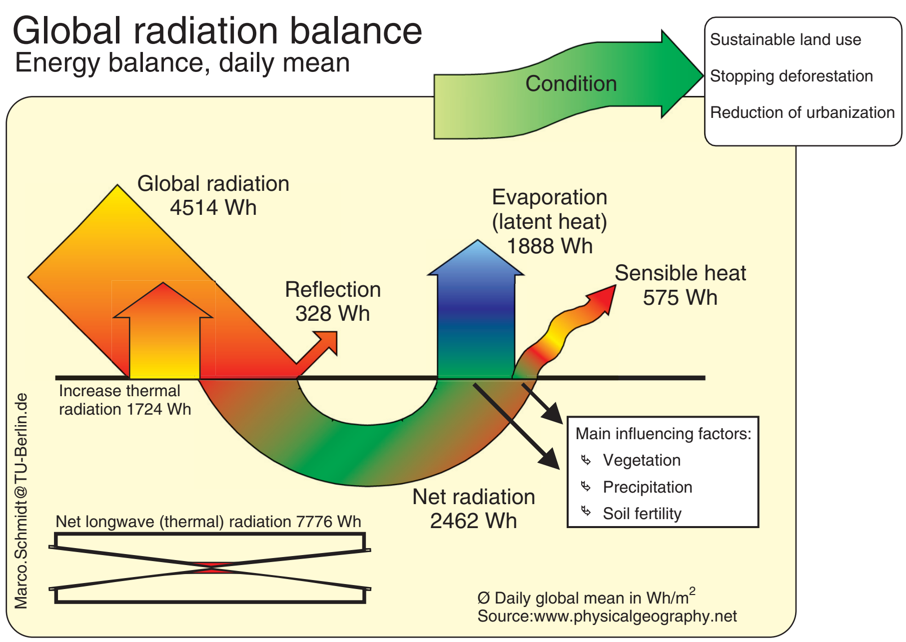


Figure 8.1: *Global daily radiation balance as annual mean.*

Source: Schmidt et al. *(2007). Energy data based on www.physicalgeography.net.*

[MITIGATION] Box 8.3 Conceptualizing the generation of greenhouse gases in urban areas

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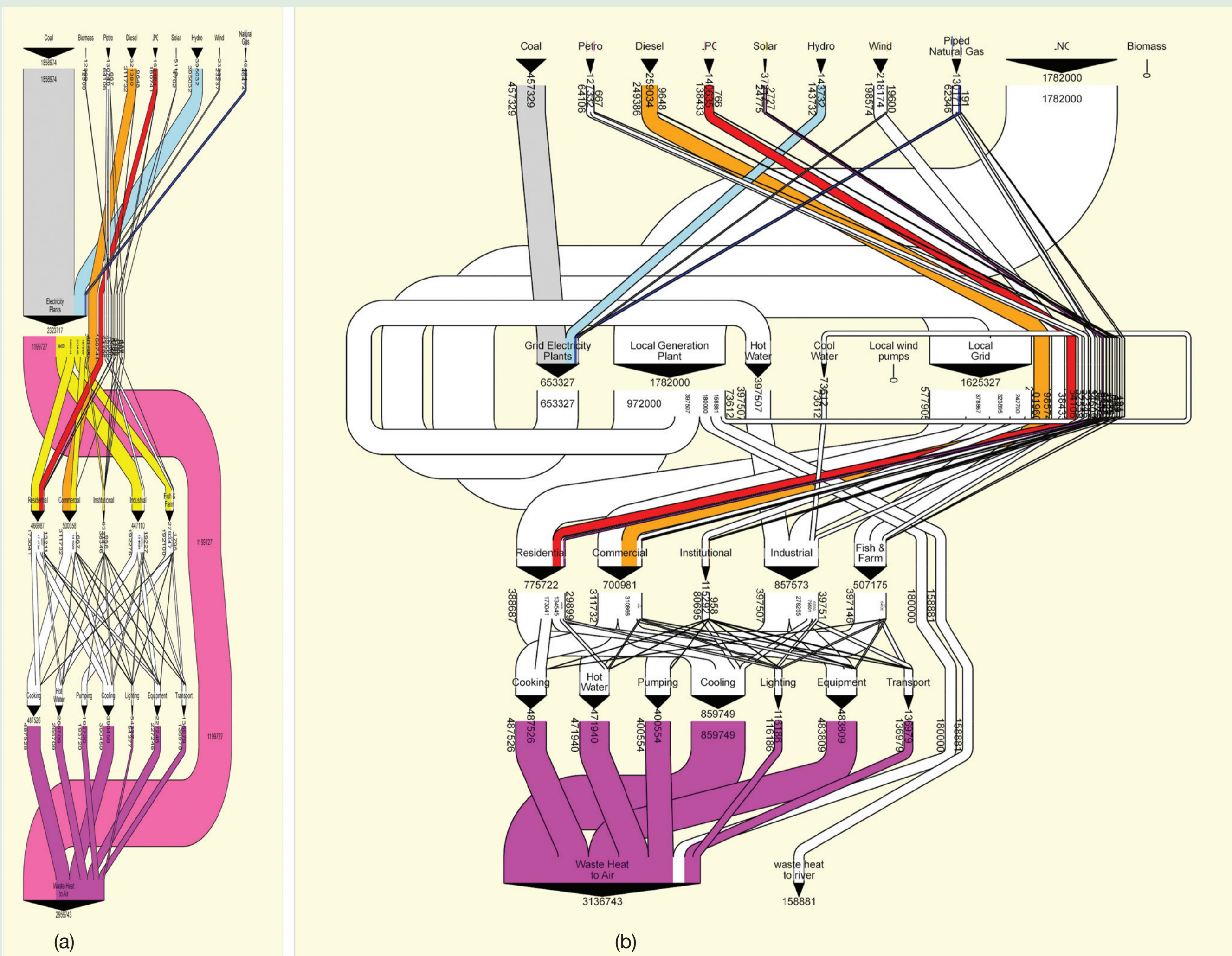
Many urban activities generate greenhouse gases, but measuring their emissions at the urban scale is a new enterprise. Wackernagel and Rees (1996) originally developed the concept of the ecological footprint to provide a simple measure of the extent of land and water resources used by cities. The carbon footprint, developed out of the concept of the ecological footprint, has become a popular measure of the extent of greenhouse gas emissions generated by a person, organization, city, or nation in equivalent CO_2 emissions (Wiedmann and Minx, 2007). Connected to this concept is the earlier urban metabolism concept, developed in a pioneering article by Wolman (1965), to analyze the energy, materials, and water inputs and outputs of a hypothetical city of one million. More recently, urban metabolism is defined as "the sum total of technical and socioeconomic processes that occur in cities, resulting in growth, production of energy and elimination of waste" (Kennedy *et al.*, 2007). Urban metabolism can be illustrated through the use of flow or Sankey diagrams. These input–output diagrams are useful for conveying existing energy flows from different sources and for different uses, as well as for developing alternative energy futures. The energy flows are represented by arrows, and the width of the arrows represents the magnitude of the flow (Schmidt 2008a, b; Suzuki *et al.*, 2009). See Box Figure 8.3 for an illustration of a Sankey or meta diagram of energy flows in Jinze Town,



Box Figure 8.2: *(a) Meta Diagram of Jinze Town, Shanghai, Current Energy System; Box Figure 8.2(b) Meta Diagram for Jinze Town, Shanghai, Advanced System. This Meta Diagram provides a scenario for an advanced system that helps to reduce emissions and costs and increase local jobs and energy security. The advanced system represents a substantial change: for example, a local electricity generation facility is powered by liquefied natural gas, and provides a majority of electricity needs as well as hot and cool water for industry (cascading).*

Source: Suzuki et al. (2010), p. 128. Author elaboration for the diagrams by S. Moffat, with approximate data provided by Prof. Jinsheng Li, Tongji University, Shanghai.

Shanghai. The urban metabolism concept can also be used to illustrate the interrelation between urban land and infrastructures. Urban land contains the shelter for urban populations and economic activities as well as for the urban infrastructures that are major conduits for the inputs and outputs of urban metabolism. Transportation infrastructures are conduits for energy flows; water infrastructures bring in, distribute, and dispose of the waste and stormwater (compared to other materials processed through cities, water has the greatest volume). But energy flows through most urban services, e.g., water supply systems, often require electricity for pumping water. Waste materials are handled by solid waste disposal systems. Energy is brought into the city through a system of underground pipes, e.g., natural gas, or by trucks, e.g., gasoline, or above or underground through the electricity grid. Comprehensive urban planning determines the location of these infrastructures, and the densities permitted by zoning determines the sizing of much of these infrastructures, for example, the capacity of streets, or the sizing of water and wastewater pipes.

surface of the Earth into all its components. The figure depicts a mean energy flux on one square meter per day. Because of the increase in surface temperatures, 38 percent of the incoming solar radiation is directly converted to thermal radiation and 7.3 percent is reflected. The net radiation can either be converted into sensible heat (575 watt hours per square meter per day (Wh/(m^2 d)) or consumed by evaporation, its conversion into latent heat. Representing 1888 Wh/(m^2 d), the energy conversion by evaporation is the most important component of all, even larger than the thermal radiation converted from the incoming shortwave radiation. Additionally, evaporation influences the longwave thermal radiation due to the change in surface temperatures (Figure 8.1) (Schmidt *et al*., 2007; Schmidt, 2009).

Urban areas modify these proportions dramatically. Instead of evaporation, the solar radiation is mainly converted to heat, reflection and longwave emissions. Figure 8.2 shows the global radiation balance of a black asphalt roof as an illustration of urban radiation changes. Instead of evaporation, most of the net radiation is converted to sensible heat instead of evaporation. Increased surface temperatures also increase the thermal radiation. Urbanization results in a large change of the small water cycle of precipitation, evaporation, and condensation. Additionally, hard materials or impervious surfaces in urban areas increase the heat capacity when compared to vegetated surfaces (Schmidt *et al*. 2007; Schmidt 2009).

Research over the last two decades has generated significant understanding of the relationship between urban areas and microclimate (Voogt and Oke, 2003; Shepherd, 2005; Souch and Grimmond, 2006; Kanda, 2007). The urban heat island effect appears stronger during the night than the day (Banta *et al*., 1998). This effect is thought to be generated by the interaction among building geometry, land use, and urban materials (Oke, 1976; Arnfield, 2003). In addition to the heat island effect, recent studies show that urban surface characteristics affect precipitation (Shepherd, 2005: Jin and Shepherd, 2008), although the precise mechanism is unclear, and the effect seems to vary by region, with increases in rainfall reported for Tokyo, New York, and Phoenix (Bornstein and LeRoy, 1990; Fujibe, 2003; Shepherd, 2006) and decreases in winter rainfall in Europe (Trusilova *et al.*, 2008) and China (Kaufman *et al.*, 2007).

