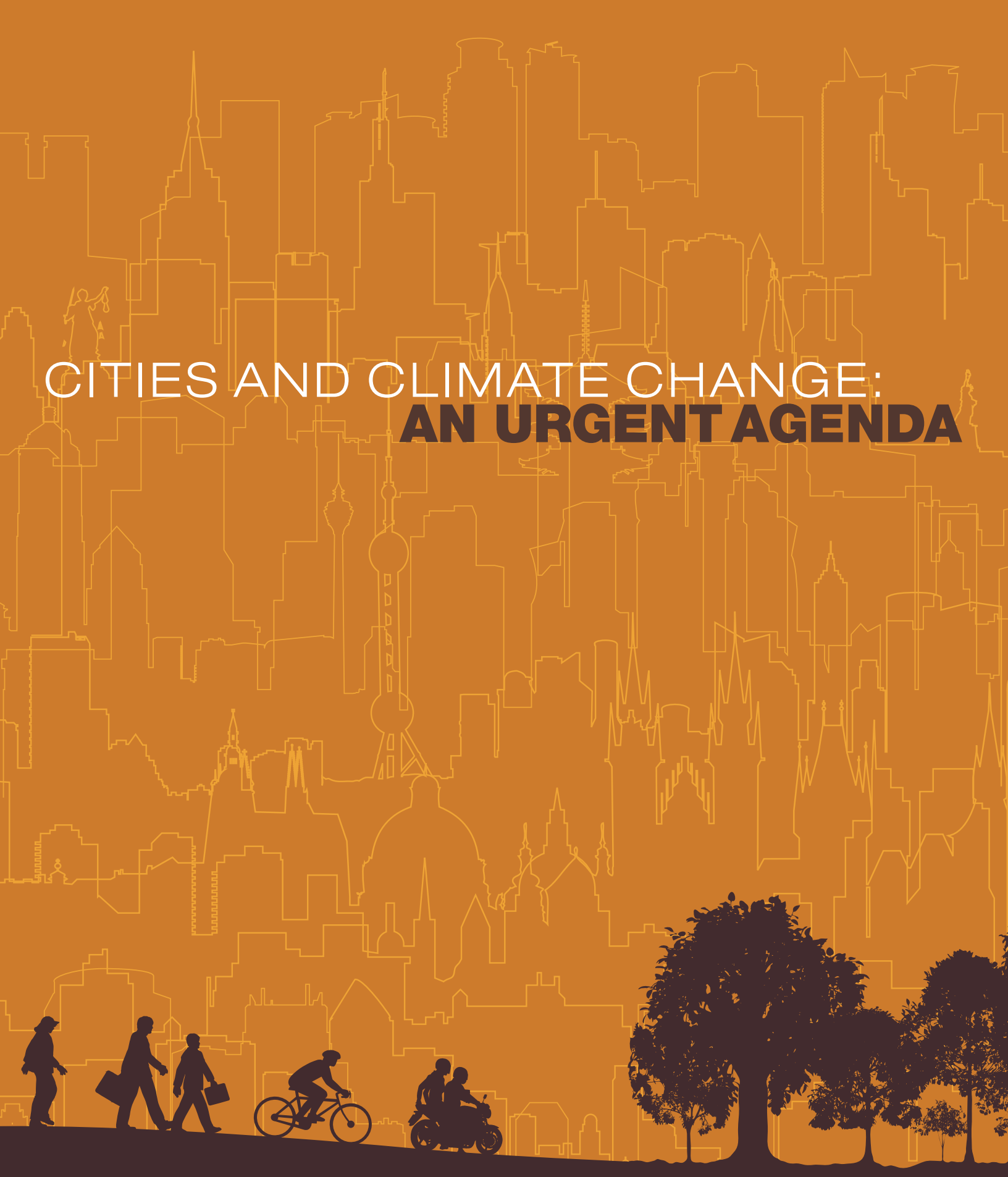
CITIES AND CLIMATE CHANGE:
AN URGENT AGENDA



THE WORLD BANK

URBAN DEVELOPMENT
& LOCAL GOVERNMENT

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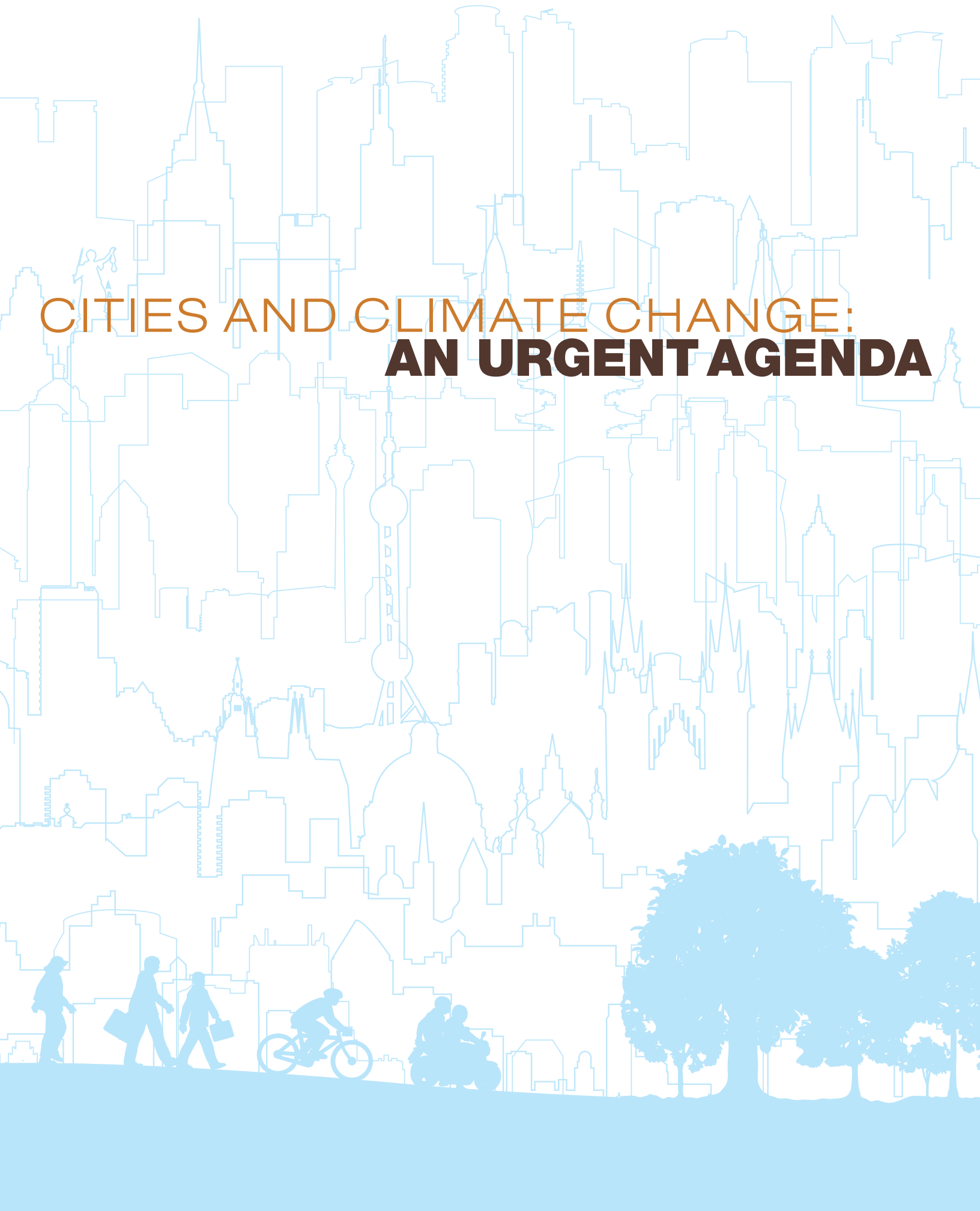

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Foreword

Climate change is affecting cities and their residents, especially the poor, and more severe impacts are expected as climate extremes and variability increase. Cities are often already overwhelmed by the number and complexity of services they need to provide. Adding climate change mitigation and adaptation to the other challenges facing cities is an enormous burden; and at the same time cities must accommodate another three million new residents every week.

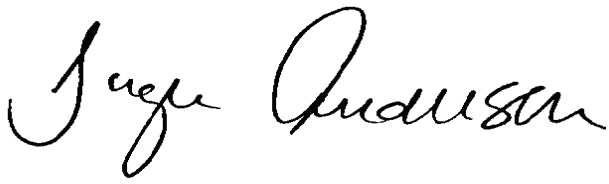
Cities also present enormous potential as the world's economies and wealth generation are anchored to cities. Many countries and cities are taking advantage of urbanization, building on this economic growth. Sustainable development can only be built upon sustainable cities.

Building cities that are green, inclusive and sustainable should be the foundation of any local and national climate change agenda. This requires better management of cities, mobilization of a global array of stakeholders, additional financing, and strengthened partnerships, as well as specific sector policy reforms such as urban transport policies, sustainable city planning, and enhancing city resilience and energy efficiency.

Decisions taken today lock in the futures of many cities. The infrastructure of 2050 is being built today, yet the world of 2050 will be very different from today. Cities will be home to another 2 billion residents, many of whom are likely to be stressed by uncertain conditions with regard to food and water availability, health and education, and employment opportunities. Paying attention to these vulnerabilities today will help cities to reap future benefits and impart greater confidence and economic dynamism to the urban population.

The Urban and Local Government Development Unit of the World Bank is pleased to present this first report on cities and climate change. The report discusses the link between climate change and cities, why cities should be concerned about climate change and adopt early preventative policies, and how the World Bank and other organizations can provide further support to cities on climate change issues. The report is one in a series of activities that explore the nexus of cities and climate change. Others include a note on climate finance, the Mayors' Task Force on Urban Poverty and Climate Change, the Urban Risk Assessment, and the Mayor's Handbook on Adaptation. The report provides a partial list of what some of the World Bank's key partners are planning in this area as well, including OECD, ESMAP, C40, Clinton Climate Initiative, UNEP, UN-HABITAT, Metropolis, the Climate Group.

The scale and urgency of climate change and cities mandates that we act differently, we act together, and we act now.



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Introduction

This report, *Cities and Climate Change: An Urgent Agenda*, focuses on three broad issues pertaining to cities and climate change. How cities contribute to and are affected by climate change. How policy makers can use cities to change human behavior and improve technology related to climate change. How cities should use climate change as an opportunity to raise their profile, reinforce sensible policies, and move toward a more sustainable community and planet.

Cities are often seen as contributing to environmental degradation and represent immense ecological burdens. However, cities can also be models of environmental efficiency, because increased density and better management reduce the cost of service delivery, promote innovation, and enable prosperity through economic development. Sustainable cities[1] are the best option to provide a quality of life while reducing net pollution such as greenhouse gas (GHG) emissions. At the political level, cities are credible laboratories of social change with sufficient scale to bring about meaningful actions. At the economic level, the world's 50 largest cities alone have a combined gross domestic product (GDP) of $9.6 trillion, more than all of China, and second only to the entire U.S. economy. Cities offer dynamism, scale, stronger linkages, and a greater sense of urgency among residents and their local leaders.

Cities have the unique ability to respond to a global issue, such as climate change at a local, more tangible level. They usually offer more immediate and effective communication between the public and decision makers than other groups can. Cobenefits of climate change mitigation and adaptation are largest in cities.

This report presents an urgent situation. In rapidly growing cities, especially in Asia, current development paths are locking in emissions and lifestyles. Many people, particularly the poor, are already affected by climate change. The next decade will be particularly challenging. Cities will take a more active role in global dialogues and policy development as citizens demand more comprehensive and immediate responses from all levels of government.

This report is organized into five parts. Part **1 sets the stage** with a summary of the main messages of the World Development Report 2010: Development and Climate Change, including the consensus on expected climate change, actions needed to cope with the challenges, and how cities can contribute to that overall agenda. The scenarios are somber and underscore the magnitude of effort needed to awaken people and governments to the consequences of ignoring early signals and failing to take preventive measures.

Part 2 **analyzes the impact that climate change has on cities** and highlights at-risk coastal cities and particularly poor cities or neighborhoods within a city. In these situations, prognostications can be highly emotive and at times sensationalized. Probabilities and risk analyses are needed to guide policy makers in making such decisions as to how much a possible disaster will cost, how much should be insured, and how much should be spent now to prevent future catastrophes. The disaster risk reduction community has evolved enormously in the past five years. This expertise can help with the analytical framework on how to address growing uncertainty, prevention, and targeted programs for the poor who will be affected the most. The Urban Risk Assessment (URA) recently launched by the World Bank in partnership with United Nations Human Settlements Programme (UN-Habitat) and

[1] A "sustainable city," as defined here is an urban community committed to improving the well-being of its current and future residents, while integrating economic, environmental, and social considerations.