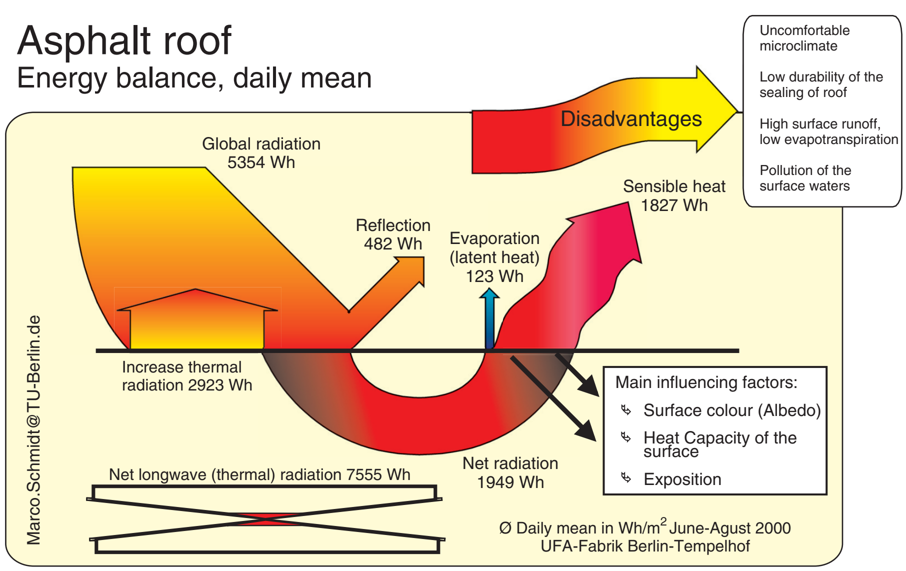


Figure 8.2: *Radiation balance of a black asphalt roof as an example for urban radiation changes.*

Source: Schmidt et al.*, (2007).*

To adapt to the overheating of cities in summer, air conditioners are used, which additionally increase the urban heat island effect. Air conditioners use electricity or gas to "pump" heat from one place to another. This releases twice as much heat into the streets, depending on the performance of these appliances. In addition, electricity has a low energy efficiency of about 30 percent, so it is likely that two-thirds of the primary energy used to air condition buildings in cities will be released at the power plant. A major effective strategy to create more comfortable air temperatures in cities and to improve the microclimate around buildings is to green (i.e., vegetate) the surfaces, thereby "consuming" solar radiation by evapotranspiration. Vegetative coverings on buildings do present additional challenges, such as weight, but offer other opportunities as well, such as water retention, microhabitat, and aesthetic value. Climate change will likely aggravate the urban heat island effect in cities, and greening urban places will be an important climate change adaptation strategy.

Figure 8.3: *Favela Santa Marta, Rio de Janeiro.*

Photo by Marco Schmidt.

8.2.3 Slums and vulnerable populations

Poor populations are more susceptible to natural disasters, and much of that susceptibility stems from the conditions of the built environment in which they live. Poverty in cities of the developing world is most often concentrated in slums or informal settlements. Although slums and informal settlements are terms often used interchangeably, informal settlements are characterized by lack of formal tenure; that is, they are settlements where people or squatters have occupied land without legal ownership or land registered in their name (Durand-Lasserve, 2006). The UN measures the degree of deprivation in slums by determining how many of five factors a household lacks: access to improved water, to sanitation, to durable housing, to sufficient living area, and to security of tenure. In 2005, according to UN-HABITAT (2008a), 36.5 percent or 810 million of the world's urban population lived in slums. Cities in Sub-Saharan Africa had the highest proportion of people living in slums, 62.2 percent, while more than half of the world's slum population lived in Asia. Most urban growth is projected to occur in cities in developing countries, and half of the urban growth "between 2001 and 2030, i.e., 1 billion people, will take place in urban slums" (UN-HABITAT, 2008a). This projection more than doubles the urban slum population of 2005 and would increase to 41 percent the worldwide urban population living in slums.

Slums and informal settlements are much more vulnerable to climate risks than the formal city. Thunderstorms highly affect these settlements due to inadequate drainage, almost complete impervious surfaces, and in many cases due to their vulnerable locations in floodplains or steep slopes. For example, in the favela Santa Marta in Rio de Janeiro, dozens of buildings were destroyed during a heavy thunderstorm in 2003. See Figures 8.3–8.5. Waste clogged the runoff areas until everything was swept away.

Figure 8.4: *Favela Santa Marta, Rio de Janeiro.*

Photo by Marco Schmidt.

Heat waves especially affect these areas. Many slums have extremely high density. Their lack of vegetation, high area of impervious surfaces, and lack of or inadequate drainage systems differ from the rest of the city. Air conditioners are lacking, and older people have limited ability to evacuate in case of emergencies.[7] Unavailable or weak water supplies worsen the situation in case of disasters. In Rio de Janeiro alone, about 1.3 millon people live in approximately 750 *favelas*. Newcomers from rural areas have been gradually building on public land inside the city for the last 100 years.

The built environment of poorer urban households is usually at higher risk due to weaker structures, less safe city locations

7 As the devastating European heat wave of 2003, causing over 35,000 excess deaths (Kosatsky, 2005) demonstrated, heat waves are not only problems facing slums in developing countries. See Chapter 7 for a discussion of this.

Figure 8.5: *Informal settlements mainly established on steeply sloped public land in Rio de Janeiro.*

Photo by Marco Schmidt.

and building sites, and weaker resilience of infrastructure to withstand damage. These factors influenced the disproportionate impact of Hurricane Katrina on the poor, sick, and disabled in New Orleans, which illustrates the persistent importance of these risk factors even in highly developed countries (Briggs and Keys, 2009). Similarly, the relation between urban health and climate change risks is particularly heightened under conditions of urban poverty in cities. When basic infrastructure is inadequate, existing conditions of poor sanitation and drainage and impure drinking water are further stressed during extreme weather events and flooding, leading to the transmission of infectious diseases, which puts poor urban households at higher risk. The higher densities in urban slums add to their vulnerability. When disasters occur, because many developing countries lack the health facilities to deal with large numbers of injured patients, there are higher death tolls than in countries better equipped for disaster. The January 2010 earthquake centered near the Haitian capital Port au Prince is a tragic example of this phenomenon.

8.3 The urban land management system

Although the multiple factors that drive urban patterns may make urbanization seem like an inevitable and uncontrollable process, citizens, cities, and other levels of government have the capacity to plan and manage urbanization to meet the challenges of climate change. Climate change risks will depend on the adaptive capacities of cities and their publics. The adaptive capacity of cities fundamentally depends on urban land management systems. The urban land management system, the overall system through which decisions concerning land use are made in urban areas, is composed of interacting subsystems: the legal framework, which defines property rights and government powers over land; the planning system, which develops plans and regulations for urban development; the administrative system, which manages urban services and infrastructures; land markets, which enable the exchange or sale of land; and the fiscal system, which levies taxes and provides revenues for government services. These systems interact in various ways to reduce or amplify adaptive capacity. For example, a planning system that works in isolation from urban service delivery agencies is likely to produce plans that are not implemented, or a fiscal system with insufficient revenue sources is not likely to be able to implement plans.

8.3.1 The legal/political framework

The legal and political framework for land management systems is crucial for understanding the potential for cities to mitigate and adapt to climate change. Typically, this framework is made up of cultural values pertaining to land, legal rights to property ownership, the roles of government in securing and regulating such rights, as well as in planning and managing cities and urban areas. Property rights to land are vital because housing and economic activities require stable land tenure. Rights to urban land/property and public powers to manage urban land are complementary. A strong urban property rights regime without strong public powers would leave owners with the obligation to defend their property rights against the harmful actions of others, and subject to environmental spillover effects. Strong public powers to regulate land without well-defined property rights would leave citizens at the mercy of local or national authorities. In cities with large urban poor populations, security of tenure is generally acknowledged as the critical first step in the social and spatial integration of slums and low-income settlements. It is now clear, however, that property rights, such as the rights to develop, use, transfer, obtain financial benefits, etc. and security of tenure, that is, security of ownership or lease or dwelling, are separate and sometimes conflicting concepts, especially in developing countries (Payne, 2004) For example, programs to provide legal titles to property have been implemented in many developing countries to increase tenure security, but such programs have yielded equivocal results for the urban poor (Sjaastad and Cousins, 2008).[8]

Today, in most developed countries, cities have wide powers to plan and regulate lands within their borders. Over the past few decades, a shift towards decentralization has provided local governments in more countries responsibility over the management of their land. Based on various arguments,

8 Instead, a growing group of experts argue that a more effective pro-poor regularization of informal settlements and slums should include the following: moratoria on forced evictions and relocations; offers of priority relocation to safe sites for residents who live in settlements subject environmental risks; entitle all other extra-legal settlements to other forms of secure/intermediate rights but not necessarily full titles, e.g., communal tenure options (to avoid high increases in land prices); audit planning and building regulations to reduce costs and time required to develop legal shelter options, etc. (Payne, 2004).

including that local governments can be more sensitive to local preferences in the provision of public goods (Tiebout, 1956; Oates, 1972) and more accountable to citizens, 75 countries since the 1980s have ceded powers over land use or other public services to localities (Ingram and Hong, 2008). France in the 1980s (Booth, 1998) and the Netherlands in the 1990s (Blanco, 1999) are just two examples. In addition, the European Union has provided strong incentives for Central European and Baltic states to decentralize land management functions. The shift to decentralize land use and fiscal powers in developing countries, accompanied by increasing globalization and privatization, have been influenced by the Millennium Development Goals (United Nations, 2008), which rely on local governments for delivering basic services to the poor, and by international aid agencies, such as the International Monetary Fund, the UN Development Programme and the World Bank, which have promoted decentralization policies (Ingram and Hong, 2008). Decentralization of land management combined with metropolitanization and the development of mega-city-regions adds to the fragmentation of government, and is an important legal/political aspect influencing a government's ability to manage urbanization.

Public powers to manage urban growth include land use and environmental planning and regulation, as well as public infrastructure planning and management. In developed nations, there is wide variation in legal and property rights systems, as well as in the formal government system responsible for urban land planning and management. The constitutions of many countries limit governmental action in relation to land and property. For example, the US Constitution protects property rights, and thus land use regulations that affect property rights can be challenged on constitutional grounds. Since the late 1980s, a politically conservative property rights movement has used such grounds to challenge land use planning (Jacobs, 1998; Jacobs and Paulsen, 2009). In Finland and Portugal, landowners are granted constitutional rights to build on their land, and these countries have difficulties in managing urban growth. In the UK, which does not have a codified constitution, no such limits to land use planning exist. The constitutions of Italy, the Netherlands, and Spain provide that all citizens have a right to a decent home, and such constitutional provisions can offer justification for urban planning and management (Cullingworth and Nadin, 2006).

China has a distinctive land tenure system. Under China's land title system, only the state and collectives can own land, and there is no private land ownership, although individuals and corporate entities can own property above the land. Under China's 1982 Constitution, all urban land is owned by the state, but there is a system for granting, leasing, or allocating long-term (40–70 years) land use rights. Collectives own much rural land, and thus, in order to control urbanization of agricultural land, the national government has had to increasingly regulate the conversion of land uses under collective ownership. According to Article 10 of the Constitution of the People's Republic of China, all land belongs to the state, and individual farmers have no property rights. In 1988, Article 10 was amended to allow the transfer of land use rights (Sharkawy *et al.*, 1995). Ownership of the land still remains in the hands of the state, but land use rights are available by negotiation, bid, or auction. One result of the amendment has been that farmers and collectives can rent out their land to foreign and local ventures, and large areas of farmland have been converted to urban uses. The land reform of 2008 will significantly change the land tenure system in China. Under the new system, farmers are allowed to lease or transfer land use rights (Yardley, 2008). Some argue that this new system will lead to even more rapid rates of urban expansion, with associated increases in greenhouse gas emissions.

In many parts of the developing world, colonial systems of town planning continue to operate, but relatively high and unaffordable standards have not been expanded to the settlements of indigenous people. Instead, the colonial system, e.g., in South Africa (Toulmin, 2008), continued for a small elite core, while informal markets and unregulated expansion of towns allows urban development by wealthy landlords, many of whom provide little or no service infrastructure and minimal formal security of tenure to the urban poor. With urban growth, cities also spilled into areas of land managed under traditional practices where common property rights prevailed, creating a complex web of land use regulation and property rights. For example, over the past 50 years, Latin America underwent rapid urbanization and expansion of informal developments and slums without adequate infrastructure and urban services. This is typically seen as a failure of urban planning, but legal systems have played a large role in the expansion of informal settlements in Latin America. In the case of Brazil and Colombia, for example, scholars argue that a key factor in the expansion of informal settlements was inadequate legal codes that protected private property rights while failing to recognize the public interest in land development regulations (Fernandes, 2003, 2007; Fernandes and Maldonado Copello, 2009).[9] As previously discussed, the characteristics of informal settlements and slums will make them most vulnerable to climate change impacts.

Often underlying constitutional provisions are the historical and cultural attitudes of nations towards land. Although there are likely many variations, the increasingly dominant attitude

9 A promising development in Brazil and Colombia is the emergence of a legal reform movement in the 1980s promoting a new legal paradigm, Urban Law, which promotes urban democracy. The proponents of Urban Law argue that civil codes contain principles that can support appropriate state intervention, emphasize the concept of the social function of property, and an integration of law and management that incorporates urban democracy and decentralization of decision-making processes. Establishing this new legal approach, Colombia enacted constitutional changes in 1991, as well as a new law (No. 388 in 1997), and Colombia's Constitutional Court has upheld this approach in its rulings. In Brazil, the 1988 Federal Constitution proposed, and the 2001 City Statute consolidated the Urban Law approach. Recent studies indicate that high court judicial decisions in Brazil have incorporated this new interpretation in 50 percent of their decisions (Fernandes, 2003, 2007; Fernandes and Maldonado Copello, 2009). This new legal approach can result in greater security of tenure for the poor, more effective urban planning, development, and infrastructure financing mechanisms, all crucial for effective climate change adaptation efforts in developing countries.

towards land in the world today is to view land as a private good, where owners are entitled to use land in its most profitable way. Still, there is cultural variation, for example, in the UK, land is conceived as a special type of property, "to be preserved and husbanded" (Cullingworth and Nadin, 2006). Land does pass the market economic criteria of a private good; it is both an excludable good (we can exclude others from the use of a land parcel), and a rivalrous good (if I put a house on this parcel, it prevents others from putting something else on it). In addition to its social function, environmental science increasingly makes clear another aspect of the special nature of land. Its use determines the health of the ecosystems on which we and other life on Earth depend. Land has living and systemic aspects that the dominant concept of property rights does not capture. Unfortunately, we have yet to adopt a modern alternative concept of land rights and obligations that adequately captures the ecological aspects of land. Instead, the increased acceptance of market economics around the world over the past three decades has diminished the variation in cultural attitudes towards land.[10] Developed and developing nations have been adopting more market-oriented property rights systems either in the absence of effective urban planning and management institutions, as in the case of many developing countries, or that weaken their traditional public powers, as in the case of many European countries, such as Denmark. In general, this trend has likely decreased the ability of governments to address climate mitigation challenges and adaptation impacts, since addressing climate challenges will require government regulations in the public interest that will restrict private property rights.

8.3.2 The urban planning system, its history and institutions

Planning is the steering function in government, and land use is a, if not the, primary concept in urban planning (Krueckeberg, 1995). A major objective of UN Agenda 21[11] explicitly recognizes the importance of comprehensive urban planning and management to achieve sustainable urban areas. Urban planning as a government function emerged in some parts of the developed world, e.g., in the UK and the USA, out of sanitary and housing reform movements in the early twentieth century. These movements were prompted by public health concerns related to infectious diseases, such as cholera, typhoid, scarlet fever, and tuberculosis, that swept through industrial cities at the turn of the twentieth century where people were housed in crowded tenements without access to light or ventilation, and lacked sanitary water, wastewater, and solid waste disposal systems. (Peterson, 2003; Lubove, 1967). The broad rationale of urban planning and regulation is to ensure public health and safety. For example, the strict residential districts in urban zoning, developed in the context of the industrial city, were designed to protect residential uses from noxious industrial uses. The modern profession of urban planning developed as a field of studies linked to architecture and engineering faculties, beginning in the 1930s in the USA. In many parts of the world, urban planning is a specialization in architecture, engineering, or public administration schools, very often offered at the post-graduate level. Urban planning practices are now well diffused throughout the world (Ward, 1999), although there are major gaps in such practices in many countries. Several scholars (Harvey, 1989; Sassen, 1991) have argued that planning diffusion is a key aspect of economic globalization, especially given the global character of property development.[12]

Most developed countries have planning institutions that engage in long-term, comprehensive planning, zoning, and other land use regulations (Nivola, 1999). Long-range comprehensive planning refers to a type of plan that typically has a 20-year horizon, and includes citywide plans for the land uses and needed infrastructure and public facilities for a projected population and economy. Typically, local legislative bodies are responsible for approving land use plans, and thus plans have the status of law. The administering of regulations, or permits for land use actions, is carried out by an administrative department, usually under the local executive's supervision. In the USA, urban planning and the administration of land regulations are conducted by several major institutions: lay planning commissions and local legislatures, who make decisions on plans and changes to regulations; and professional departments of planning, which prepare the plans and regulations, administer them, and are part of a city's bureaucracy. Planning commissions are made up of lay citizen volunteers instead of experts or professionals, and have quasi-legislative functions subject to approval by the elected city council (Sanders and Getzels, 1987). Planning commissions, a government reform initiative from the early twentieth century, were meant to buffer planning decisions from the political process. These lay commissions, with their public hearing requirements, laid the groundwork for a more participatory approach to urban planning, which is now prevalent in the USA. This is in contrast to other departments in city government, which are governed in a more typical bureaucratic mode, lacking strong participatory processes (Blanco, 1994). The greater uncertainty associated with climate change adaptation planning will require significant new information, public education, and strong community participation to build consensus on local adaptation strategies.

8.3.3 Types of plans and their limitations

The planning system is a key element in determining a city's adaptive capacity. Urban planning is typically conducted at the city level. Local plans in developed countries typically take the form of comprehensive long-range plans, which are primarily driven by demographic and economic trends, and thus

10 Although several legal scholars are addressing the issue of how ecology affects the traditional concept of private property rights (Freyfogle, 2003: Goldstein, 2004).
11 UN Agenda 21, Chapter 7, sets out the objective of promoting sustainable human settlement development, including programs to ensure adequate shelter, improve urban management, and sustainable land use planning and management, as well as the provision of urban infrastructure, sustainable energy and transport systems, etc. (UNCED, 1992).
12 But diffusion need not occur in a monolithic fashion as through the authoritarian imposition of colonialism, and planning institutions have also been the subject of selective borrowing and more synthetic innovations (Ward, 1999).

[MITIGATION/ADAPTATION] Box 8.4 Urban growth management and smart growth in the United States

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Urban growth management by aiming to manage land conversion from rural to urban uses and by influencing urban form can be a key strategy for reducing greenhouse gas emissions and for adapting to climate change.

The state-wide growth management movement that emerged in the USA in the 1970s, motivated by the rise of the environmental movement, is a promising effort to provide planning mandates at the provincial/state level for coordinating inter-jurisdictional planning, and appropriate tools to accomplish this. Several of these programs require consistency between plans and regulations, and explicitly address and link land use, infrastructure, and environmental objectives. In the 1990s, reacting to continuing sprawl despite planning efforts, a new urban planning movement, smart growth, advocates several measures: (a) limiting expansion of new development through urban growth boundaries[13] or utility districts; (b) increasing residential densities in existing and new growth areas[14]; (c) promoting more mixed use and pedestrian amenities to minimize car use; (d) charging infrastructure impact fees to consumers instead of having the community in general pay through property taxes; (e) emphasizing public transit to reduce the use of private vehicles; and (e) revitalizing older existing neighborhoods (APA, 1998; Burchell *et al.*, 2000; Downs, 2001). About a dozen states in the USA have adopted state-wide measures that incorporate some of these features. The programs of the states of Oregon and Washington are perceived to be the most successful in reducing sprawl, although some studies indicate mixed results (Song and Knaap, 2004; Bae, 2007). These two state programs require planning efforts by their counties and cities to link land use, infrastructure, and environmental concerns, and incorporate urban growth boundaries as a major strategy (DeGrove and Miness, 1992; Weitz, 1999).

More recently, the Lincoln Institute of Land Policy conducted an evaluation of state-wide smart growth programs by comparing four states (Florida, Maryland, New Jersey, and Oregon) to four states without such programs (Colorado, Indiana, Texas, and Virginia). It evaluated programs on various parameters of smart growth, including growth patterns, natural resources and environmental quality, transportation, and affordable housing. The study concluded that smart growth states only marginally outperformed the states without such programs, although only one of the smart growth states, Oregon, performed best on each objective (Ingram *et al.*, 2009). Consistently, studies indicate that the most successful of these state-wide growth management efforts in the USA is in the Portland metropolitan region, which is the only elected metropolitan government in the USA (established in 1992) with metropolitan land use powers, infrastructure management, and some fiscal powers. These results suggest that effective metropolitan planning for climate change is likely to require new political arrangements.

are growth-accommodating. In some countries, however, the attitude towards trends is different, in the UK, for example, trends can be modified in more socially desirable directions (Cullingworth and Nadin, 2006). These local long-range plans incorporate various elements, including, traditionally: land use, housing, transportation, public facilities and services, natural resources or environmental protection, open space and recreation. Some cities also include economic development and urban design elements, and coastal cities include shoreline management elements. In developed countries, the connection of these long-term plans to implementation steps is not straightforward, and does not proceed in a linear fashion, since local planning departments are separate units within a multiplicity of local government agencies, including transportation, housing, water and sewer, etc. Such agencies also plan for their services, and coordination between land use planning and other related local government departments is often lacking. Reaction to this lack of coordination among city agencies in the USA led to urban growth management efforts after the 1970s that link land use plans to infrastructure planning, especially to transportation planning. But the lack of coordination among these agencies is still prevalent today, and is a major obstacle to effective growth management.

8.3.3.1 Metropolitanization requires metropolitan planning

As cities and their populations spread out beyond their historical borders into metropolitan areas, jurisdictional boundaries, political demarcations, and traditional governing structures and institutions of planning and land use management are becoming outdated. Increasingly, these functions demand more integrated planning, infrastructure investment, service delivery, and policy decisions than these fragmented jurisdictions can provide. Effective planning and management of these inter-municipal territories requires an integrated metropolitan approach that transcends the traditional municipal boundaries. The fragmented local government structure of metropolitan areas facilitates the conversion of agricultural, forested, or otherwise undeveloped land to urban uses. These expanding urban areas also have fiscal deficiencies and weaknesses, face heightened

13 Urban growth boundaries are planning lines drawn around an urban area to separate it from the rural area. These boundaries are growth accommodating: in Oregon, for example, the areas within the growth boundary are drawn to accommodate growth projections for the next 20 years, and can be adjusted to accommodate growing demand (Easley, 1992; Nelson and Dawkins, 2004).

14 Studies indicate that higher densities than typical suburban densities are more cost-effective from the perspective of infrastructure and public facilities provision, and contribute to more effective public transit (Burchell *et al*., 2005), but we have yet to investigate whether, from the perspective of climate change, there is a point of diminishing returns or diseconomies as density increases.

challenges of metropolitan transportation, as well as deficiencies in critical physical and social infrastructures (Rusk, 1995; Ladd, 1998; Norris, 2001; Orfield, 2002; Carruthers, 2003). In addition to these challenges, cities face a context of competition with other cities at a national, continental, and often, at a global level.

The challenges of equitable development among different groups in these vast urban territories highlight the need for major improvements in the provision of public services such as health, decent shelter, education, water, and sanitation. As urban poverty worsens, especially in developing countries, poor populations have been spreading outwards, making the peripheries of these metropolitan areas the poorest and most heavily under-serviced settlements. Concerns related to an increasingly divided urban society, together with inequalities and poverty that stretch across large metropolitan areas, emphasize the need for metropolitan planning and governance frameworks that address these imbalances (McCarney, 2010).