United Nations Environment Programme (UNEP), and supported by Cities Alliance, is discussed here. The URA lays out a comprehensive methodology for cities to assess both increasing risk from climate change, along with their already full agenda of current disaster risk reduction efforts and improved provision of basic services, especially to the poor.

Part 2 **also explains why climate change is an urgent issue for cities.** Given that the climate is a global good, it is difficult to put a price on agents who refuse to take actions to reduce emissions. Regulations are widely used, but the policy debate on who should pay for what, and when, has confounded the public debate for too long.

This paper argues that climate change is an urgent agenda for cities for two reasons. First, climate change is a cumulative process. The longer one waits to reduce GHG emissions, adopt energy efficient systems, or retrofit buildings, the steeper is the curve and the harder to reverse the trend. This is true for the world as a whole (see WDR 2010), and particularly for cities. Pollution will only get worse, congestion more intractable, and urban heat islands more pernicious. "Act now" seems to be the only plausible response.

Second, embracing the climate change agenda now makes eminent sense from an individual city's perspective, be it economic, social, or political. It shows that the city is part of the global sustainable development agenda. By belonging to a "green cities" club, the city is branding itself as progressive, responsible, and intelligent. This so-called green cities club need not be limited to richer cities. Additionally, climate change policies lead to lower energy costs, ensure a higher quality of life (for example, improved air quality, increased walkability with density, more parks, and fewer cars), and attract more human capital and private investment (such cities as Vancouver, New York, and Barcelona).

Part 3 **discusses the contribution of cities** and urban agglomerations to GHG emissions, which naturally vary according to the economic development of the city, its energy base, and overall efficiency of resource use. The discussion is rooted in a basic understanding of urban metabolism including energy production and consumption at the city level. Affordable alternatives are proposed, with possible incentives and pricing regimes to promote a shift to energy efficient or green cities. Concepts and definitions are presented to help move forward discussions on standards and measurements to monitor performance and facilitate rudimentary comparability and policy development.

Part 4 **discusses why most cities have been slow to join the "green cities" club** and which incentives would help to spur action. Finance, inertia, political factors, and culture mix to delay decisions on urban design, choice of urban transport, land policy and densification, and building codes. This section reviews how cities take decisions in this critical but difficult sector. The reasons for lack of action are discussed along with what actions could be taken to enhance the interests of cities in the green agenda. The chapter reviews traditional ways to finance green investments in cities as well as new options, such as private sector partnerships in smart grids, and involving citizens within a participatory strategy. "Green cities" are defined synonymously as a precursor to sustainable cities.

Part 5 **summarizes how the Bank and the international community could help.** Cities have always led the environmental movement. An example is London's need for clean water in the early 1800s to escape cholera and its efforts to reduce deadly smog. Moreover, the United States Environmental Protection Agency (EPA) was developed largely to help provide clean water and air to cities. The Cayahoga River in Ohio catching fire catalyzed this action. Although cities are now facing environmental threats of a more global scale, they will again be the main catalyst to bring about local and global environmental leadership. Local clean air initiatives were the first outcomes of increasing concern about urban environments. Cities learned to assess their local environmental imperatives, develop strategies,

urge national governments to act, and monitor progress. Shared responsibilities were defined and monitored. Climate change strategies draw from those early experiments. They integrate dialogue from the city, to the state or province, to the country, and to the wider global community.

Cities and Climate Change: an Urgent Agenda is an expansion of an internal document that contributed to the *2010 World Development Report: Development and Climate Change*. This extended report presents a proposed agenda for the World Bank in moving forward on the cities and climate change agenda, in addition to showing how cities and climate change are inextricably linked. The report highlights recent work of the World Bank on cities and climate change, such as the Eco2 Cities Program, GHG Standard, City-wide approach to carbon finance, Energy Sector Management Assistance Program-Energy Efficient Cities Initiative (ESMAP-EECI), and the Global City Indicators Program. It outlines how these initiatives are related to each other, and how they link with and reinforce efforts by key partners, such as UNEP and UN-HABITAT. Where possible, gaps are noted and suggestions for a plan forward are proposed.

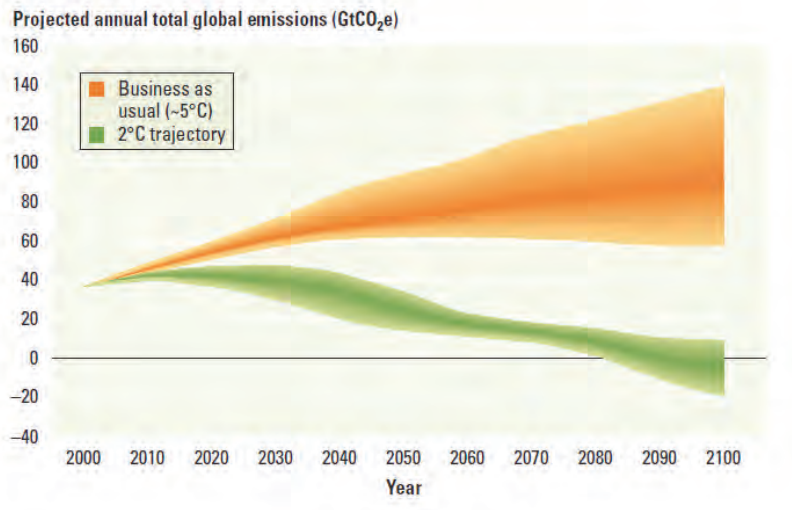
PART I
The Challenge

"Tackling the immense and multidimensional challenge of climate change demands extraordinary ingenuity and cooperation. A climate-smart world is possible in our time – yet, affecting such a transformation requires us to act now, act together and act differently." (WDR 2010).

The 2010 World Development Report (WDR) on Development and Climate Change sets out a global overview of climate change and its implications for development.

Although scientists may differ on the pace of climate change, and economists may argue about the optimal maximum mean temperature increase, they agree that climate change is happening now, that anthropogenic emissions are contributing to this climate change, and that humanity can dramatically mitigate the impact of climate change by seriously reducing greenhouse gas emissions (Figure 1). The call of WDR 2010 is, therefore, extremely pertinent. We need to act now, act together, and act differently.

Figure 1
Business as Usual versus Aggressive Mitigation



Source: World Bank 2009b.

Five Main Messages of the WDR 2010 stand out:

- Climate change threatens all countries, with developing countries being the most vulnerable. Developing countries are likely to bear 75 percent of the costs of damages produced by climate change. Even a 2 C warming above preindustrial levels could result in permanent GDP reductions of 4 to 5 percent in Africa and South Asia.

- Economic growth will not be able to counter the danger of climate change, especially if growth remains linked with increased emissions and accelerates climate change. We need climate-smart policies that will enhance development, while reducing vulnerability, and financing the transition to low-carbon growth paths.

- Climate-smart growth requires the following:

  - **Act now.** This is essential or options that exist now will disappear and costs will increase as the world commits itself to high-carbon pathways and largely irreversible warming trajectories. Even if we keep climate change to 2°C above preindustrial levels, an "energy revolution" is needed.

  - **Act together.** This is key for adaptation and mitigation and keeping the costs down, to protect the most vulnerable, and to open space for developing countries to grow.

  - **Act differently**. In the next few decades, the world's energy systems must be transformed so that total global GHG emissions drop 50 to 80

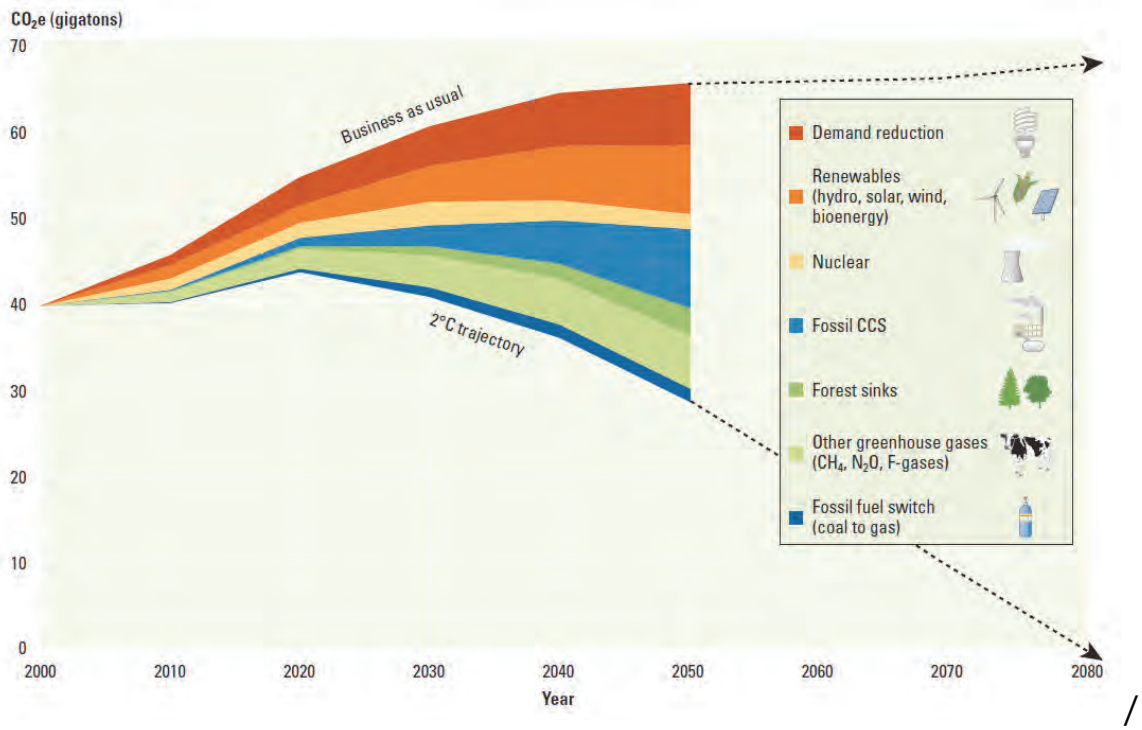


Figure 2
Getting to a 2-Degree Trajectory

Source: World Bank 2009b.

percent. This brings challenges at all levels, for example, the agricultural sector needs to feed an additional 3 billion people, and cities need to house another 2 billion people.

But how to do it? If financing is available, can emissions be cut sufficiently deep without sacrificing growth? The WDR 2010 shows that this is possible (Figure 2). Higher energy efficiency, management of energy demand, and large deployment of low-CO_2 emitting electricity sources could produce half of the necessary reductions.

Another key component of cutting emissions is rethinking energy pricing. Variation in pricing explains why European emissions per capita (10 tons of CO_2e) are less than half those in the United States (23 tons). In a world that suffers from market failures, high transaction costs and financing constraints, norms, regulatory reform and financial incentives are also needed to reduce emissions (World Bank 2009b).

- We need a global climate deal. Developing countries will need assistance both to finance adaptation requirements as well as to access low-carbon technology that will allow them to grow without drastically increasing carbon emissions. Current financing for adaptation and mitigation is less than 5 percent of what will be needed annually by 2030. But innovations in financing should help fill the gap.

- Success hinges on changing behavior and shifting public opinion. "Although an increasing number of people know about climate change and believe action is needed and urgent, too few make it a priority and many fail to act when they have the opportunity" (WDR 2010).

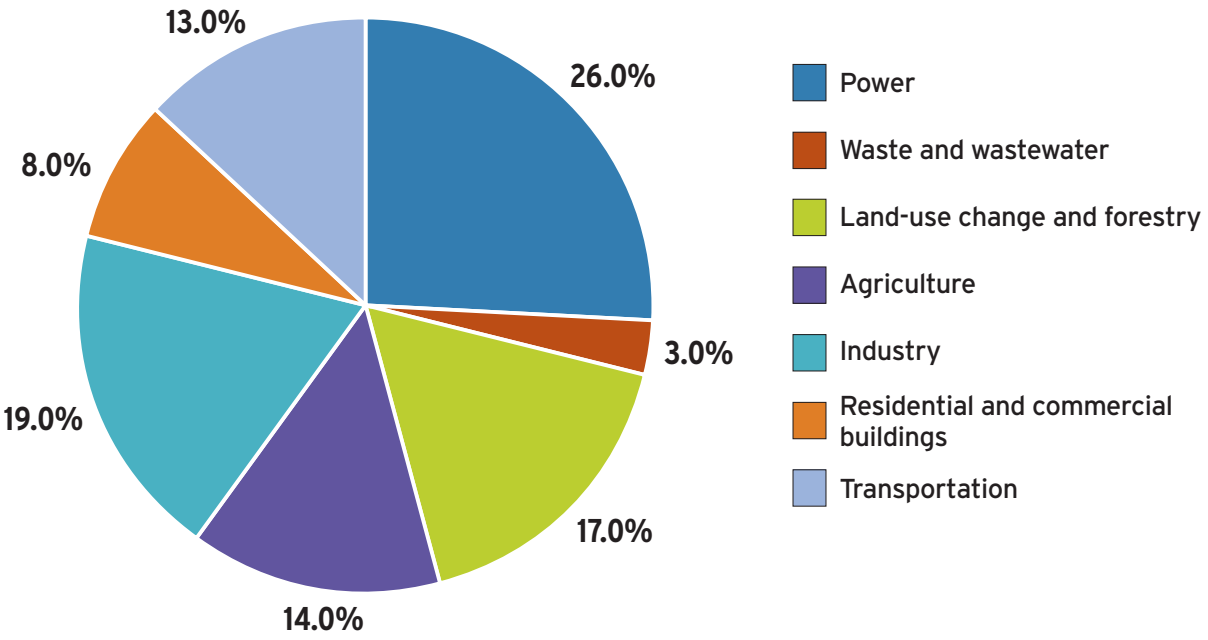
The impacts of climate change are already evident. According to the latest Intergovernmental Panel on Climate Change (IPCC) report, the average global temperature has increased by 0.76°C and sea level has risen by 17 cm since the 19th century (IPCC 2007).