Although decentralization could be an effective administrative reform strategy, decentralization efforts have sometimes further entangled the institutional problems facing fragmented metropolitan areas. In India, for example, under the new national strategy of the 1990s, the 74th Amendment of the Constitution (1992) conferred constitutional status on urban local bodies, and transferred to them responsibility for urban development. But whether peri-urban areas, where poor rural migrants to the cities locate, can be managed by the municipal corporations is left up to the states to determine. Thus, while some states, such as Tamil Nadu have been responsive, other states have not been (Shaw, 2005; Dupont, 2007). In Bangalore, with a population of over 7 million in 2007, the land use planning authority for the region is vested in two state agencies: the delivery of urban services is the responsibility of the elected metropolitan government, while several other independent agencies are in charge of water supply, police, transportation, etc. (Sudhira *et al.*, 2007).

8.3.4 Urban land regulation

Zoning, especially in developed countries, is a system of land classification widely used for development purposes: areas are zoned for residential, commercial, industrial, or agricultural, and each of these broad classifications can be further subdivided.[15] For example, residential districts are often subdivided into low-, medium-, and high-density districts. Zoning is composed of a map that divides the city's land into zoning districts, and the zoning code or local law, which sets out permitted uses by district and other regulations, e.g., the permitted height of buildings (Lerable, 1995). Zoning codes have been traditionally exclusive; for example, the zoning code would not permit a high-rise apartment building in a low-density residential area. Zoning also determines the percentage of a parcel that can be built upon, as well as the height of structures, and thus can regulate solar access. Through building coverage and landscaping requirements, zoning can influence the extent of impervious surfaces, a very important determinant of drainage and the heat island effect. Zoning is empowered to restrict property rights to ensure the public's health and welfare. Traditionally, this type of zoning, which is geared to prevent the nuisances of high density or commercial or industrial activities in single family residential districts, is currently controversial since, combined with widespread automobile ownership, it segregates activities in urban areas, and increases automobile use. In the USA, for example, there is a growing movement of planners and architects that argue for mixing land uses, that is, for new zoning districts that permit several compatible uses, such as low- and medium-density residential and neighborhood commercial uses. Such mixed use districts, advocates argue, would provide more livable neighborhoods, as in historic towns and cities, where residents would be able to walk or bike instead of driving for neighborhood services, and where there would be a greater mix of social classes (APA, 1998; Grant, 2002; Talen, 2006). The mixture of land uses is an important element of a compact city strategy that could reduce the number or length of automobile trips, and thus energy use and associated greenhouse gas emissions.

Subdivision regulations (Freilich and Schultz, 1995) are major instruments for converting rural land into urban, and have been instrumental in determining the dispersed suburban pattern in the USA and other countries. Subdivision regulations are crucial for climate change, since, for example, street widths and orientation can influence ventilation patterns for a city, important for mitigating the heat island effect, and open space and drainage options will be important to adapt to increased precipitation events in many cities.

Building standards are also a major form of land regulation, administered by urban planning departments, which require adequate design, construction processes, and building materials, such as minimum room size, or heating and cooling standards to meet fire and safety codes. Very few cities develop and maintain their own building codes, New York City and Chicago being exceptions in the USA. Instead, building codes are developed either by government agencies, in which case such codes are typically mandatory for states/provinces and their cities, or by national or international associations of professionals[16] organized to develop such model codes. These latter codes are then adopted and can be amended by states and cities. Important for climate change, building codes include energy standards and regulations on heating and cooling. The updating of national and international standards is ongoing, and more energy-efficient building standards have been developed. The updating

15 For a comprehensive review of the state of urban planning and related tools in developed and developing countries, see the UN-HABITAT *Global Report on Human Settlements 2009: Planning Sustainable Cities* (2009).

16 Building codes are increasingly becoming consolidated and worldwide. The International Code Council, for instance, develops building codes that have become the dominant standards in the USA and are also widely adopted internationally. The heating and cooling standards of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) are also widely adopted in the USA and around the world.

of building codes by cities is haphazard even in developed nations, such as the USA, where some cities retain older versions of codes, and some lack certain codes altogether, e.g., the state of Mississippi lacks a commercial building energy code, its residential energy code dates to 1992, and although cities and counties have the ability to adopt such codes, the largest city, Jackson, Mississippi, still lacked such a code.[17] The issue with building codes, however, is as much enforcement of codes as adoption of newer codes. The fatal collapse of so many structures in the 2008 Sichuan earthquake in China, for example, was not due to China lacking modern seismic codes. Instead, engineering experts have noted that the Chinese government had adopted a strong seismic design code after a devastating earthquake in 1976, but that there has been uneven application of it and lack of enforcement (Bryner, 2008). Thus, both the adoption and enforcement of energy-efficient building codes will be crucial for reducing building energy use and the emission of greenhouse gases.

Land use planning and regulations require up-to-date records on land ownership and transfers as well as on the dimensions of land parcels and structures. Local governments maintain such records in cadastral and/or land registration offices (Bogaerts and Zevenbergen, 2001). Cadastral systems provide legal protection regarding land ownership, facilitate transactions in land and real estate markets, and are necessary for levying local property taxes or fees on urban land and development. Land registration agencies are the first agencies that need to be established to develop a land management system in countries where no formal documentation exists of who owns or has rights to use land, as in many countries in Sub-Saharan Africa (Toulmin, 2008). In order for urban areas to inventory their emission of greenhouse gases and to prepare for climate change impacts, they require up-to-date data on ownership patterns and the location and condition of buildings that land registration offices maintain.

8.3.5 Development markets and their influence on urban growth

Most urban development is privately produced and exchanged through urban land and real estate markets. Real estate markets include land and the structures or development built on land. Land and real estate markets and groups who benefit from them all depend on urban growth. The role of urban land and development markets remains powerful even in countries, such as China, that have recently established such markets. In China, urban land development has largely been driven by a growing private sector and formal planning has had a relatively minor role compared to large-scale investments by overseas interests (Ding, 2007). As in most markets, developers as capitalists are seeking the highest profit. This leads to several development dynamics that have relevance to urban growth patterns. Developers seek the cheapest land for their projects, thus leading to the conversion of agricultural or otherwise undeveloped land in the periphery of existing urban areas, since these areas are cheaper than urban land (O'Sullivan, 2006). In addition, under the fragmented governance structure of metropolitan areas, if a city enacts land use regulations that marginally increase development costs, such as a higher energy-efficiency code, or if a city requires that new developments maintain a certain level of service in transportation or other infrastructure services, developers can often take their projects to localities without such regulations. Also, major developers have undue influence on local politicians. They are often major sources of local campaign financing contributions. Responding to climate change may require effective metropolitan governance that reduces the opportunities for developers to game urban planning and management systems, and rely instead on alternative coalitions to the urban growth machine (Logan and Molotch, 1987; Jonas and Wilson, 1999) to counter current urbanization trends.

8.3.6 Fiscal aspects of urban land: property taxes and city budgets

An important component of the urban land management system is the local fiscal system, the sources of revenues from which local governments draw their funds. Most local governments receive transfer of funds from national and provincial levels of government, and with increasing decentralization of government throughout the world more local governments have their own sources of revenues. In developed countries, cities typically have several sources of local taxes or fees that are used to provide local urban services, from street maintenance to water supply, public health, and safety services. For example, the property tax in the USA is the major source of revenues for local governments (Raphaelson, 2004). Property tax, the tax on the value of real estate property including land and structures, in effect provides funding for general urban services, and thus intimately links land development with the provision of local infrastructure and services. Local reliance on the property tax is not without problems. It generates inequities among cities as communities with, for example, highly valued properties (or *ratables* as they are referred to in the fiscal literature), either high-income residents with highly valued houses or large and highly valued shopping malls, generate more local tax revenues than communities with a lower valued tax base. Thus, communities with a higher proportion of ratables are able to fund better levels of urban services. In this way, reliance on the property tax can lead to fiscal or exclusionary zoning where communities, in order to attract high ratables, restrict their zoning to large, single family or other highly valued development, thereby excluding lower-income residents (White, 1975; Ladd, 1998). Fiscal zoning can aggravate affordable housing shortages, and generate greater regional road congestion and further urban sprawl as lower-income workers are forced to move farther and

17 However, the American Recovery and Renewal Act of 2009 (Stimulus Bill) made State Energy program grants available on condition that states adopt energy building standards for both residential and commercial buildings that meet energy standards of 2007 within 8 years of enactment of the Act (Barbour, 2009). By 2017, this will make states such as Mississippi 10 years at most behind the most recent energy standards. The passage of the American Clean Energy and Security Act (ACES) of 2009 (US House of Representatives Bill 2454 accessed at www.opencongress.org/bill/111-h2454/show) would mark a more significant milestone. The Bill requires that US DOE work with residential and commercial code developers to ensure that model codes are developed by 2010 and 2016 that will improve energy efficiency by 30 percent and by 50 percent respectively.

[ADAPTATION] Box 8.5 Decentralization of fiscal authority in Ghanaian cities

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Reliable own-source revenues will make it more feasible for local governments to respond in the future to the increased costs of coping with climate change impacts without complete reliance on their central governments.

Many African countries have devolved various government powers to local governments over the past few decades, including fiscal responsibilities. Although in most African countries, local governments still rely heavily on central–local government transfers for local budgets, localities seek ways to develop their own-source revenues. Local property tax is widely perceived as an appropriate local tax, since the land and structures are fixed and easier to monitor, and since the resource taxed and the benefits received are both local (Raphaelson, 2004). In addition, in developed countries such as the US and OECD countries, for example, property tax is a major source of own source revenues for local governments.

Decentralization began in Ghana in 1988 when the central government approved the local government law (Provincial National Defense Council Law 207) through which local government was reviewed and reorganized into district assemblies, which, as of 2008, number 166.[19] Ghana is a country on the western coast of Africa, with a population of over 21 million people, with a per capita GDP of US$682, and an urbanization rate of 36 percent. Its capital city is Accra, with a population of about 3 million. As a result of Ghana's decentralization policies, Ghanaian localities have the power to levy urban property taxes. Unlike the USA, in Ghana, property tax is levied on improvements (buildings and structures) only and not on vacant land, except in Accra's metropolitan area where, beginning in January 2008, differential property rates are being imposed on undeveloped land in different parts of the metropolitan area. The property tax on improvements is imposed on a depreciated replacement cost of the improvement. The Act on Rating (Act 462) of the Local Government Act of 1993 set the maximum tax assessment value of an owner-occupied property at 50 percent of replacement cost, and set a ceiling of 75 percent of replacement cost for other non-owner-occupied improvements. The authority for setting the actual rate, the administration of the tax, and the entitlement to the revenues from the property tax are left to the local authorities (Jibao, 2009). This type of property tax system, where the base of the tax, or the ratable, is calculated based on the value of the property depends on the capacity of localities to assess the value of properties on a regular basis, since property values vary depending on land market conditions. This is a problem in Ghana and many other developing countries, which requires authorized evaluators or assessors of property values. Although Ghana did have over 200 registered assessors in 2007, this was not sufficient to cope with the evaluation of properties. The lack of evaluators needed in a system of taxation where the value of the property needs to be evaluated periodically means that the system is "neither practical, nor sustainable". In addition, in order to fulfill the goal of private sector participation, the Local Government Act of 1993 requires that local governments hire private companies to collect local taxes. In Accra, for example, private entities are hired to collect the property tax. The collection of taxes is fraught with many problems; for example, many houses lack house numbers, and cannot be identified to serve tax bills.

The Accra Metro Area is Ghana's largest metropolitan area with the largest industrial center. With an estimated tax base of approximately 39 trillion Cedis for about 120,000 properties, the property tax should have generated 229 billion Cedis in 2006. Instead it generated 15 billion Cedis, for a 6.71 percent tax yield. In contrast, Tema is a coastal city 25 km east of Accra with a population of about 600,000. Tema has undergone a rapid transformation from a fishing village to an industrial center, handling 70 percent of all shipments to Ghana and land-locked countries in western Africa. Unlike Accra, Tema in 2006 collected more property tax revenues than it projected, and the property tax contributes 36.7 percent of the city's own source revenues. The different experiences with the property tax in Accra and Tema are attributed to the greater percentage of industrial and commercial property in Tema. Such properties are seen as being more "tax compliant". Also, industrial and commercial properties can be taxed at higher rates.

The comparison of these two cities in Ghana indicating better tax yields under the property tax with commercial and industrial ratables could, in time, set up a dynamic comparable to the rateables chase found in US localities. Today, however, as the examples of Ghana's cities illustrate, a major problem is the lack of sufficient capacity to administer the property tax systems. This hinders the ability of local governments to supply local services including climate change adaptation.

farther away from places where they work.[18] On the other hand, the absence of robust fiscal systems in many cities of the developing world is likely a major reason there is inadequate capacity to plan or enforce land use regulations at the local scale (Razin, 2000), which could be effective in mitigating climate change or adaptation planning.

18 An alternative to the property tax, which taxes both land and structures, is a land tax, originally proposed by Henry ([1879] 1992), where only land and not structures would be assessed a tax. Split-rate taxation is a variant of this, where land and improvements are taxed at different rates, with lower rates imposed on improvements. A land tax would be more efficient than the property tax, not distorting investment choices, and counteracting fiscal zoning. The land tax is also seen as reducing speculation on land, promoting economic development, as well as compact development (Dye and England, 2009).

19 Much of the information contained in this profile is a summary of S. S. Jibao's monograph on the property tax system in Anglophone West Africa (2009) prepared for the Lincoln Institute of Land Policy.

8.3.7 Relation to urban infrastructure systems

Land uses and urban infrastructures and public services are intimately interconnected. Typically, in developed countries, infrastructure or capital facilities planning is based on land use plans and zoning. Land use plans and regulations, for example, project a total number of new dwelling units, a certain increase of commercial or industrial space at the build out of the zoning districts. The total number and type of dwelling units or floor area become the inputs for infrastructure multipliers that are used to project traffic generated, water usage, wastewater generated, parks and open space needed, waste generated, etc.[20] These projections are, in turn, converted to new transportation or other infrastructure improvements needed to serve new development. The costs of these improvements can then be incorporated into capital facilities plans or capital improvement programs that identify the facilities required and the local and intergovernmental funding sources available to construct the facilities (Bowyer, 1993). The process just outlined, however, is an ideal process, given the sectoral divisions in local government. As discussed in Section 8.3.3, local departments of transportation, public works, parks and recreation, etc., that operate infrastructure facilities often have their own planning units with different professional practices and cultures. These departments have been slower in making the shift from their traditional role of supplying new infrastructure to managing the demand for urban growth. Without strong executive leadership or state or national mandates for integrated urban planning and management, this fragmentation of planning and operational functions makes it difficult to manage growth, and increases the climate change challenge for cities.

8.4 Climate change risk

From the perspective of urban land, climate change risk depends on the character, magnitude, rate, and variation of climate change impacts to which urban land and populations are exposed, on sensitivity factors, and on a city's adaptive capacity (IPCC, 2007). "Sensitivity refers to the degree to which a system is affected by climate change impacts. Adaptive capacity is seen as a function of behavior, resources, and technologies" (IPCC, 2007, p.720).

Chapter 3 discusses in greater detail the climate change risks and major impacts for cities: temperature increases, sea level rise, precipitation changes, and extreme weather events. We should note here, however, that from the perspective of urban land, sea level rise poses an especially significant risk, since low-elevation coastal zones (LECZ), areas less than 10 meters above sea level, take up 2 percent of the world's area, but contain 10 percent of the world's population and 13 percent of the urban population (McGranahan *et al.*, 2007). Over 3,000 cities are located in the LECZ and more than one-half of these cities are located in Asia (UN-HABITAT, 2008a). In Australia, 86 percent of the population lives along the coastline (Norman, 2009). LECZ cities risk inundation and destructive storm surges. Sea level rise thus poses the risk of land loss as well as loss of buildings and the infrastructure on such lands.

To determine the extent and character of the climate change hazard for specific cities requires downscaling the global projection models to take into account regional/local climate, hydrology, and other relevant factors. This is particularly important for determining the adequacy and cost-effectiveness of climate adaptation strategies. Downscaling involves data and modeling capacity often unavailable for cities in developing countries. Several recent attempts have been made to provide cities in developing countries with easily accessible methodologies to determine local risk levels, For example, the World Bank report on resilient cities (Prasad *et al.*, 2009) outlines a process to enable cities to take the first steps in determining their susceptibility and resilience to climate change. Building on the similarities between natural hazard and climate change risks, the report sets out a simple method to establish whether a city is a "hot spot" or has high climate change risk, based on a city typology and risk characterization matrix that probes for the following: disaster-prone locations, e.g., coastal areas, plains; size; governance structure; built environment; political and economic impact of disasters; threat of natural hazards; disaster response system; vulnerability to climate change in various sectors, etc.

As discussed in Section 8.1.2, the land sensitivity factors related to climate change in cities include the natural setting of a city, its urban form, and its built environment. Although poverty is the fundamental cause of slums or informal settlements, urban form and built environment factors in urban slums amplify the vulnerability of slum populations to climate change risks.

While the natural setting, the existing settlement pattern, and the character of the built environment are relatively stable or fixed, although subject to modification, the urban planning and management system represents a major human or adaptive capacity to respond to changing conditions, including making changes in urban settlement patterns. Urban planning and management, however, are not the only important adaptive factors. Other factors include public attitudes, political leadership, and financial resources to implement certain strategies, such as engineering or retrofitting strategies. The more vulnerable the natural setting, or the urban form, or the built environment, *ceteris paribus*, the more vulnerable is a city to climate change: the weaker the capacity to change these patterns to more resilient ones, the greater the risk to a city. A city with strong institutions of planning, regulation, and management is more likely to have the capacity to prepare local mitigation or adaptation plans that take into account local conditions and engage the local populations in these efforts. Such plans are likely to be more effective in reducing climate change risk.

20 Professional associations typically provide these infrastructure multipliers. For example, in the case of traffic multipliers, the Institute of Transportation Engineers publishes trip generation and parking generation handbooks that assist transportation planners to estimate the traffic generated by specific land uses (ITE, 2008).

[VULNERABILITY/ADAPTATION] Box 8.6 Vulnerability and resilience in a rapidly growing coastal city: Florianópolis, Brazil

Sandra Baptista

CIESIN, Earth Institute at Columbia University

Rapidly expanding coastal cities in low- and middle-income countries face the linked development challenges of managing accelerated urban growth, reducing social inequity and exclusion, maintaining ecosystem services, preparing for climate hazards, and adapting to climate change. Florianópolis on the coast of southern Brazil is one such city. As observed across Latin America, in Greater Florianópolis low-income households, businesses, and communities are most likely to occupy poorly built structures and informal settlements located in high-risk areas (e.g., steep slopes or low-lying lands), which often lack adequate access to basic infrastructure and services. These conditions leave poor populations highly vulnerable to climate-related hazards including high-speed winds, storm surges, heavy rainfall, floods, landslides, and post-disaster outbreaks of water-borne and vector-borne infectious diseases.

Florianópolis is the state capital of Santa Catarina. Greater Florianópolis – which extends into Santa Catarina Island and the mainland municipalities of São José, Biguaçu, and Palhoça – has emerged as a dynamic globalizing coastal city. It is one of southern Brazil's largest urban agglomerations. While in 1970 Greater Florianópolis had about 217,000 residents, it is now home to roughly 800,000 people (IBGE, 1974, 2007). The region's landscapes, ecological diversity, and urban amenities attract hundreds of thousands of tourists each year. Ecosystems include dense broadleaf forest, mangroves, coastal sandy plains, lagoons, estuaries, sandy beaches, dunes, and rocky headlands. Over the past four decades the region has experienced both ecosystem degradation and ecosystem recovery as interacting demographic, socioeconomic, land use, and institutional changes have occurred (Baptista, 2008a, b). Today, over one-third of Santa Catarina's 6 million people live near the coast. In 2000, the 37 municipalities situated directly on the coast had nearly 2 million people inhabiting about 10,000 km^2, an increase of about 1.2 million residents since 1970 (IBGE, 1974, 2001).

Since the mid twentieth century, rainfall measurements in southern Brazil have shown an increasing precipitation trend (e.g., Haylock *et al.*, 2006). Based on daily air temperatures from 27 meteorological stations in southern Brazil, Marengo and Camargo (2008) identified warming trends for the period 1960–2002. Scientists predict continued precipitation increase, positive trends for warm nights and negative trends for cold nights (Vincent *et al*., 2005), and higher frequency and intensity of rainfall events resulting in flooding and landslides (Marengo, 2008). These changes will have consequences for ecosystems, agriculture, urban development, and human health. For example, warmer and wetter environmental conditions are likely to contribute to outbreaks of infectious diseases such as malaria and leptospirosis (Kupek *et al.*, 2000; Confalonieri, 2003).

Major infrastructure projects enabled the expansion of public services, tertiary sector growth, and real estate development in the region, thus spurring the institutionalization of modern public planning for urban development. In 1955, the first Master Plan for Florianópolis was approved and a state development plan was legislated to initiate major public works projects, including electric energy sector development (Caballero, 2002; Reis, 2002). By the late 1960s and early 1970s, the Florianópolis Metropolitan Area Development Plan prioritized the construction of a high-speed road network to economically integrate Santa Catarina Island with the mainland and promote urban expansion and tourism development (Amora, 1996; Reis, 2002). This plan led to a bayside landfill project, which added 6 square kilometers to the island, initially supporting construction of two new bridges connecting the island to the mainland and later accommodating the city's central bus terminal. During the 1970s, several new federal and state government agencies were established in the Central City District, and the jobs created stimulated new residential and commercial development.

The municipal urban planning agency IPUF (Instituto de Planejamento Urbano de Florianópolis) was established in 1977 (Adams, 2004). In 1981, the Tourism Development Plan for the Florianópolis Urban Agglomeration was proposed as part of a larger federal economic development program targeting medium-sized cities (Amora, 1996). IPUF was also involved in the preparation of Master Plans for neighboring municipalities towards metropolitan integration (Sugai, 2002). Since the 1980s – in response to observed land use trends, reevaluations by the municipal legislature and federal legislative changes – IPUF has revised the Central City District plan and has prepared plans for other submunicipal units. Furthermore, Brazil's 2001 City Statute (Federal Law No. 10257/01) institutes new tools to regularize informal settlements in urban areas and mandates municipalities to democratize local decision-making processes for urban planning, legislation, and management, including the formulation and approval of municipal master plans (Fernandes, 2007).

Since the 1980s, as impoverished urban communities have expanded in Brazil, middle- and upper-income households have responded with self-segregating behaviors and actions intended to minimize their exposure to crime, violence, and environmental hazards. As elite entrepreneurs and middle-class migrants claim emergent territories and economic opportunities in Brazil's newly expanding metropolises, they reproduce the exclusionary patterns of land use that are now characteristic of the older metropolises, while maintaining connections to national and international centers of informational, financial, and political power. The case of Florianópolis illustrates these socioeconomic dynamics and the ways in which they contribute to disparities in human well-being, including disparities in social vulnerabilities and resiliencies to climate risk. Ongoing efforts in Florianópolis, and other Brazilian cities, to develop direct democracy and formulate participatory municipal master plans have the potential to: provide important institutional mechanisms for inclusive governance and sustainable development planning, facilitate successful adaptation to climate variability and climate change, and foster more equitable outcomes.