In addition to changes in mean climate conditions, climate change will also bring about alterations in climate variability and extreme events. Impacts can

vary on temporal and geographical scales, ranging from drought to flooding, more heat waves, and an increase in the frequency and intensity of extreme weather events, such as cyclones. Indirect impacts, such as decreases in food production, freshwater availability and ocean acidification, will also affect global economic growth and standards of living. In terms of food production, the World Bank (2009b) argues that "*even under the most conservative climate projections, the net cereal production in South Asian countries is likely to decline by 4 to 10 percent by the end of this century.*" Unfortunately, developing countries will disproportionately bear the consequences of climate change because they are more exposed, less resilient, and generally have lower adaptive capacity to climate hazards (World Bank 2009b).

Climate change is caused by the emission of greenhouse gases. The Kyoto Protocol identifies and regulates six major GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbon, and sulphur hexafluoride. These are released by anthropogenic activities, the most significant of which are power generation, wastewater treatment, landfills, and fuel for transportation. Power generation for electricity, heat, and industrial activities makes up the bulk of emissions. This is followed by land use changes (for example, deforestation and burning), agriculture (including fertilizer use and livestock), and transportation (fossil fuels for automobiles) (see Figure 3).

Figure 3
Global CO_2e emissions by sector



Source: World Bank 2009b.

BOX 1

Cities and Climate Change: A Perspective

Arguably, climate change is not the most serious environmental issue facing cities today. Biodiversity loss and nitrogen pollution exceed safe planetary limits, even more than climate change, as shown in the figure below. In many World Bank-client cities, poverty is a more pressing and vexing problem than climate change. Climate change is, however, a global problem with unprecedented complexity, urgency and scope that requires cities and other levels of government and stakeholders to work together in new ways.

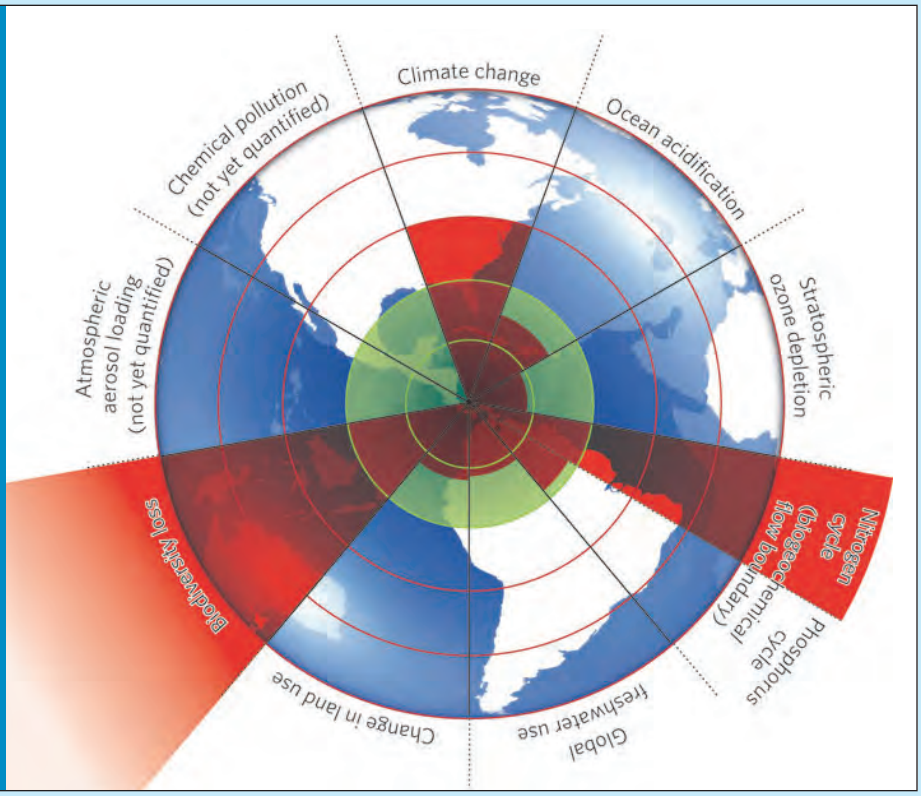
On one hand, residents of cities, especially the rich, are the largest contributors to climate change and will be required to adjust their current lifestyles. On the other hand, climate change will affect most residents of cities, particularly the urban poor and vulnerable.

Climate change is inextricably linked to urbanization. Urbanization, as well as the increased connectivity and economic growth it brings, is the world's most important phenomenon. Social interaction, quality of life, and the changes urbanization brings are now moving rapidly. For example, 80 percent of the scientists, engineers, technicians, and physicians who ever lived are alive today—almost all of whom live in cities (Cetron and Davies 2010). These knowledge workers are constantly exchanging ideas across the Internet, by phone, and in technical conferences and publications. This knowledge grows exponentially: all the technical knowledge today represents only 1 percent of the knowledge that will be available in 2050.

A change in typical problem-solving behavior by cities and countries is a critical aspect that climate change is driving. Just as knowledge workers need to embrace continuous learning (and action), so too do cities. Problems, and opportunities, facing cities will grow in urgency and complexity. How cities respond to climate change will provide critical insight into responding to other complex issues over the next 40 years.

Exceeding the safe operating space in global environmental systems.

The green circle above represents the proposed safe operating space for each system. Red shading denotes an estimate of the current status of each. The rate of biodiversity loss, climate change, and human interference with the nitrogen cycle are far beyond the safe operating space (Rockstrom et al 2009).



PART II
The Impact of Climate Change on Cities

Cities are particularly vulnerable in that they are immobile. Such infrastructure as bridges, subway systems, buildings, and roads, the historic sense of place, and rootedness of residents are critical attributes of cites. These strengths of place can, however, become liabilities if the local ecosystems that they are based on are unable to adapt to the climate-induced changes. Climate change poses serious threats to urban infrastructure, quality of life, and entire urban systems. Not only poor countries, but also rich ones will increasingly be affected by anomalous climate events and trends (World Bank 2010b).

In 2003, more than 70,000 people died in Europe from a severe heat wave (World Bank 2009b; Dhainut et al. 2004). These kinds of extreme events will increase in coming years. The deaths were also considered a harbinger as the victims were disproportionately elderly. This acute vulnerability of the elderly, children, and infirm is even more pronounced in the cities of developing countries. The effects of climate change are especially unfair as those most unable to adapt, and those who contributed least to the problem, will be harmed the most.

Cities are highly vulnerable to the disruption of critical supplies. During medieval wars, for example, a primary tactic of armies was to prevent water and food from entering cities under siege. In recent times, the dependency of large cities on food imports has dramatically increased. London imports more than 80 percent of its food from outside the United Kingdom. Food distribution, energy provision, water supply, waste removal, information technology, and susceptibility to pandemics are all the Achilles heels of cities. Social unrest from shortages and price spikes of key commodities, mass migration, high unemployment, terrorism, geophysical and climatic disasters also threaten cities. Climate change exacerbates these current threats.

Climate Change and Coastal Cities

Traditionally, cities were located near rivers and oceans for transportation and connectivity purposes. This natural geographic advantage is now increasing vulnerability of cities as sea levels rise and wind storms increase in severity and frequency. In Europe, 70 percent of the largest cities have areas that are particularly vulnerable to rising sea levels, and most of these cities less than 10 meters above sea level. Port cities in developing countries — such as Kolkata, Shanghai, and Guangzhou — are as vulnerable as such cities in developed countries —Rotterdam, Tokyo, or New York City. China alone has more than 78 million people living in vulnerable low elevation cities; this number is increasing annually at 3 percent (McGranahan et al. 2007).

Approximately 360 million urban residents live in coastal areas less than 10 meters above sea level and are vulnerable to flooding and storm surges (Satterthwaite and Moser 2008). Fifteen of the world's 20 megacities are at risk from rising sea levels and coastal surges (Figure 4). The IPCC predicts a rise in average sea level over the next 100 years ranging between 13 to 28 centimeters in a low scenario and 26 to 59 centimeters for a high scenario (IPCC 2007).

Planning in a regime where up to a 60 centimeter increase in sea level during the next 100 years is possible poses enormous uncertainty. Long-lived infrastructure, such as flood protection works, major transportation systems, large-scale energy plants (which are often located near cooling-water sources), are designed with service-lives in excess of 60 years. For example, subways, sewers, bridges, and other major infrastructures in London, New York, and Paris are more than 100 years old. Building similar infrastructure in Shanghai, Jakarta, Bangkok, Rio de Janeiro, and others to account for likely sea

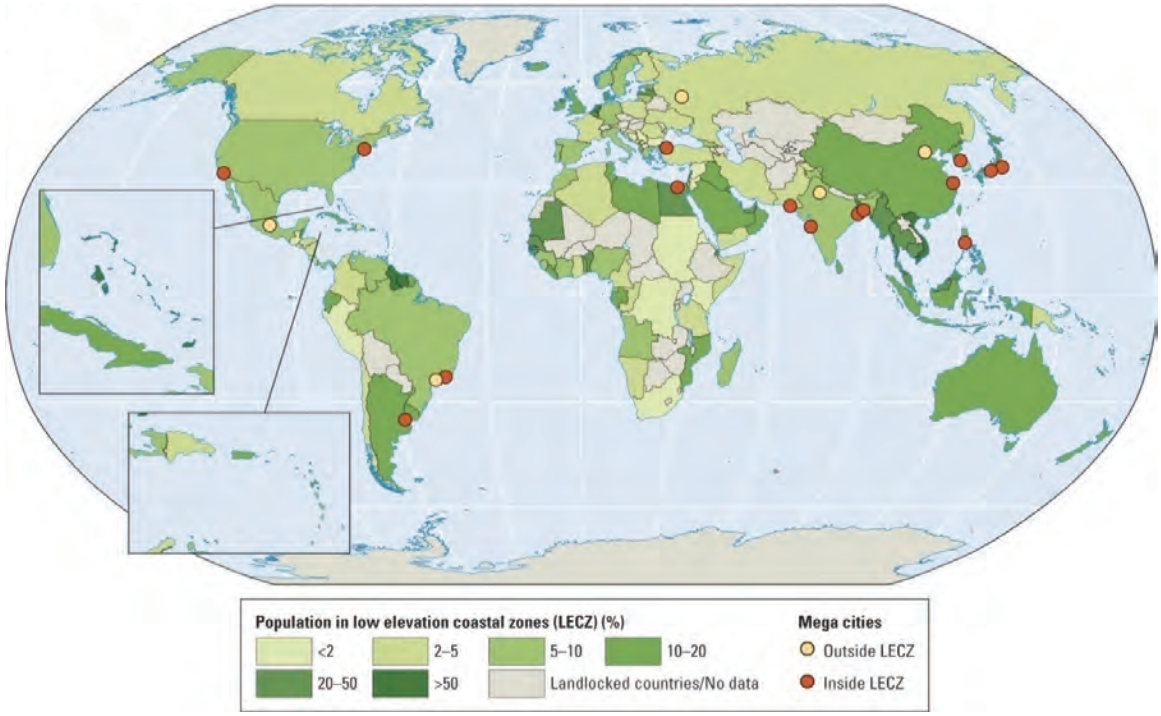


Figure 4a
At Risk: Population and Megacities Concentrated in Low-elevation Coastal Zones (LECZ) Threatened by Sea-level Rise and Storm Surges

Source: World Bank 2009b.