8.5 How urban planning can address the mitigation of greenhouse gas emissions

Planning and management tools can help to address the critical link between emissions and urban form, particularly in terms of transportation, more compact development, building energy consumption, and conversion of land for urban use. For example, official plans, development guidelines, development permits, densification plans, infill development, reuse of buildings, transit planning and pricing, building codes, and a number of other planning tools can help to address greenhouse gas emissions in cities as climate change mitigation strategies. Effective planning, however, requires spatial data that link greenhouse gas emissions with their sources.

8.5.1 What cities are currently doing

Many cities have begun to incorporate strategies to reduce greenhouse gas emissions in their urban plans. Most mitigation plans focus on energy efficiency in buildings and the transportation sector. More difficult to address are ways to change land use patterns to reduce automobile use and increase the use of public transit and non-motorized travel. Most European urban areas have a compact core and effective public transit systems, but land conversion to urban uses and resulting sprawl and automobile use are increasing problems (Kasanko *et al.*, 2006). Several European cities in countries with strong land use powers have traditions of greenbelts and other urban growth containment measures, but their effectiveness is mixed, and in times of strong real estate markets, they are often weakened.[21] For example, the future of London's greenbelt policy, dating back to the 1940s and1950s, was recently in question, given a strong real estate market before the 2008 recession, and the government's plans for 3 million new homes by 2020 (Brogden, 2007). In addition, the effect of greenbelts is often mixed. London's greenbelt had the effect of scattering growth beyond the greenbelt (Bruegmann, 2005). Seoul's greenbelt, inspired by London's, has been more strictly enforced for the past 30 years, but Bae and Jun (2003) argue that Seoul's metropolitan area is larger as a result of the greenbelt than it would have been without it, and this has generated a severe jobs–housing imbalance. Seoul's greenbelt policy was also recently revised, and by some reports, weakened (Bengston and Youn, 2006). In the USA, as indicated in Box 8.4, the smart growth movement has advocated compact development, mixed land uses, and public transit, all strategies with great promise to reduce automobile use and thereby energy use. But although a number of studies indicate that growth management has had some successes (Nelson, 1999; Wassmer, 2006; Yin and Sun, 2007), others point to more mixed results (Kline, 2000; Carruthers, 2002; Song and Knaap, 2004; Bae, 2007; Ingram *et al.*, 2009). A milestone in this movement and in mitigation planning is the passage in 2008 of California's Sustainable Communities and Climate Protection Act or SB 375, the first legislation in the USA to link transportation and land use planning with climate change. Major new requirements of the law are: that regional targets for greenhouse gas emission reductions be tied to land use plans; that regional planning agencies create plans, Sustainable Community Strategies, to meet such targets, even if in conflict with local plans; and, that the funding of regional transportation agencies be consistent with the regional plans. Promising as it is, SB 375 still leaves local governments in charge of their land use plans and regulations, even though it creates more incentives for regional coordination (State of California, 2008; Higgins, 2008).

8.5.2 Next steps

Leadership at the national and international levels is needed to provide either incentives or mandates to turn individual and voluntary local programs into widespread practices. Building energy efficiencies can be achieved through the adoption of more energy efficient building codes by national governments. Once adopted, national governments through national policy or incentives should require their timely adoption by provincial (sub-national, state) and local governments. Smart growth policies to reduce sprawl and automobile travel are more discussed than carried out in practice in the USA, because there are major impediments to their implementation. Two major obstacles requiring national leadership are: consumer demand for low-density living patterns, and local home rule. Local governments have the legal power over land use, but in order to implement anti-sprawl policies, such as urban growth boundaries, which should be metropolitan in scope, such policies require state-level support (Downs, 2005).

8.6 How urban planning can address the impacts of climate change

Adaptation planning fits naturally the agenda of urban and regional planning, since, unlike the global-scale strategies and benefits of mitigation planning, adaptation impacts, strategies, and benefits are all local. In addition, adapting to extreme impacts of climate change is essentially a planning challenge, which is likely to call for public, community-wide planning and not just individual or autonomous planning (Blanco and Alberti, 2009). Traditionally, the major drivers of urban plans have been population and economic projections and existing land uses. Urban planning has increasingly incorporated natural hazard constraints into the factors considered in developing land use plans. Natural hazards mitigation planning has become a subfield in planning in the past two decades, closely connected to the emergency management community but focused on mitigating, through land use planning and regulations, communities' vulnerabilities to natural hazards (Godschalk *et al.*, 1999; Mileti, 1999; Schwab *et al.*, 2005). Plans have increasingly included the

21 Another major urban containment strategy, greenbelts are physical areas of open space, forest, or farmland surrounding a city or metropolitan area established to become permanent barriers to urban expansion.

analysis, mapping, and regulation of environmentally sensitive, or critical areas, such as floodplains, watershed areas, or erodible soils and endangered species habitats (Steiner, 2000). Planners, for example in Washington State, work with environmental agencies and scientists to prepare such analyses using "the best available science," as state regulations require (Municipal Service Research Center, 2009). In the case of adaptation planning, hazard and environmentally sensitive areas mapping can help identify urban areas sensitive to climate change impacts, such as landslide-prone areas. However, if such mapping is based on historical records of natural disasters or static conditions, it may not take into account the variability of climate change impacts (Smit *et al.*, 2000). As discussed, such mapping should be based on downscaled climate models that incorporate local conditions. For coastal cities, for example, determining the impacts of sea level rise will require more than the mapping of low elevation areas. Shoreline erosion, wetlands displacement, saltwater intrusion, and more severe storm surge flooding, as well as changes in sedimentation patterns, are other key impacts of sea level rise, which must be taken into account. Urban planners will need to collaborate with and contribute to interdisciplinary teams of natural scientists to produce the type of model-based impacts analysis required to prepare adaptation plans. Adaptation planning will challenge the urban planning profession to develop a wider knowledge-base of earth and natural sciences, and of interdisciplinary modeling methods.

Using the best available science and methods for adaptation planning is essential, because major urban planning adaptation strategies are likely to require restricting development on privately owned land. As urban areas at high risk to climate change impacts begin to experience more frequent and intense floods, or sea level rise with storm surges, or wildfires, at a certain point, as the frequency increases, land use restrictions will be required, and they will be contentious. A second set of land management adaptation strategies, less contentious, will involve changes to building codes to ensure that buildings on coastlines are elevated, or construction designs that have the capacity to withstand higher wind speeds, or require building materials, surfaces, and colors that reflect solar radiation (Stone and Rodgers, 2001; Gartland, 2008). Another set of strategies involves increasing the number of urban trees and the greening of cities to reduce the heat island effect (Schmidt and Kohler, 2008). In addition, there is a set of urban adaptation strategies that involve changes to urban infrastructures and public health, from elevating roads in coastal areas, or raising levees, to heat wave plans, as discussed in other chapters of this volume.

8.6.1 What cities are currently doing

While hundreds of cities across the world are working on mitigation plans, few local governments have developed adaptation plans. Of these, the city of London provided an early model for climate change adaptation planning. London's efforts were aided by a national program, the UK Climate Impacts Programme, which fostered research on climate change and led to the establishment of the London Climate Change Partnership (LCCP) (Blanco and Alberti 2009, p. 166). The Partnership, with strong political leadership from the mayor, generated regional scenarios, and identified strategy options for climate impacts, including temperature increases, flood risks, and water availability (LCCP, 2002, 2005, 2006). In Canada, the city of Toronto's adaptation plan is also noteworthy (Blanco and Alberti 2009, p. 166). In partnership with the city, Toronto's Clean Air Partnership (CAP) undertook a climate change adaptation program. CAP led stakeholder workshops, developed a scan of climate change impacts for the city, prepared a study of six major cities' climate change adaptation efforts, and identified a set of options for two areas of impact, the urban forest and heat, including heat's impacts on health and energy use (Wieditz and Penney, 2006, 2007a, 2007b; Penney and Wieditz, 2007).

In the USA, New York City's 2007 plan, PlaNYC 2030 (New York City Office of the Mayor, 2007), is a model of an integrated, strategic plan that incorporates both mitigation and adaptation strategies to climate change and addresses energy, sea level rise, and water resource issues (Blanco and Alberti 2009, p. 165). Both London and New York City's adaptation planning efforts benefited from scientific studies and regional modeling of climate change impacts. The New York City Plan relied on the Metropolitan East Coast (MEC) Assessment for the New York region (Rosenzweig and Solecki, 2001) funded by the U.S. federal program on climate change research, and the just-completed work of the New York City Panel on Climate Change (Rosenzweig and Solecki, 2010). NYC's MEC assessment was the only one of the 18 US regional assessments that was primarily focused on urban issues. Also in 2007, Washington State, King County, where Seattle is located, published a county climate plan that incorporates both mitigation and adaptation measures (King County, 2007; Swope, 2007). The University of Washington's Climate Impacts Group provided the scientific studies that supported the plan. King County's plan included a set of guidelines for incorporating mitigation and adaptation goals into county and city agencies' plans and policies. It also identified urgent adaptation needs, such as county roads within or close to floodplains that would be impacted by more intense storms. The county plan also incorporated steps to improve the county's capacity to undertake adaptation planning, for example, by educating appropriate county staff in climate change science, and by raising public awareness on this issue. Although the plan does not include specific implementation steps, its goal of incorporating climate change adaptation considerations in all relevant county plans and projects is farsighted (Blanco and Alberti 2009).

As indicated, the development of adaptation plans is a complex process. In addition to the World Bank guide discussed in Section 8.4, in partnership with the Climate Impacts Group at the University of Washington and King County, ICLEI (Snover *et al.*, 2007) has developed a handbook on adaptation planning. While the World Bank guide is focused on helping cities organize and develop an initial scan to determine whether a city needs to prepare a full-scale adaptation plan, ICLEI's handbook details all the steps for preparing such a plan, including tips on obtaining information, sifting and judging information, selecting

[MITIGATION/ADAPTATION] Box 8.7 Benefits of urban forests in Oakville, Canada

Eva Ligeti

Clean Air Partnership

The Town of Oakville is located on the northwestern shore of Lake Ontario, 40 km west of Toronto. Oakville is home to approximately 165,000 residents and has gained much acclaim in recent years due to its progressive approach to urban forestry. In 2005, Oakville adopted the Urban Forest Effects Model (UFORE), designed by the United States Department of Agriculture, Forest Service. UFORE studies aim to quantify urban forest structure and numerous urban forest effects in cities where randomly generated sample plots combined with local pollution and weather data measure the air quality benefits provided by trees, shrubs, and other types of vegetation. These benefits are then converted to their economic value, allowing the municipality in question to develop a business case for their urban forest. Their UFORE study has enabled Oakville to estimate the replacement value of their urban forest at Canadian $878 million (from 1.9 million trees), with carbon sequestration levels of 6,000 tons/year ($141,000) and energy savings of $840,000 annually. The amount of air pollution filtered by Oakville's urban forest is equivalent to all (102 percent) of the local industrial and commercial emissions of particulate matter (PM10) and 15 percent of PM2.5, as well as over two times (243 percent) the amount of sulfur dioxide plus other criteria pollutants. The study results give decision-makers the tools they need to manage, maintain, and balance green and gray infrastructures.

The UFORE study allowed Oakville's urban foresters to develop key action items. These action items include the development of a private urban forest stewardship education program and an incentive program for private large-stature trees in order to maximize filtration of criteria pollutants and greenhouse gases. To complement this, the creation of a pro-active under-planting program in those communities at risk of decreasing urban forest canopy cover due to aging trees was proposed. Other action items include a review of the 10-year capital forecast to ensure that operating costs for rigorous, standardized tree maintenance are captured, and a review of the Tree Habitat Design Guidelines to incorporate them into the town's urban design standards. Other policy recommendations include amending the town's Official Plan to recognize the municipal urban forest as a component of the municipality's "infrastructure" and investigate the potential role of zoning bylaws to reserve the land which supports trees. Building on the results of their UFORE studies, the town developed an Urban Forest Strategic Management Plan (UFSMP) 2007–2026. A key component of this plan is the creation of an interdepartmental/interagency technical Advisory Committee that will identify, through the UFSMP, a range of future potential urban forest canopy cover targets for Oakville and the development of a private stewardship incentive program for residents and local businesses through initiatives in order to support the potential urban forest canopy targets. The town is also investigating the feasibility of the town exchanging carbon credits.

Further information regarding Oakville's urban forest can be viewed at www.oakville.ca/forestry.htm.

scientific advisors, etc. The handbook is based on, and draws most of its examples from, the King County Climate Plan. ICLEI has started a pilot project with four cities in the USA to test out the methodology of the handbook.

8.6.2 Next steps

Adaptation planning is still a novelty. The process to conduct such planning is evolving and many cities lack the capacity to develop such plans. The World Bank's recent guide on resilient cities (Prasad *et al.*, 2009) provides guidelines for conducting a first scan of the degree of risk a city faces, and ICLEI's handbook (2007) provides guidelines for preparing community adaptation plans. Adaptation planning, however, especially for coastal cities, will require analytic and modeling work to scale down global projections to the city scale. Most cities, whether in the developed or developing world, lack this analytic capacity in their planning departments. Urban planning, as a profession, is late in recognizing its role in adaptation planning (Blanco and Alberti, 2009).[22] In addition, national and/or state or provincial level downscaling models and the data required for such models are needed to form the basis for local downscaling modeling. For example, the state of California, among several states at the forefront of climate change modeling, through its energy commission has developed regional climate models downscaled to 12 by 12 km grids (California Climate Action Team, 2009), but, to identify the sea level rise impacts for a coastal city, further analytic work is needed. A recent study of the city of San Diego's climate change impact scenarios required additional technical studies, including wave and sea modeling to develop impacts on several low-lying coastal areas in San Diego (Messner *et al.*, 2009). In general, a key constraint for effective local planning to address climate change impacts is the lack of regional/local-scale models of climate change. This is a widespread problem (Kehew, 2009), even in developed countries. In the United States, for example, the federal government's National Oceanic and Atmospheric Administration has established eleven Regional Integrated Sciences and

22 The profession is moving forward to incorporate climate change in its agenda. The most recent version of the handbook on city planning, widely used in planning schools, *Local Planning* (Hack *et al.*, 2009) includes a brief article on planning and climate change (Beatley, 2009), and recent articles in various planning journals address the topic (Wheeler, 2008; Blanco and Alberti, 2009; Wheeler *et al.*, 2009). Professional institutions, such as the Lincoln Institute of Land Policy, are beginning to publish handbooks on climate change (Condon *et al.*, 2009). In the USA, the journal of the American Planning Association will be publishing a special issue in October of 2010 on planning for climate change.

[ADAPTATION/MITIGATION] Box 8.8 Urban land use and the urban heat island phenomenon in Shanghai, China

Stephen Solecki

C. W. Post, Long Island University

Shanghai is China's largest city and one of the largest metropolitan areas in the world at 6,340 km^2 with a population of 18.9 million as of 2008 (UNEP, 2009). Rapid urbanization and expansion has produced a strong urban heat island effect. The urban heat island phenomenon has been the cause of temperatures in excess of 7 degrees Celsius warmer in Shanghai as opposed to surrounding rural areas (Hung *et al.*, 2006). The city is what is often referred to as an urban canyon, consisting of myriad narrow streets enclosed by towering buildings (EPA, 2009). As the sun penetrates down to the streets, heat becomes trapped and cannot escape. Key to reducing the urban heat island phenomenon in Shanghai is the incorporation of green practices.

MEASURING URBAN HEAT

To better understand the effects of the urban heat island, Shanghai has been monitoring urban heat intensity. Five different weather stations are set up across Shanghai and temperature readings are taken every 30 minutes at each location. Each month, temperature readings are downloaded and analyzed (Bai *et al.*, 2000). Infrared remote sensing utilizes satellites to take thermal images in order to determine precise surface temperatures. Remote sensing devices also allow the construction of a land use database for the city. Industrial, residential, green, and business areas can be distinguished. This helps experts statistically track anthropogenic heat emission levels (Bai *et al.*, 2000). Thermal infrared remote sensing has revealed that the warmest areas in Shanghai tend to be concentrated around industrial centers, such as the Pudong Steel Factory, densely populated areas, and locations that are heavily traveled (Zhang *et al.*, 2005).

MITIGATION OF THE URBAN HEAT ISLAND EFFECT THROUGH URBAN GREENERY

Shanghai has relied heavily on integrating greenery into its urban setting to reduce the heat island effect. However, the main obstacle to implementing this policy is the lack of available space. As the population of the city grows, methods of mitigation that take up little space are essential.

Increasing vegetation through an urban forestation plan has been the most successful way of reducing the urban heat island effect in Shanghai. The city's plan stresses the importance of incorporating greenbelts into downtown Shanghai within the layout of urban development (Shanghai Agriculture, 2003). By the end of 2008, the city's parks and urban green space amounted to 33,000 hectares. Urban greenery per capita has increased to 12.5 m^2 as of 2008 from 1.0 m^2 in 1990 (UNEP, 2009). The shade provided by trees and bushes reduces the heat island effect. Since the increase of urban greenery in Shanghai, the average temperature in the city has dropped by 5 percent (Saum, 2008). The strategic planting of trees around residential areas especially can cut air conditioning use, which in turn reduces electricity usage and harmful emissions that can affect the environment.

GREEN ROOFS

Green roofs have become widespread across the city. A green roof integrates vegetation into the design of a building's covering. For cities such as Shanghai, green roofs are one of the best ways to reduce urban heat. They are a form of "cool roofs" that absorb solar energy and emit more heat back into the atmosphere than traditional roofs. As an incentive, district governments in Shanghai are willing to pay for nearly half the conversion costs of creating a green roof (Olear, 2009).

FUTURE LAND USE GOALS

By 2020, Shanghai envisions 30 percent of the city being covered with greenery (ULI, 2006). The city intends to continue to increase green space by building more small parks throughout the city. Ideally, officials want residents in the city to be no less than 500 meters away from the nearest park (ULI, 2006). Parks and other green spaces will potentially be connected via a "green grid" whereby people can get from one green space to another through a direct route. By mitigating the heat island effect, Shanghai is also contributing to the global reduction of greenhouse gas emissions.

Assessments (RISA) centers, with growing capacity for regional climate change impacts modeling, but not all regions in the United States have this regional modeling capacity (Blanco and Alberti, 2009). In order to advance adaptation planning for high risk cities, consortia of universities with climate change impacts modeling capacity, relevant state/provincial government agencies, and local planning and other agencies will be needed to provide credible impacts analyses. The UCCRN provides one example of an existing science-policy partnership for cities responding to climate change.

Although most mitigation and adaptation strategies are synergistic, recent studies point to potential conflicts, e.g., the adaptation policy of restricting building on floodplains, which is likely to reduce a city's density and the mitigation strategy of compact development (McEvoy and Handley, 2006; Stone *et al*., 2007; Hamin and Gurran, 2009). These conflicts merit further study.

In addition, little attention has been paid to worst-case land use strategies, cases where land must be abandoned to sea level rise, or where future development should not be permitted or severely limited, and where existing development should be relocated due to frequent and extreme impacts of climate change. Issues of property rights and of public compensation, of plans and policies for relocation of populations, and of financing mechanisms for such relocations should be examined.

[ADAPTATION/MITIGATION] Box 8.9 Initiatives towards reducing the impacts of the urban heat island (UHI) in Tokyo, Japan

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Tokyo, home to roughly 13 million people (TMG, 2009a) and one of the world's most liveable yet expensive megacities, is struggling to conquer the challenges posed by the urban heat island (UHI) effect. As a result of rapid urbanization in the last few decades, more than 80 percent of the city's surface is covered by buildings or paved roads, which retain absorbed solar and waste heat (TMG, 2003). Similarly, 80 percent of Tokyo's rivers are either reclaimed or covered to carry sewerage (Science Council of Japan, 2003). Petrochemical and iron–steel complexes occupy approximately 25,000 hectares of landfill sites in the bay area of Tokyo (TBEIC, 2009). Studies reveal that annual mean temperature in central Tokyo has increased by about 3 degrees Celsius during the past 100 years, which is five times higher than the world average (TMG, 2003; Mikami, 2006). Increased consumption of anthropogenic energy and waste heat from buildings, altered urban built environment by way of higher density of buildings, and reduced green spaces are some of the major factors that cause excessive warming in certain pockets of the city. Notably, within the past three decades, energy consumption in Tokyo has increased by 85.3 percent (TMG, 2003). The number of nights hotter than 25°C doubled from 15 per year in 1980 to more than 30 in the 1990s. The number of people suffering from heat stroke and sleep disorders in summer is growing, while localized rainfall exceeding 50mm/hour is also increasing – a phenomenon reported to have close links with UHI (TMG, 2003; Mikami, 2006; Asaba, 2008). In 2001, Metropolitan Environmental Temperature and Rainfall Observation Systems (METROS) were installed at 120 locations citywide to further investigate the condition of the heat island diurnal change of temperature patterns as they vary with land and sea breeze circulation. Of the five largest Japanese cities, only Tokyo experienced 3 percent growth in population density over the last 5 years, resulting in amplification of UHI affected areas from the central city to the western and northern suburbs, which are surrounded by hilly terrain (TMG, 2003, 2009b).

INITIATIVES TOWARDS REDUCING THE IMPACTS OF UHI IN TOKYO

The UHI, already in discussion among climatologists in the 1980s, started appearing on the policy table of the Ministry of Environment (MoE) as "an urgent matter of concern" beginning in the early 2000s. In 2004, MoE issued the Outline of the Policy Framework to Mitigate Urban Heat Island Effects, suggesting that UHI counteractions should co-benefit and synchronize with other relevant plans of the city's revitalization and environmental projects pertaining to urban planning, transportation, and climate change, without compromising the living standards of citizens. This policy encouraged the coordination of many urban activities at local level. The Tokyo Metropolitan Government (TMG) first incorporated UHI in its Environmental Master Plan of 2002 and stated in its subsequent revision in 2008 that it aims at: reducing anthropogenic heat; improving urban structure where the UHI is significantly observed; and organizing a better wind flow in certain selected areas in the central city, as well as preventing deterioration of the present heat environment in other areas including suburbs by 2016. This landmark decision was further reinforced by doubling the budget for UHI mitigation from 10.9 billion yen in 2008 to 22 billion yen in 2009. This aims to provide funding for introducing innovative pavements that block heat and absorb moisture, roadside tree plantings, increasing greening of roofs and walls, providing saplings, planting grasses on school playgrounds, planting trees for riverbank protection, installing devices to spray mists on the streets, and so on (TMG, 2009c). In addition, land rezoning has been initiated in Chiyoda ward, which is the city's government and business district. Office workers in Chiyoda ward swell its daytime population to 860,000, which is nearly 24 times greater than the ward's registered residents (MIAC, 2000). The plan for readjustment of streets and buildings is being gradually implemented in the ward to improve the ventilation environment by securing open space for land and sea breezes to come in and heat waves to pass through. Every stage of implementation, which includes research, planning, and construction, to provide links between parks, rivers, and streets involves multi-stakeholder participation, which is already embedded in city planning. The members of the Area Development Committee are drawn from business sectors, non-profit organizations, universities and research institutions. There is also built-in flexibility in existing UHI policies to progressively incorporate new scientific findings and technological developments.