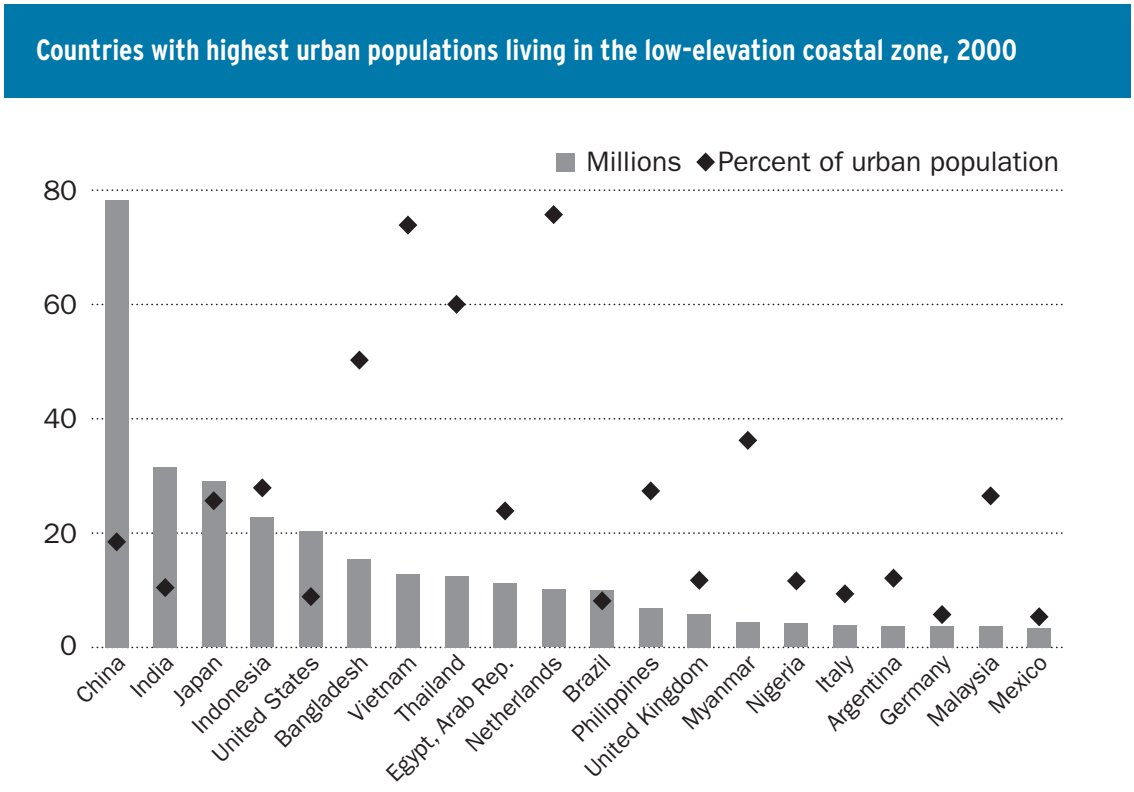


Figure 4b
Urban Populations in LECZ Zone

Source: CIESIN 2007.

level increases adds further complexity to an already challenging environment.

An even more difficult issue, and one that is rarely mentioned in the literature, is the possibility (and potential desirability) that some cities and their national governments will assess the need for relocation and potential abandonment of key infrastructure and areas prone to flooding. This would represent one of the largest losses of value in land and infrastructure and the largest transfer of economic wealth in human history. Tensions will grow as specific land owners and residents demand increasingly costly infrastructure hardening, while others push for less costly shifts in habitation. The complexity of flood protection in New Orleans is an important early window on future city development.

Cities now concentrate large numbers of the poor who are especially vulnerable to climate change. Poor city residents tend to locate in the most vulnerable locations and housing construction materials are not robust. The consequences of surging seas, wind storms, and flooding are much more dramatic in these areas.

How to Deal with Adaptation Issues

Although climate change will bring about gradual change over time in some parameters (for example, mean annual temperatures and mean sea levels), it will also produce changes in extreme events (for example, a greater number and intensity of cyclones, heat waves, and flooding) in many locales. Responses to such extreme events need to build on current experiences in disaster risk reduction. Climate change will place an even higher premium on municipal capacity and management structures. Existing disaster reduction experience has shown that social capital is a critical aspect of all urban communities. Cities with strong social networks often have support systems that can aid in recovery from natural disasters and slower onset challenges, such as high heat, changing weather patterns and lack of water. It is an enormous challenge to grow these networks as they are increasingly stressed.

Cities are complex systems where service delivery mixes with robust infrastructure and social and political factors that determine much of the success or failure of social and economic policies. The best way to deal with city complexity in the face of serious climate change is to improve the city's resilience. Building resilience can, however, be difficult, while reducing it is all too easy.

New Orleans and Hurricane Katrina provide important lessons where resilience was compromised:

- Military personnel were not available as many were posted overseas
- Levees were weak
- Communications and responsibilities were unclear
- Recovery (pumping of water) was delayed, leading to more mold and hardship;
- The rebuilding process was hampered by limited access to credit because of the U. S. housing collapse
- Preparedness was limited in some areas, for example, local buses and vehicles could not be quickly commandeered for the evacuation

Building resilience in a city requires a systems, or integrated, approach. An 'ecosystems approach' can provide a useful context. A few key initiatives can yield large results. For cities, these include (i) robust decision making (incorporating broader-based cost and benefit assessments that include societal values, ecosystem services, risks, and longer time horizons); (ii) buttressing of key infrastructure (e.g. increased robustness of water and power supply systems); (iii) social inclusion (ecosystems abhor extremes, for example, pronounced differences between rich and poor); (iv) urban risk assessments (see Box 2); (v) emergency preparedness (practice, know where the risks are likely, make this information public); (vi) partnerships with other cities, agencies, and governments; (vii) greater adaptive capacity through buildings and critical infrastructure to withstand increased climate variability, for example, metros; (viii) reduced social tensions; (ix) where practicable,

and cost effective, streamlining of key services and infrastructure; and (x) protection and integration of key ecosystem services

There is a significant distinction between climate change mitigation and adaptation. Mitigation efforts aim to prevent further climate change. Adaptation involves readjusting life to the reality that a certain amount of climate change will inevitably occur. An effective climate change policy for cities however needs to include both, and they need to be approached in an integrated manner.

Major difference between mitigation and adaptation is the scale of their effect and the associated costs. Adaptation will have impacts primarily on a local scale: actions are based on specific needs of the affected regions. Costs might be very high, especially in large-scale infrastructure such as flood protection works, roads, ports, and power generation facilities. The cost savings from adaptation efforts mainly accrue through reduced risk impacts (for example, insurance) often at an individual homeowner, business, or community level.

Mitigation is a global effort requiring broad changes of behavior and technological advancements. Mitigation strategies are usually expensive in the short term, because they are capital intensive (change in technology, urban transport, and collective infrastructure) and require fundamental changes to urban systems. Over time, the cost of mitigation is generally self-financed through cost savings (mainly in energy bills).

Cities need an integrated approach that considers mitigation, adaptation and urban development. The improvement of city services is related to the ability of cities to adapt to climate change and reduce their greenhouse gas emissions. Cities with excellent services are generally resilient cities:

- Advanced drainage systems can alleviate flooding during intense storms
- Healthcare services are equipped to respond to emergency situations
- Warning systems and transportation infrastructure allow citizens to evacuate in response to risk

As cities develop, it is essential to evaluate infrastructure and service improvements through a climate change lens so as to promote long-term mitigation, adaptation, and poverty alleviation.
Cities that focus on provision of basic urban services to the poor tend to do so in an integrated manner that follows a simple hierarchy. Adaptation to, and mitigation of, climate change should follow a similar integrated city-wide approach: (i) fully providing basic health and environmental services (and primary education); (ii) encouraging and enhancing the resilience of community organizations; (iii) improving building quality, particularly residential; (iv) avoiding development in hazardous or sensitive areas; (v) protecting buffering capacities of local ecosystems and minimizing degradation (for example, groundwater, mangroves, and wetlands); (vi) ensuring food security (for example, evaluating relevance of local agriculture provision); (vii) ensuring the security and resilience of water supply (and quality) and energy provision; (viii) strengthening city-wide security nets, resilience planning, and effective public information; (ix) providing and regularly updating publicly available land-use or development plans; (x) effectively integrating migrants and other marginalized groups; (xi) increasing energy efficiency of buildings and transportation; (xii) identifying and, where possible, ameliorating local climate impacts such as 'urban heat islands'; (xiii) participating in regional and national programs to increase resilience; (xiv) enhancing local economies; (xv) switching to low consumption lifestyles; and (xvi) participating in global policy dialogues (for example, city-influence on national and international policies, such as agriculture and energy subsidies and UNFCCC negotiations).

The above hierarchy suggests that the most important form of city adaptation to climate change is to push for progress on the Millennium Development Goals, especially providing potable water and sanitation and reducing the number of people living in slums.

Table 1
Benefits of Combining Mitigation, Adaptation, and Development

City	Action	Integrated Value
Mexico City, Mexico[(i)]	Infrastructure improvements for water supply pipes to reduce water losses and leaks	-Increases water supply -Reduces vulnerability to lack of water -Increases access of basic services to the poor
Dar el Salaam, Tanzania[(ii)]	Coastal and marine conservation project to plant mangrove trees along the coast	-Sequesters carbon via mangroves -Protects the city from storm surges -Maintains a healthy coastal ecosystem
Bogota, Colombia[(iii)]	Urban agriculture program	-Reduces transportation costs to deliver produce to cities -Reduces the need for fertilizers, pesticides, and large agro-systems -Provides a supply of food during disasters -Provides employment and is a source of food to poorer sections of society -Prevents settlements in high-risk areas such as slopes and coastal areas
Makati City, The Philippines[(iv)]	Major citywide tree-planting program, where 3,000 trees are planted each year	-Sequesters approximately 25,000 kg of CO_2e/year in GHG emissions -Reduces atmospheric pollution -Reduces the urban heat island effect -Provides recreational space
Lviv, Ukraine[(v)]	Energy efficiency program for buildings	-Reduces energy consumption for buildings -Reduces energy costs -Makes buildings, and their occupants, better able to withstand extremes in temperature and precipitation

[(i)]Summary of Mexico City Climate Action Program: 2008-2012, Secretaria del Medio Ambiente, Gobierno Del Distrito Federal.
[(ii)]Community Infrastructure Upgrading Programme-Get to know the Programme currently implemented in Dar es Salaam City, Tanzania (2005-2010).
[(iii)]Resources Centres on Urban Agriculture and Food Security (RUAF).
[(iv)]Climate Resilient Cities, World Bank: 2008 Primer.
[(v)]Energy Efficient Cities Initiative Practitioners' Roundtable. Workshop Proceedings Series. World Bank - ESMAP. Nov. 2008.

A growing number of cities are addressing climate change in an integrated approach. Table 1 lists projects in five cities that are addressing mitigation, adaptation, and development.

Cities have always had to respond to the vagaries of their local climate. Climate change as brought about by anthropocentric greenhouse gas emissions will likely be greater in complexity and scale. Cities need to integrate climate change within an already full agenda of basic service provision, usually with insufficient funding.

Climate change forces an even more urgent imperative to move toward sustainable cities. Sustainable cities are the foundation of sustainable development; they drive local and global economies, protect the poor, and build in increasing adaptive capacity. The Melbourne Principles for Sustainable Cities[2] are a practical foundation to highlight how local actions, when magnified globally, lead to substantial results.

[2]The Melbourne Principles were adopted at the Local Government Session of the Earth Summit 2002 in Johannesburg, as part of the final communiqué, known as Local Action 21 or the Johannesburg Call. They consist of 10 statements on how cities can become more sustainable.

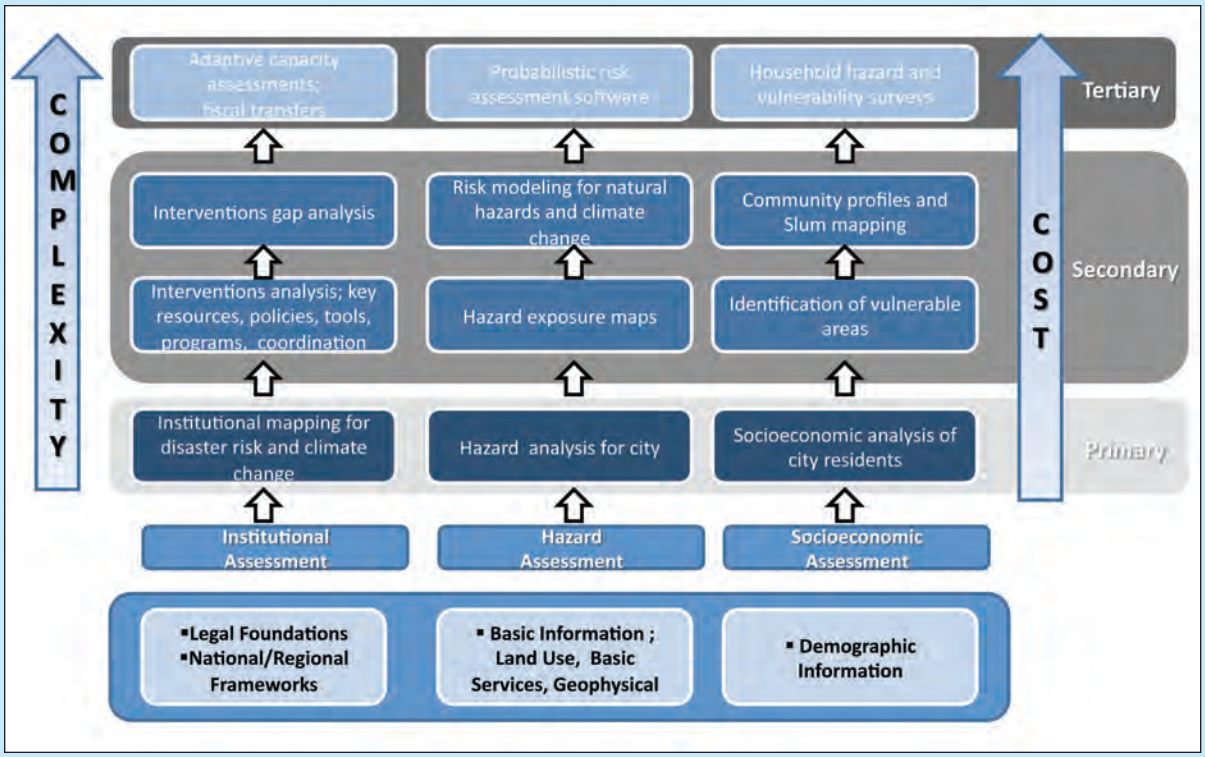
BOX 2

Urban Risk Assessment

The Urban Risk Assessment (URA) as recently proposed* lays the groundwork for the definition of a plan for strategic collaboration across city governments, the private sector, and development agencies to begin benchmarking their own progress towards the reduction of urban vulnerability. The objective is to move toward a common cost effective approach for specifying where and how many people are vulnerable to natural hazards, in addition to identifying susceptible infrastructure that if damaged, would also have detrimental effects on the urban population.

The assessment is based on four principal building blocks to improve the understanding of urban risk: historical incidence of hazards, geospatial data, institutional mapping, and community participation. The URA is structured to allow flexibility in how it is applied based on available resources and institutional capacity of a given city. Through a phased approach linked to complexity and required investment, city managers may select a series of subcomponents from each building block that individually and collectively enhance the understanding of urban risk (see below).

*The development of the Urban Risk Assessment is part of a joint Cities and Climate Change work program among UN-Habitat, UNEP, and the World Bank, supported by Cities Alliance. Through consensus building and collaboration, the URA is being developed and piloted with the support and guidance of various agencies including: ITHACA, ESRI, GTZ, International Development Research Centre, Joint Research Commission, UNEP, Office of Space & Advanced Technology (U.S. Department of State), United Nations University, United Nations Population Fund, Arizona State University, Association of American Geographers, Cisco, UN-HABITAT, International Institute for Environment and Development, Development Seed, and Fortius One.



Primary, Secondary, Tertiary Building Blocks

Source: The World Bank 2010d.

PART III
Cities' Contribution to Climate Change

"We are increasingly interconnected—no city can wall itself off from the consequences of climate change, and no city can prevent catastrophic climate change on its own."

—KEN LIVINGSTONE
Former Mayor of London (2007)

Reasons for Addressing Climate Change at the City Level

Cities are an organic form of government and often express the aspirations of their citizens more succinctly and quicker than higher levels of government. When these rising voices are credibly articulated, their global impact is considerable, and growing, as the worldwide response to climate change illustrates. In the United States, for example, 1,017 cities have signed on to meet or exceed Kyoto Protocol targets to reduce greenhouse gas emissions (US Conference of Mayors 2008).

Cities are first-responders in a crisis; they are the first to experience trends. For example, many local governments were aware of the 2008 financial crisis six months before national governments provided warnings as waste generation rates and values for recyclables had dropped significantly. Moreover, cities are usually the key agency to implement national government directives.

Because of their proximity to the public and their focus on providing day-to-day services, cities tend to be more pragmatic than senior levels of government. National governments may set the rules of the game, but it is cities that are the athletes. For the athletes to play the game, not only is it crucial that they know the rules, but also that their voices and those they represent are incorporated during the formulation of the rules.

Climate change will require city administrations to develop more robust partnerships with their constituencies, especially in developing countries. The public needs to be an integral part of future responses to climate change and trust needs to be strengthened before specific actions are introduced. One way to achieve this is to regularly supply the public with credible standardized information that encourages active debate but also outlines the need for scheduled concrete actions. Climate change will probably still require cities to lead initiatives that do not always have wide-spread public support, despite well intentioned efforts to better include the public in municipal management. For example, the city of Bogota's initial plans to reduce car use were widely rejected even though they are now broadly supported, as were Curitiba's initial pedestrian zone and bus rapid transit system.

> **"Cities are where change is happening the fastest and we must seize the opportunities we have been presented with to make that change significant and permanent."**
>
> **DAVID MILLER**
> Mayor of Toronto (2007)

How Cities Affect Climate Change

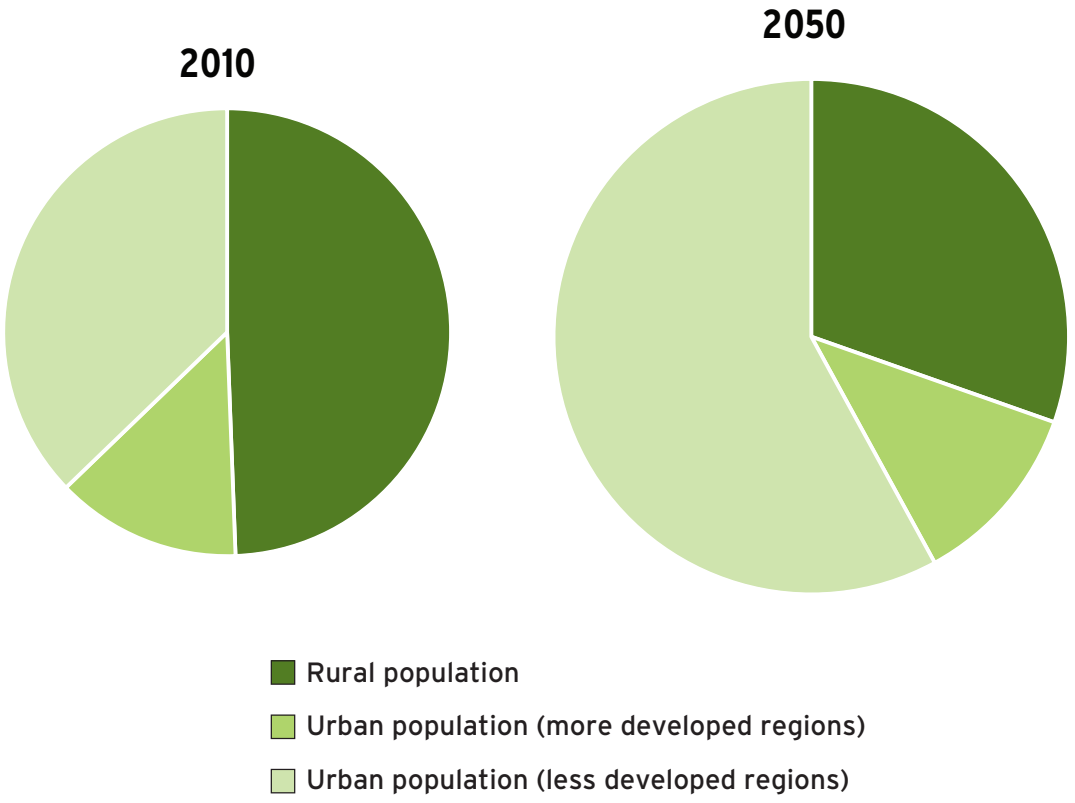
Economic growth and urbanization move in tandem, as economic growth and greenhouse gas emissions have for at least the last 100 years. Because most economic activity is concentrated in urban areas, cities have a key role in climate change. Affluence and lifestyle choices determine greenhouse gas emissions, and historically developed countries have had greater greenhouse gas emissions than developing countries. The world is urbanizing quickly and under the business-as-usual scenario, greenhouse gas emissions will also increase dramatically.

Cities are major contributors to greenhouse gas emissions. Half of the world's population lives in cities, a share that is likely to reach 70 percent in 2050 (Figure 5). Cities consume as much as 80 percent of energy production worldwide and account for a roughly equal share of global greenhouse gas emissions. As development proceeds, greenhouse gas emissions are driven less by industrial activities and more by the energy services required for lighting, heating, and cooling.

The International Energy Agency (IEA) estimates that urban areas currently account for over 67 percent of energy-related global greenhouse gases, which is expected to rise to 74 percent by 2030. It is estimated that 89 percent of the increase in CO_2 from energy use will be from developing countries (IEA 2008).

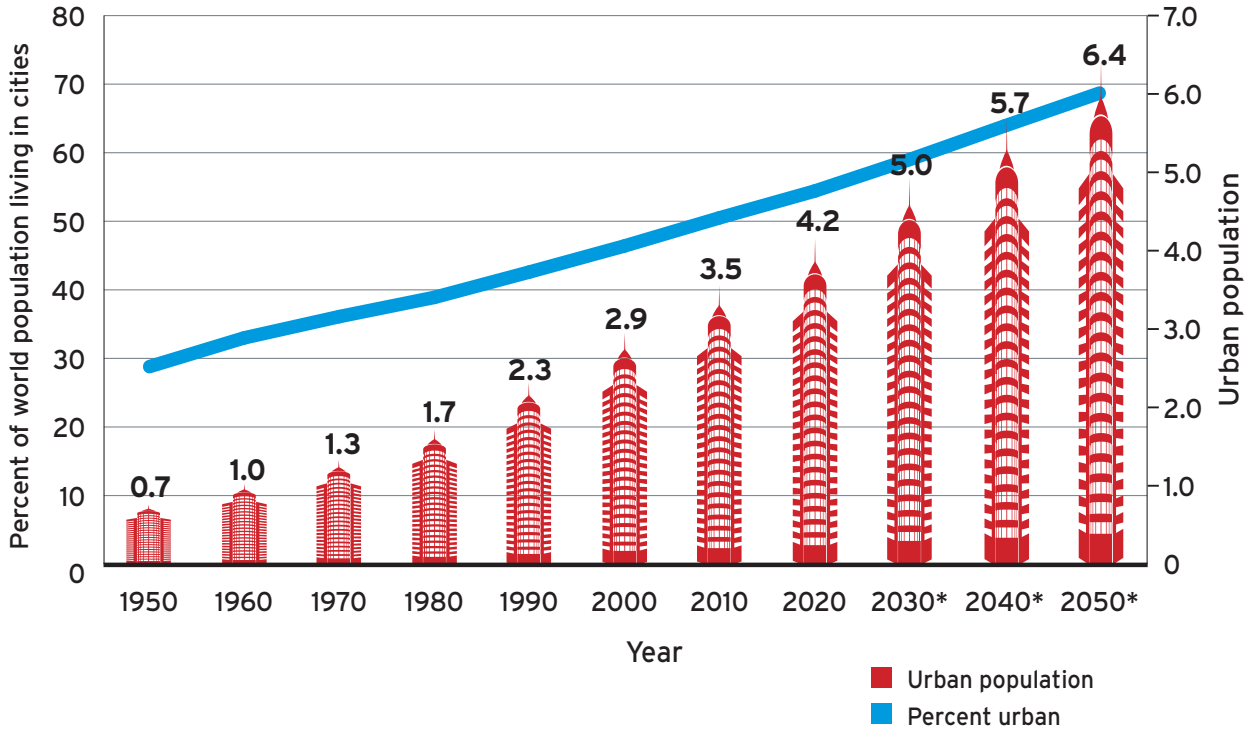
Urban population is expected to double by 2030; however the global built-up area is expected to triple during the same period (Angel et al. 2005). This building out instead of building up will dramatically increase energy requirements and costs of new infrastructure. Poorly managed cities exacerbate enormous new demands for energy and infrastructure investment.

Figure 5
Share of Urban and Rural Population in 2010 and 2050



Source: United Nations 2007

Figure 6
People Living in Cities (percentage of world population and total)



Source: UN, Department of Economic & Social Affairs, Population Division.

Cities matter because they are large economies in themselves and they emit greenhouse gases in line with the combination of energy sources used by each individual country (see Table 2).

The impact of cities is ***proportional to the level of output and the combination of energy sources*** they use. Richer cities, less dense cities, and cities that depend predominantly on coal to produce energy all emit more greenhouse gases.

Tables 2 and 3 illustrate the economic and environmental weight of the world's largest cities. The world's 50 largest cities by population and the C40[3] alone have combined economies second only to the United States, and larger than all of China or Japan. The world's 50 largest cities, with more than 500 million people, generate about 2.6 billion tCO_2e annually, more than all countries, except the United States and China. The top 10 greenhouse gas emitting cities alone, for example, have emissions roughly equal to all of Japan.