TOWARDS AN INTEGRATED APPROACH

UHI is inevitably a byproduct of urbanization. It is rather complicated to clearly determine the causes of UHI with certainty since the topographical and meteorological conditions as well as patterns of anthropogenic energy consumption differ from city to city. The long-term vision and planning along with the concerted actions of the city of Tokyo that incorporate specific local characteristics is a significant step towards mitigating UHI. Redevelopment of selected city-pockets as well as careful improvement in other areas to make the city tolerant to UHI enhances Tokyo's global competence and competitiveness among many other developed or emerging urban megacities. All efforts are carefully examined and closely coordinated with other ongoing or planned projects related to climate change, city planning, energy efficiency, urban transportation, etc. Policymakers are closely observing to what extent current pilot initiatives for UHI contribute to UHI mitigation and adaptation. Creation of policies that ensure participation of stakeholders across sectors and scales is a challenging task in an urban setting. In addition to further scientific investigation and technological development, future steps in the UHI mitigation program in Tokyo call for summing up and sharing such individual projects and actions. This will not only help to effectively implement countermeasures across Tokyo city, including its suburbs where the UHI is becoming a serious concern, but also in other cities of the world facing similar problems.

[ADAPTATION] Box 8.10 Climate change adaptation in Stockholm, Sweden

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Climate Adaptation, Department of Environment, City of Stockholm

The city of Stockholm has been working on climate mitigation issues since the 1990s. The City Council adopted its first Action Programme in 1997 with the goal to reduce the greenhouse gas emissions to the level of emissions in 1990. The city has reached a second goal of reducing greenhouse gas emissions to 4 tons per capita through various projects on sustainable transportation, energy efficiency, and renewable energy. The current goal, approved by the Stockholm City Council, is to reach a level of 3 CO_2-eq tons per capita by 2015. The long-term goal is to be fossil-fuel free by 2050.

Undoubtedly, climate change is occurring and affecting Stockholm. A hundred years from now, Stockholmers are projected to experience the following climate change impacts:

- average temperature will rise 4 to 6 degrees Celsius
- winters will be mild and the very cold winter days below −10 °C are expected to disappear
- more precipitation – more intense rain but less snow
- risk of flooding will increase, but dry summers and heat waves may imply low water levels as well
- spring flooding will come earlier or not occur at all
- growing season will be extended by one or two months and the conditions for the natural environment in Stockholm will change
- the average water level in the Baltic Sea might rise by 0.5 meters or more.

In 2000 Stockholm experienced high water levels in Lake Mälaren. Future flooding and high water levels will cause problems. With increased burdens on the sewage system, leakage from contaminated soils and increased landslide risk will occur. A more humid climate will increase the risk of moisture damage and mold forming in buildings. The heat waves might also increase risks to health.

Stockholm's many green areas will mitigate the effects of projected climate impacts, strengthening the ecosystems. Strong ecosystems can help us cope with the changing climate by absorbing great amounts of rain, evening out water flow, providing shade, and diminishing the city's urban heat island effect. The greenery will also filter contaminants and produce oxygen.

Stockholm Royal Seaport is a new development district, mainly redeveloped on existing industrial land with new, tough environmental requirements on buildings, technical installations, and transportation. A major goal is to be fossil-fuel free by 2030. By 2020 the inhabitants are to use less than 1.5 tons CO_2-eq per capita, and the third goal is focused on adaptation. The planned adaptation is to build up the ground so that all buildings are placed 2.5 meters above the average sea level. The building materials used will be required to resist high humidity. Other requirements call for greenery on roofs, walls, yards, and parks to give shade and coolness, and absorb rain and CO_2. The rainwater from roofs and yards will be directed to the wetland zone to minimize the burden on the sewage system. Great measures will also be taken to stabilize the ecosystem. Part of the Royal Seaport is a very good habitat for species connected to oak trees. Oak is extremely valuable to Stockholm's ecosystem. The planned buildings will become a barrier to the spread of different species of oak. To counter this, the city has planned to develop a corridor with oaks and other plants to help the oak-dependent species to find their way from one habitat to the other. Stockholm hopes the species will even use the corridor as a habitat in the future. The area is also a healthy habitat for frogs. To ensure the frog habitat, the seaport redevelopment will include the construction of two ponds, a tunnel for frogs, and a wetland zone. Both the oak corridor and the frog habitat measures in the seaport redevelopment will strengthen biodiversity and the overall ecosystem.

Another development project in Stockholm is the renovation of Slussen – a floodgate between Lake Mälaren and the Baltic Sea. Here the City of Stockholm is taking adaptive measures to double its capacity so that it can better manage the risk of flooding to meet climate change impacts. The goals of this renovation are to reduce the flooding risk and the risk of low water levels during dry periods. The Slussen reconstruction will also prevent saltwater leakage from the Baltic Sea. This is important because Lake Mälaren is a drinking water reservoir. The renovation will also facilitate natural water level variation to support the ecosystem along the beaches.

A Steering Committee for Climate Adaptation was formed in 2008 by the City of Stockholm. It is led by the City Executive Office and includes members of agencies for social welfare, the fire brigade, urban development, and the environment and health administrations. The City of Stockholm is going to develop a local Climate and Vulnerability Analysis with local scenarios for extreme rain events, flooding, and heat waves, and apply the scenarios to different parts of Stockholm. The local Climate and Vulnerability Analysis is going to be included in Stockholm's Risk and Vulnerability Analysis.

This will provide the city with the information needed to assemble a plan for further adaptations throughout the entire city. For instance, Stockholm hopes to:

- look over the city's plan for tree planting
- devise new guidelines on the size of pipelines for sewage water
- come up with new ways to strengthen Stockholm's ecosystem by deciding how much greenery the urban city should have in order to cope with future climate changes.

More information on Stockholm can be found at: www.stockholm.se/klimat.

8.7 Policy issues

Urban planning and management systems constitute key adaptive institutions to mitigate greenhouse gas emissions in cities and to adapt to unavoidable impacts of climate change. However, as this review has made clear, these institutions face several impediments or constraints. The following is a list of the urban policy issues raised by this review in need of further attention grouped by topic:

Governance

- *Vertical coordination among levels of government*: What are effective mechanisms for ensuring coordination and support among national, provincial, and local governments on urban growth and climate change agendas?
- *Horizontal coordination at the metropolitan scale*: What are effective governance structures for managing urban growth in metropolitan areas? The current spatial/political mismatch between metropolitan areas and their fragmented local jurisdictions permit and encourage sprawl development, an urban pattern with high greenhouse gas emissions.
- *Horizontal coordination at the local scale*: How can cities better structure and integrate their local government agencies to deal with the systemic nature of urban growth and climate change risk? Mainstreaming and climate change teams are institutional mechanisms that have been identified as effective mechanisms for carrying out effective climate change agendas. But can an integrated climate change agenda be implemented if the underlying structure remains sectoral and fragmented?
- *Inadequate legal frameworks*: How can we better conceptualize our system of land property to capture the ecological and the social aspects of land?

Planning capacity

- *Climate change modeling at regional/local scales*: There is a lack of capacity, or of adequate capacity to model climate change impacts (e.g., sea level rise, changes in precipitation) at the local and regional scales, the level which is required for local level climate change adaptation planning, even in developed countries.
- *Planning capacity for developing countries*: How can the planning capacity of cities in developing countries be expanded to effectively address their climate change risk? For cities with high climate change risks, effective urban planning and management agencies will be crucial, and yet cities in developing countries lack such institutions and/or lack sufficient pools of professional planners and administrators.

Planning and land markets

- *Role of land markets in climate change*: How can cities change the current incentive system for the "growth machine" partners and engage such partners in climate change mitigation and adaptation agendas?

Planning strategies

- *Vulnerable populations*: Slum populations in developing countries are at highest risk from climate change. What are effective strategies to upgrade and reduce slum settlements? For developing countries, this is a particularly difficult problem, given the large percentages of urban slum populations and the insufficient resources of these cities.
- *Urban growth management*: What are the new and most promising urban growth management strategies? How effective are the existing strategies, such as urban growth boundaries, farmland preservation, or requirements for adequate infrastructure?
- *Planning strategies for existing development*: In general, urban planning is future-oriented, many urban planning climate strategies can make a difference for future development, which raises the issue of low-cost ways for cities to address existing settlement patterns. What mechanisms are available for reducing risks for *existing* settlements, especially in developing countries?
- *Worst-case scenarios land use strategies*: How do we prepare, policy-wise, for worst-case land use scenarios, i.e., the abandonment of developed urban areas due to climate change risks?
- *Conflicting strategies*: Do some adaptation and mitigation strategies conflict? Based on what criteria should we make choices among conflicting strategies?
- *Financing planning strategies*: Both for developed and developing countries, what mechanisms are available for financing strategies to reduce climate change risk?

8.8 Research needs

In addition to the need to provide downscaling modeling capacity for metropolitan areas, research on several urban land topics is currently needed: urban growth modeling; urban growth policy issues; and measurement of greenhouse gas emissions in cities.

8.8.1 Forecasting urban growth

Current urban growth models focus primarily on western and developed cities in the industrialized world where socio-economic data are usually readily and widely available. Yet, since most of the urban growth in the future will occur in the developing world, it is important to develop models that are applicable in these data-poor contexts. In less developed and developing cities, socio-economic data can be non-existent, incomplete, inaccurate, unreliable, or all the above. Forecasts of urbanization utilizing such data have been severely criticized (Cohen, 2004).

There exist two basic types of land use change models: regression-based models and transition-based models. Regression-based models aim to establish functional relationships between land use change based on historical land use data and a set of predictor variables that are used to explain the locations of future land use change on the landscape. These models use different methods to build prediction functions, including linear/logistic regression (Theobald and Hobbs, 1998; Fragkias and Seto, 2007; Arai and Akiyama, 2003) and artificial neural networks (Pijanowski *et al.*, 2002). One advantage of regression models is that they can explicitly express the effects of each predictor (spatial variables) on future land use change (Pijanowski *et al.*, 2002). Spatial transition models are characterized by transition rules, neighborhoods, and decision-makers – often called agents – within a cell. They differ from regression models in that a group of simple rules that express land use change patterns and neighborhood effects (e.g., spatial adjacency) can be incorporated to drive the prediction of land use change. Cellular automata (CA) and agent-based (AB) models have become increasingly popular tools for modeling urban growth (Batty and Xie, 1994; Clarke *et al*., 1997; White and Engelen, 1997; Clarke and Gaydos, 1998). Many transition models have been developed over the last 20 years, but they retain a number of limitations. First, many models have significant data input requirements, limiting their utility in developing countries where data are usually sparse (Fragkias and Seto, 2007). Second, CA-based modeling techniques are still far from being mature. Despite their flexibility, there are many limitations to CA models (Torrens and O'Sullivan, 2001) and more research is needed for such models to capture the richness of urban systems.

8.8.2 Urban growth policy research

Similarly to other public administration functions, urban planning research is not well funded by traditional national research foundations. In the USA, for example, there are no urban planning or urban management research funding categories in the National Research Foundation, although NSF has over the past decade or so funded a number of interdisciplinary projects on urban land cover/land use. In particular, there is lack of funding for conducting adequate research on many of the complex policy topics identified in the section above, such as the effectiveness of urban growth strategies, or effective models of metropolitan organization.

8.8.3 Standard measurement of climate change data at the city scale

Although climate change is monitored at global and national levels according to an adopted set of measures globally agreed upon, similar statistics are rarely collected at the city level, and devising indicators on climate change at the city level is proving difficult. Several research challenges remain: a credible and globally standardized measurement for how cities impact climate change; city mitigation targets based on sound research; data on climate change impacts by category of risk and degree of vulnerability at the city scale. The World Bank's Global City Indicators Program (undated) is making progress in this area. The program has various indicators that can assist cities with climate change mitigation strategies, including for example indicators on modal shifts from road transport to rail and public transport and non-motorized transport. Indicators on cities and greenhouse gas emissions are under development that can help to create a standard and globally recognized index on cities and greenhouse gases. The program also has a pilot program that compiles indicators by cities according to their political boundaries and then aggregates these data across the area municipalities to obtain metropolitan measurements.

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