As shown in Table 3, the 50 largest cities in the world combined rank third in both population and greenhouse gas emissions, and second in GDP when compared with the largest and wealthiest countries. However, in per-capita emissions large cities are quite efficient. For example, New York City is the city with the world's highest total greenhouse gas emissions, but on a per capita basis, New York City's emissions are much lower than other large cities. For example, they are 40 percent lower than Houston's per capita emissions. Although cities are responsible for high total greenhouse gas emissions, per capita emissions can be comparatively low in cities that are efficient and well planned. Such cities as Hong Kong, Paris, Sao Paulo, Tokyo, Dhaka, and

[3]The C40 is an association of 40 of the world's larger cities, plus affiliate cities, focused primarily on greenhouse gas mitigation (see www.c40cities.org)

Country
City
Company

Table 2

World's Top 100 Economies, 2008

	Country/ City/Company	GDP/ Revenues $ billions PPP		Country/City/ Company	GDP/ Revenues $ billions PPP		Country/City/ Company	GDP/ Revenues $ billions PPP
1	United States	14,204	35	Exxon Mobil	426	69	Chevron	255
2	China	7,903	36	Osaka/Kobe, Japan	417	70	Toronto, Canada	253
3	Japan	4,354	37	Wal-Mart Stores	406	71	Detroit, U.S.	253
4	India	3,388	38	Colombia	395	72	Peru	245
5	Germany	2,925	39	Mexico City, Mexico	390	73	Portugal	245
6	Russian Federation	2,288	40	Philadelphia, U.S.	388	74	Chile	242
7	United Kingdom	2,176	41	Sao Paulo, Brazil	388	75	Vietnam	240
8	France	2,112	42	Malaysia	383	76	Seattle, U.S.	235
9	Brazil	1,976	43	Washington, DC, U.S.	375	77	Shangai, China	233
10	Italy	1,840	44	Belgium	369	78	Madrid, Spain	230
11	Mexico	1,541	45	Boston, U.S.	363	79	Total	223
12	Tokyo, Japan	1,479	46	Buenos Aires, Argentina	362	80	Singapore, Singapore	215
13	Spain	1,456	47	BP	361	81	Sydney, Australia	213
14	New York, U.S.	1,406	48	Venezuela	357	82	Bangladesh	213
15	Korea, Republic of	1,358	49	Sweden	344	83	Mumbai, India	209
16	Canada	1,213	50	Dallas/Forth Worth, U.S.	338	84	Rio de Janeiro, Brazil	201
17	Turkey	1,028	51	Ukraine	336	85	Denmark	201
18	Indonesia	907	52	Greece	329	86	Israel	201
19	Iran, Islamic Rep	839	53	Switzerland	324	87	Ireland	197
20	Los Angeles, U.S.	792	54	Moscow, Russian Federation	321	88	Hungary	194
21	Australia	762	55	Hong Kong, China	320	89	Finland	188
22	Taiwan	710	56	Austria	318	90	General Electric	183
23	Netherlands	671	57	Philippines	317	91	Kazakhstan	177
24	Poland	671	58	Nigeria	315	92	Volkswagen Group	158
25	Saudi Arabia	589	59	Atlanta, U.S.	304	93	ENI	158
26	Chicago, U.S.	574	60	Romania	302	94	AXA Group	157
27	Argentina	571	61	San Francisco/Oakland, U.S.	301	95	Phoenix, U.S.	156
28	London, UK	565	62	Houston, U.S.	297	96	Minneapolis, U.S.	155
29	Paris, France	564	63	Miami, U.S.	292	97	Sinopec-China Petroleum	154
30	Thailand	519	64	Seoul, South Korea	291	98	San Diego, U.S.	153
31	South Africa	492	65	Norway	277	99	HSBC Holdings	142
32	Royal Dutch Shell	458	66	Algeria	276	100	Barcelona, Spain	140
33	Egypt, Arab Rep	441	67	Toyota Motor	263			
34	Pakistan	439	68	Czech Republic	257			

Source: Country data from the World Development Indicators; city data from Hawksworth et al. 2009, PriceWaterhouseCoopers; company data from Forbes 2008 (based on sales). The table is intended for illustrative purposes only, as company revenues are different from GDP.

Table 3

The 50 Largest Cities, C40 Cities, and Top 10 GHG Emitting cities[4]

Population (Millions)	GHG Emissions (M tCO_2e)	GDP (billion $ PPP)
1. China: 1,192	1. USA: 7,107	1. USA: 14,204
2. India: 916	2. China: 4,058	**2. 50 Largest Cities: 9,564**
3. 50 Largest Cities: 500	**3. 50 Largest Cities: 2,606**	**3. C40 Cities: 8,781**
4. C40 Cities: 393	**4. C40 Cities: 2,364**	4. China: 7,903
5. USA: 301	5. Russian Federation: 2,193	5. Japan: 4,354
6. Indonesia: 190	6. Japan: 1,374	**6. Top 10 GHG Cities: 4,313**
7. Brazil: 159	**7. Top 10 GHG Cities: 1,367**	7. India: 3,388
8. Russian Federation: 142	8. India: 1,214	8. Germany: 2,925
9. Top 10 GHG Cities: 136	9. Germany: 956	9. Russian Federation: 2,288
10. Japan: 128	10. Canada: 747	10. United Kingdom: 2,176

Source: See Annex D. Data for the urban agglomeration associated with each C40 city is used in calculations to maintain consistency with the 50 largest cities, 2005.

London have the world's lowest energy intensity—about about one-quarter of the five highest cities and less than half of the 50-city average (see Annex D for energy intensity estimates of the world's 50 largest cities).

It is not surprising that rich **cities use more energy** than poor cities and therefore emit more greenhouse gas emissions. In fact, the link between economic growth, urbanization and greenhouse gas emissions is by now accepted as a basis from which to start discussing alternatives. Because so much economic activity is concentrated in urban areas, urbanization and growth have a direct consequence on city greenhouse gas emissions and related climate change. To promote growth and also mitigate climate change, cities will need to shift energy sources, improve energy efficiency, and increase city density.

How cities grow and meet energy demand is critical to climate change. Energy use and carbon emissions are mostly driven by how electricity is produced and how energy is used in buildings and transit (Kamal-Chaoui 2009). Cities meet approximately 72 percent of their total energy demand from coal, oil, and natural gas—the main contributors to greenhouse gas emissions. Cities also use about 70 percent of the energy generated from renewable sources; however, these sources still make up just a small share of total energy consumed.

Cities, especially dense city centers, represent our best chance to improve quality of life for the greatest number of people across the world. U.S. cities provide a useful example of how denser urban areas are the most efficient way to provide a high quality of life. Glaeser (2009) calculated that an average household in 48 major metropolitan areas generates up to 35 percent less greenhouse gas emissions when located in the city than when located in the corresponding suburb. The largest difference is seen in New York City where a Manhattan household generates 6.4 tCO_2e *less* than their suburban neighbors. According to Glaeser, "To save the planet build more skyscrapers" (2009). In Toronto, detailed neighborhood greenhouse gas emissions inventories

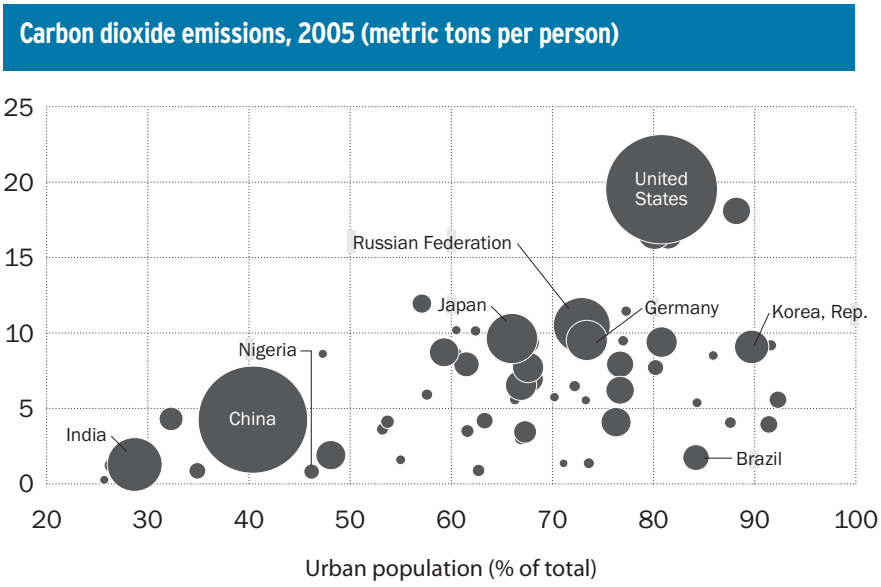
[4]Table 3 is detailed in Annex D where population, total GHG emissions, GHG per capita, and GHG per GDP (or energy intensity) are provided for the world's 50 largest cities. The World Bank and its key partners UNEP, UN-HABITAT, with support from City Mayors, the Global City Indicators Facility (for population and boundary details) and PriceWaterhouseCoopers biannual GDP of the largest cities, intend to update the table annually.

showed a variation from a low of 1.31 tCO_2e per capita in an area with multifamily units proximate to services and public transit, to a high of 13.02 tCO_2e per capita in a typical sprawling neighborhood with large single family homes distant from all services and totally automobile dependent (VandeWeghe and Kennedy 2007).

Urban density and spatial organization are crucial elements that influence energy consumption, especially in transportation and building systems. Urbanization and increased prosperity has happened with urban sprawl and increased demand for land. Although the urban population has doubled, occupied urban land has tripled (Angel 2005). In developed countries, this expansion has been particularly extensive in suburban areas as demand for space increases with income, and land prices are often lower in suburban areas. Increasing density could significantly reduce energy consumption in urban areas.

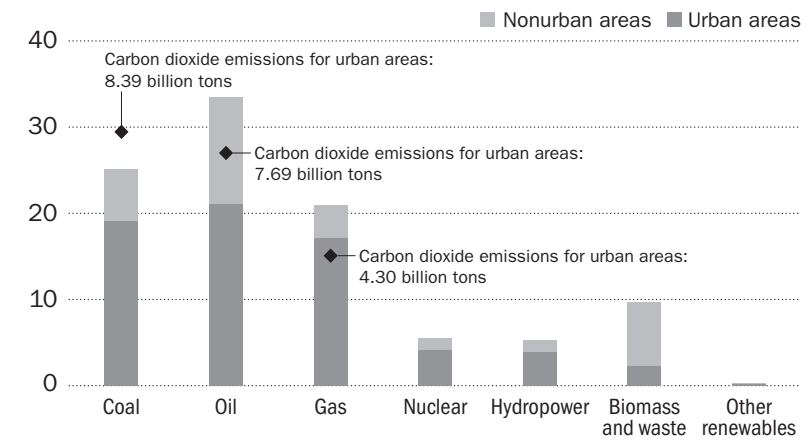
Cities pose a unique challenge to engineers in that they require concentrated energy supplies. Most cities are supplied with electricity from large-scale power plants, transmitted over a distance as short as possible to reduce transmission losses. Similarly, trucks, automobiles, and aircraft require fuel with high energy content. Switching to electric vehicles will likely only intensify the need for concentrated sources of energy and again requires a complex fuel distribution network. As water availability decreases, cities may also need additional energy sources for desalination. Renewable energy sources, such as wind and solar, will be an important and growing source of energy for cities, but as currently envisaged, they will likely not be able to replace the more concentrated hydroelectric, carbon-based, and nuclear energy sources. Major changes in energy supply for the purpose of reducing GHG emissions will also require changes to the energy use habits—for example, less automobile use and more energy efficient buildings.

Figure 8
Development and CO_2 Emissions



Source: World Bank, 2009a.

Figure 9
Emissions from Urban and Nonurban Sources



Source: World Bank, 2009a.

BOX 3

CITIES AT COP15
How Cities are Taking Action on Climate Change Internationally

With the growing importance of cities, many believe that cities need to be better represented in international fora. A Climate Summit for Mayors was convened in December 2009 during COP 15 in Copenhagen. This was the first time that a large group of mayors convened to discuss climate change; and it sent a strong signal that cities are at the forefront of climate change mitigation and adaptation actions. The Summit for Mayors was organized jointly by the city of Copenhagen, C40, and ICLEI. Approximately 500 participants attended the summit: 79 cities participated with 67 mayors and deputy mayors.

At the summit, a group of mayors formed a task force to review climate change in cities, particularly how climate change will affect the urban poor. The mayors of Dar es Salaam, Jakarta, Mexico City, and Sao Paulo were founding members of this new Mayors' Task Force on Climate Change and the Urban Poor. Mexico City Mayor Marcelo Ebrard is the Chair of the Task Force. As Chair of C40, Mayor Miller of Toronto is also a member. The task force will undertake a study on climate change and urban poverty in four cities around the world. A comprehensive report will be presented at the C40 biannual conference in Sao Paulo, Brazil, in May 2011. The World Bank is acting as secretary to the Task Force.

The important role of cities in climate change is further highlighted by the recent decision of the Intergovernmental Panel on Climate Change (IPCC) to dedicate a chapter on human settlements in its upcoming fifth assessment report. Human settlements will be addressed in both the adaptation report in the fifth assessment, as well as in the mitigation report. This will be the first time that the IPCC has dedicated chapters to the issue of cities and human settlement.

Measuring City Emissions and their Impact

City greenhouse gas emissions reflect the structure of a city, its energy sources, and its residents' lifestyles. Resource use, water consumption, wastewater production, toxic releases, and solid waste generation are all linked among themselves and with greenhouse gas emissions as well. For example, Figure 10 highlights the strong correlation between greenhouse gas emissions and municipal solid waste. Greenhouse gas emissions are an important component of a city's overall urban metabolism.

Defining city emissions—scope and boundaries. The first step in considering city greenhouse gas emissions is to define a greenhouse gas baseline of the annual greenhouse gas emissions produced in a given geographical area. The IPCC has issued guidelines to calculate national greenhouse gas emissions that include all emissions produced within the boundaries of a given country. These guidelines are used by national governments to report greenhouse gas emissions and include all emissions related to energy consumption, industrial processes, agriculture, land use change, and waste production.

A similar methodology should be used to measure GHG emissions at the city level. However, **city emission inventories face two additional complexities—the scope** of the emissions being measured and the boundaries of the city unit. The scope of emissions included in the city GHG Standard produced by UNEP, UN-HABITAT and the World Bank includes all emissions produced within a city, major emissions from consumption within a city, and major upstream emissions that are attributable to city residents. The question about the relevant boundaries of a city has to do with the unit to measure—strict city boundaries or the metropolitan area. A metropolitan, or functional limit of the city, may be the best scale to use, especially for larger cities. Providing emission in per capita units is helpful to highlight city-boundary issues, as most policy makers and the public can relate easily to which people are being counted.

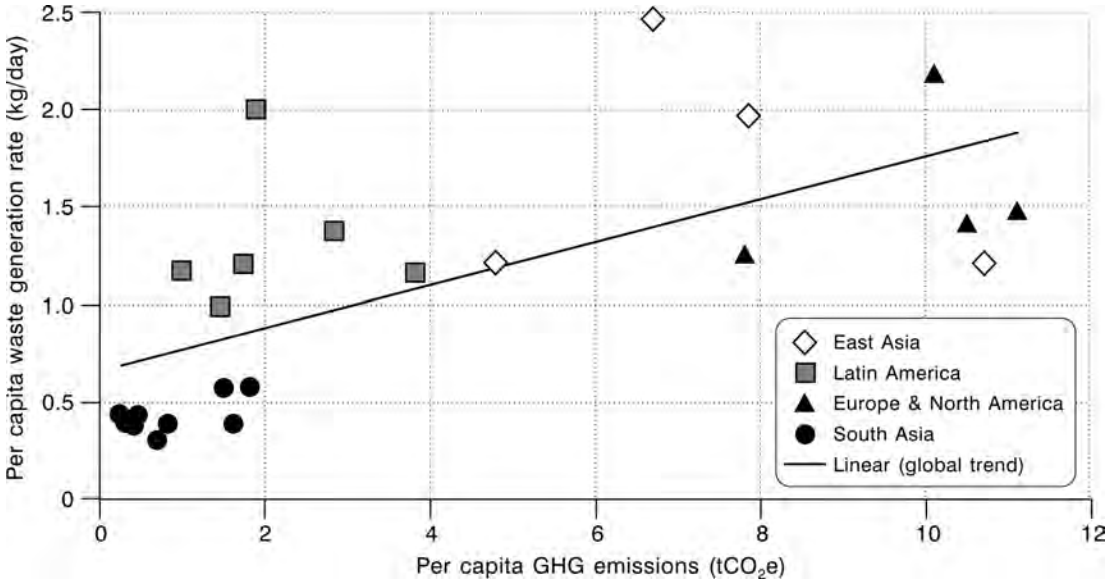


Figure 10
Per Capita GHG Emissions (tCO_2e) and Waste Generation Rate (kg/day)

Source: Waste data from World Bank, "What a Waste" 2010; GHG data from Table 4.

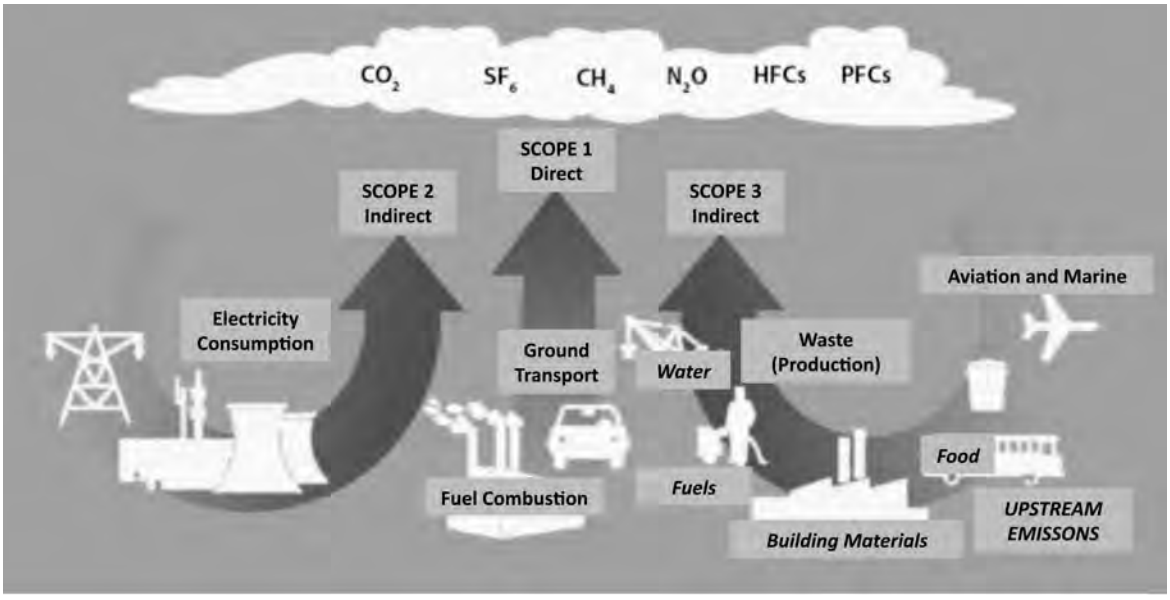
For the definition of scope, many emissions methodologies refer to the process used to measure GHG emissions at the corporate level. The World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) introduced three scopes that should be considered for calculating greenhouse gas emissions:

- **Scope 1.** Emissions are from sources under the direct control of the organization, such as furnaces, factories or vehicles.
- **Scope 2.** Emissions are from electricity consumed by the organization, though emissions may be produced elsewhere.
- **Scope 3.** Emissions, also called upstream emissions or embodied emissions, are associated with extraction, production, transportation of products, or services used by the organization (Figure 11).

These scope concepts have been applied to cities (Figure 11). Under Scope 1, city-based attribution takes into account greenhouse gas emissions from all production within the boundaries of a city. Under Scope 2, city-based attribution takes into account greenhouse gas emissions from city consumption, even if the production of emissions falls outside the boundary of a city. This includes emissions such as those produced by a power plant located outside of a city but whose power is consumed within the city.

Under scope 3, upstream emissions of cities are counted. This includes aviation and maritime emissions, which can increase a city's per-capita greenhouse gas emissions by as much as 20 percent, depending on the connectivity of city residents. Scope 3 emissions also include upstream emissions from food production, landfills, and fossil fuel processing. These upstream scope 3 emissions

Figure 11
Scope of Urban Greenhouse Gas Emissions



Source: Adapted from UNEP and UNEP SBCI 2009.

BOX 4

The Development of a City-Based Greenhouse Gas Standard

Harmonized standards encourage rapid uptake and comprehensive policy development. In the case of greenhouse gas emissions, the harmonization of emissions inventory methodologies exists for national, institutional, and project-level measurement. The IPCC methodology for national inventories is part of the methodology for UNFCCC required national reporting. The WRI/WBCSD Greenhouse Gas Standard covers corporate reporting and follows the prescribed national methodology. The International Standardization Organization (ISO 14,064) provides standardized methodologies for corporate and project or product emissions inventories. However, a significant gap exists at the urban and subnational level.

With urban greenhouse gas inventories now being conducted using differing methodologies, there is a need for an international greenhouse gas standard that provides consistency in the calculation and reporting of GHG emissions attributable to cities. Such greenhouse gas emissions standard for cities should be third-party verifiable. Cities need stand-alone inventories to facilitate targeted financing, for example, Bangkok's Urban Transformation program supported by the Climate Investment Fund, as well as rapid and credible feedback on GHG emissions resulting from various land-form patterns.

ICLEI—Local Governments for Sustainability was one of the first organizations to undertake local-scale GHG emissions reporting. Shortly after its founding, as part of the 'Local Agenda 21' efforts following the 1992 Rio de Janeiro conference, ICLEI initiated a campaign to quantify and reduce GHG emissions in cities. By 1998, there were over 240 city-members participating in the campaign, which enabled research efforts to support local governments in reducing GHGs. The focus was on identifying pragmatic methods for governments to track emissions. Issues of boundary, emissions allocation, and methodological consistency across cities were discussed in the academic literature (Harvey 1993, Kates et al. 1998).

During the past 10 years, the number of organizations producing greenhouse gas inventories has increased, and methodological issues are continually discussed (summarized in Kennedy et al. 2009b). More cities have recognized the importance of greenhouse gas emissions and are conducting inventories of their own. Bader and Bleischwitz (2009) compare six local-scale inventory tools, concluding that interoperability between tools requires rectification in six sources of inventory variability:

- List of gases to be measured
- Emissions sources included
- Sector definitions
- Measurement scope
- Values of climate change potential for non-CO_2 gases
- Tiers/accuracy of emissions factors

To cope with this problem, the development of an international standard for local-scale GHG reporting was suggested. Building on this work, and the work conducted by ICLEI and other organizations over the past 20 years, UNEP, UN-HABITAT, and the World Bank jointly developed the International Standard for Determining Greenhouse Gases from Cities. The standard was discussed at the Fifth Urban Research Symposium in Marseille, June 2009, and launched at the World Urban Forum in Rio de Janeiro, March 2010.

A significant aspect of the Greenhouse Gas Standard is that it requires a city's greenhouse gas inventory methodology and results to be transparent, accessible, and available to everyone — similar to national inventories submitted to the UNFCCC. The standard also takes into account the strides made by the academic community in countries like India, China, Thailand, where peer-reviewed city-based Greenhouse Gas standards are now available. An "open-source" format, such as that launched by the academic community ensures greater transparency, better replicability, and cost effectiveness.

A list of cities with the standard completed is now regularly updated by UNEP, UN-HABITAT, and the World Bank (see table 4). When developing the greenhouse gas standard, it is critical to see this as just one indicator, albeit an important one, of a city's overall urban metabolism.

sources are an important component of city greenhouse gas emissions. Ramaswami et al. (2008) demonstrate that Denver's emissions increase by 2.9 tCO_2e/cap when the emissions from food and cement are included[5,6].

The inclusion of greenhouse gas emissions associated with activities occurring outside cities but that benefit directly or indirectly urban residents can be difficult, especially when dealing with wide global goods and activities such as deforestation in Brazil and oil sand extraction in Canada, but it remains important to understand and take stock of all emissions attributable to cities.

Taking account of a city's greenhouse gas emissions per capita is vital, because city per capita emissions often differ greatly from regional or national per capita emissions. For example, the ratio of city per capita primary energy demand to the regional average, varies significantly across countries and regions. In the European Union, energy demand at the city level is only 94 percent of the national level; in China, the energy demand of cities is almost double (182 percent) the national average (IEA 2008).

Table 4 presents a comprehensive list of currently assessed urban greenhouse gas baselines for about 70 cities, reported as values per-capita, with a per-capita inventory value for the corresponding country. The organization responsible for preparing each inventory is indicated. While the methodology and data available for each city may vary, Table 4 is an important starting point for future consistency in urban inventory reporting. The table is now available on UNEP, UN-HABITAT, the Global City Indicators Facility and World Bank websites. It is regularly updated as new data becomes available.

In looking at the inventories presented in Table 4, some important trends emerge: developing countries tend to have lower per-capita emissions than developed countries; dense cities tend to have relatively lower per-capita emissions (particularly those with good transportation systems); cities tend to have higher emissions, if in a cold climate zone. The most important observation is that there is no single factor that can explain variations in per-capita emissions across cities; the variations are due to a variety of physical, economic, and social factors specific to the unique urban life of each city. The details of each inventory and its ability to undergo peer review are critical to developing and monitoring an effective mitigation strategy.

Box 5 gives examples of the differences in carbon emissions of three individuals living in different global cities. The three countries in the examples–Colombia, Canada, and Tanzania—have different levels of commercial and industrial activity, which provide for varying lifestyles and consumption, while informing the lifecycle carbon emissions associated with those activities. The national emissions for the three countries represented below are as follows: Canada has the highest GHG per capita at 22.65 tCO_2e; Colombia is 3.84 tCO_2e per capita; and Tanzania is 1.35 tCO_2e per capita. In the examples that follow, the individuals have greenhouse gas emissions that differ significantly from the national per capita values. This highlights the importance of calculating emissions at various scales (including national, regional, and city) to capture differentiation.

[5]Denver's 14.6 million $mtCO_2e$ in 2005 were made up of commercial/industrial buildings (34 percent), residential buildings (14 percent), heavy and light trucks (12 percent), food (10 percent), cars (7 percent), fuel processing (7 percent), air travel (6 percent), commercial trucks (4 percent), city government buildings (3 percent), cement (2 percent), transit (1 percent).

[6]This is one of the most comprehensive urban emissions baselines, employing a methodology that uses spatial allocation and lifecycle analysis consistent with EPA, IPCC, WRI and ICLEI protocol.

Table 4
Per Capita Greenhouse Gas Emissions by Country and City

Country/City	GHG Emissions (tCO_2e/capita) and Year	
ARGENTINA	**7.64**	2000
Buenos Aires	3.83	1
AUSTRALIA	**25.75**	2007
Sydney	20.3	2006, 2
BANGLADESH	**0.37**	1994
Dhaka	0.63	1
BELGIUM	**12.36**	2007
Brussels	**7.5**	2005, 3
BRAZIL	**4.16**	1994
Rio de Janeiro	**2.1**	1998, 3, i
São Paulo	**1.4**	2000, 3, i
CANADA	**22.65**	2007
Calgary	**17.7**	2003, 3
Toronto (City of Toronto)	9.5	2004, 4
Toronto (Metropolitan Area)	**11.6**	2005, 5, i
Vancouver	4.9	2006, 6
CHINA	**3.4**	1994
Beijing	**10.1**	2006, 3, i
Shanghai	**11.7**	2006, 3, i
Tianjin	**11.1**	2006, 3, i
Chongqing	3.7	2006, 7
CZECH REPUBLIC	**14.59**	2007
Prague	**9.4**	2005, 5, i
FINLAND	**14.81**	2007
Helsinki	**7**	2005, 3
FRANCE	**8.68**	2007
Paris	**5.2**	2005, 3
GERMANY	**11.62**	2007
Frankfurt	**13.7**	2005, 3
Hamburg	**9.7**	2005, 3
Stuttgart	**16**	2005, 3
GREECE	**11.78**	2007
Athens	**10.4**	2005, 3
INDIA	1.33	1994
Ahmedabad	1.2	1
Delhi	1.5	2000, 8
Kolkata	1.1	2000, 8
ITALY	**9.31**	2007
Bologna (Province)	**11.1**	2005, 3
Naples (Province)	**4**	2005, 3
Turin	**9.7**	2005, 3
Veneto (Province)	**10**	2005, 3
JAPAN	**10.76**	2007
Tokyo	**4.89**	2006, 3, i
JORDAN	**4.04**	2000
Amman	**3.25**	2008, 9, i
MEXICO	**5.53**	2002
Mexico City (City)	4.25	2007, 10
Mexico City (Metropolitan Area)	2.84	2007, 10
NEPAL	**1.48**	1994
Kathmandu	0.12	1

Country/City	GHG Emissions (tCO_2e/capita) and Year	
NORWAY	**11.69**	2007
Oslo	**3.5**	2005, 3
PORTUGAL	**7.71**	2007
Porto	**7.3**	2005, 3
REPUBLIC OF KOREA	**11.46**	2001
Seoul	**4.1**	2006, 3
SINGAPORE	**7.86**	1994
SLOVENIA	**10.27**	2007
Ljubljana	**9.5**	2005, 3
SOUTH AFRICA	**9.92**	1994
Cape Town	**11.6**	2005, 5, i
SPAIN	**9.86**	2007
Barcelona	**4.2**	2006, 5, i
Madrid	**6.9**	2005, 3
SRI LANKA	**1.61**	1995
Colombo	1.54	1
Kurunegala	9.63	1
SWEDEN	**7.15**	2007
Stockholm	**3.6**	2005, 3
SWITZERLAND	**6.79**	2007
Geneva	**7.8**	2005, 5, i
THE NETHERLANDS	**12.67**	2007
Rotterdam	**29.8**	2005, 3
THAILAND	**3.76**	1994
Bangkok	**10.7**	2005, 5, i
UK	**10.5**	2007
London (City of London)	6.2	2006, 11
London (Greater London Area)	**9.6**	2003, 5, i
Glasgow	**8.8**	2004, 3
USA	**23.59**	2007
Austin	**15.57**	2005, 3
Baltimore	14.4	2007, 12
Boston	13.3	13
Chicago	12	2000, 14
Dallas	15.2	13
Denver	**21.5**	2005, 5, i, †
Houston	14.1	13
Philadelphia	11.1	13
Juneau	14.37	2007, 15
Los Angeles	**13**	2000, 5, i
Menlo Park	16.37	2005, 16
Miami	11.9	13
Minneapolis	**18.34**	2005, 3
New York City	**10.5**	2005, 5, i
Portland, OR	**12.41**	2005, 3
San Diego	11.4	13
San Francisco	10.1	13
Seattle	**13.68**	2005, 3
Washington, DC	19.7	2005, 17

NOTE: Values in bold are peer-reviewed and considered comparable. Inventory year, source, and content are indicated in Annex B. All per capita national emissions are calculated from national inventories submitted under the UNFCCC and exclude LULUCF; national population figures are from the World Development Indicators, World Bank data, and correspond to the inventory year.

BOX 5

Greenhouse Gas Emissions and Urban Lifestyle: Three Personal Examples

Maria Acevedo, a Program Assistant for a private company, lives in **Bogota**. She shares a house with her husband and two children, and she loves to cook. To make her cooking easier, she has many electrical appliances in her kitchen, such as a rice cooker, blender, coffee machine, refrigerator, microwave, and stove. Apart from these appliances, she also has a TV set, DVD player, desktop computer, iron, washing machine, music player, video game, fixed telephone, digital camera, and two mobile phones, which she frequently leaves plugged in. There is no need for her to have air conditioning or heating in her house. When it comes to her daily eating habits, Maria considers herself to be a heavy meat eater, and likes having a combination of local and imported products in her diet. Maria has never traveled by plane, and she usually spends her vacation time in Bogota or its surrounding areas. With regard to local transportation, she always commutes from home to the office on the TransMilenio bus rapid transport system. On average, her daily travel distance is 7.2 km one way.

> Maria's personal GHG inventory, considering her electricity use, transportation habits, and food consumption, is about **3.5 tCO_2e per year.**

Further north, Nathan Tremblay, a **Toronto** citizen, is a vegetarian graduate student living in the suburbs. He lives with his parents in a detached house and owns a medium-sized car that he uses to go to school. Every day, he drives about 25 km per ride. Twice a year, he travels by plane when he goes on vacation. The flights usually last between 1.5 and 3 hours. As with many of his friends, Nathan cannot imagine himself without having his mobile phone, iPod, and laptop. In addition to these electrical devices, he also has at home a video camera, digital camera, electric razor blade, printer, and television, which are plugged in most of the time. Because of the weather conditions in Toronto, his parents' house has heating and cooling systems.

> Nathan's personal GHG inventory, considering his electricity use, home heating needs, transportation habits, and food consumption, is about **11.5 tCO_2e per year.**

In contrast with the two urban residents mentioned above, Zuhura Nganyanyuka, a Tanzanian tailor who lives in **Dar es Salaam**, never has her electrical appliances plugged in unless she is using them. She is afraid that once the power comes on after one of the very common power cuts in the city, her TV, sewing machine, radio, refrigerator, water boiler, and table fan might overload due to the power fluctuations. Zuhura lives with her husband, three children and two cousins in a typical Swahili house, composed of several rooms linked by a central corridor. Despite the warm weather, there is no air conditioning system in her home. Every day she takes a *daladala* (mini-van) 10 km (one way) to work. Along with her relatives, she considers herself to be a moderate meat eater, and generally buys local products.

> Zuhura's personal GHG inventory, considering her electricity use, transportation habits, and food consumption, is about **1.8 tCO_2e per year.**

Source: World Bank Cities and Climate Change team calculations.

Getting Ready to Change

As stated above, cities contribute the majority of total greenhouse gas emissions and no reduction will occur without major changes in cities including (a) increasing urban density (b) improving urban design to avoid sprawl, (c) improving city public transit (d) changing building practices (e) and changing sources of energy.

Figure 12 highlights the impact of policy changes in Sweden and Germany from 1967 to 2005. Efforts undertaken by cities were largely responsible for the dramatic greenhouse gas reductions in these two countries.[7] As China and India urbanize and supply an increasing share of global manufacturing, their carbon dioxide emissions will also increase. Though their per capita carbon dioxide emission levels are still lower than those in developed countries, China and India can benefit from the experience of countries such as Germany and Sweden going forward. Investment in mitigation is particularly important in rapidly urbanizing middle-income countries because long-lived capital stock, once established, can lock in emissions for long periods (potentially centuries). In their current form, carbon markets do not provide sufficient incentives for mitigation in projects involving long-lived capital stock. Therefore, targeted additional mitigation programs are needed in regions and sectors where long-lived capital stock is being built.

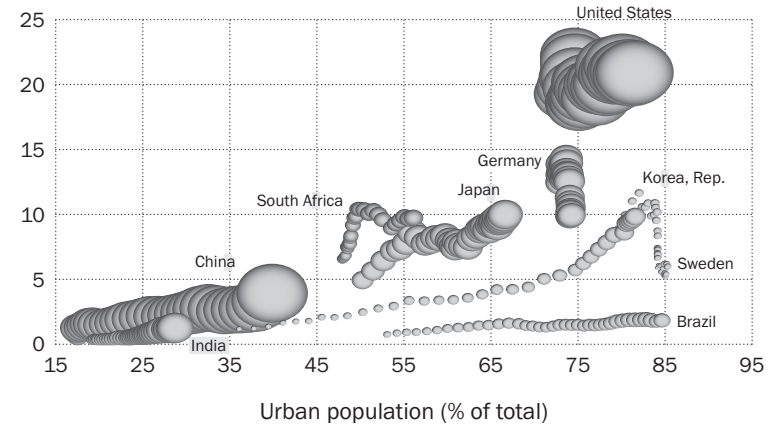
Increased density can reduce energy consumption. Japan's urban areas are five times denser than Canada's. The consumption of energy per capita in Japan is 40 percent lower than in Canada. In Madrid, city density is 10 times higher than Atlanta, and Madrid's CO_2e emissions per capita are four times lower than in Atlanta (Sorensen et al. 2007).

Urban design and mobility are crucial in CO_2 emissions. It is not urbanization alone that increases emissions, but rather how people move about the city, the sprawl of the cities, how people use energy and how buildings are heated and cooled that make the difference in how cities pollute and contribute to climate change. For example, the United States produced 50 percent more greenhouse gas emissions than European countries, which in turn have emissions twice as high as the Asian countries (because of lower GDP).

Countries that rely on private transport use more energy per passenger kilometer than countries with high levels of public and nonmotorized transport modes. As density increases, people use more public transportation and nonmotorized forms of transport, lowering transportation energy use per capita (Figure 13). Good land use policies can encourage this trend.

Figure 12

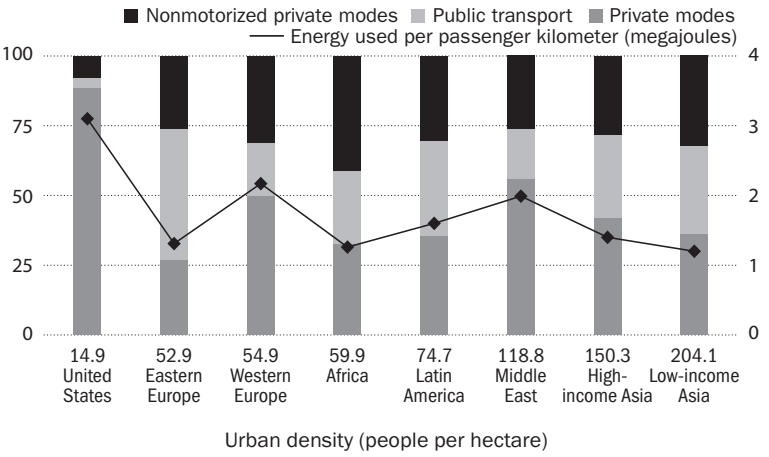
Carbon dioxide emissions per capita, 1967–2005 (metric tons per person)



Source: World Development Indicators data files.

Figure 13

Modal Split and Urban Density, 1995 (%)



Source: World Bank 2009a.

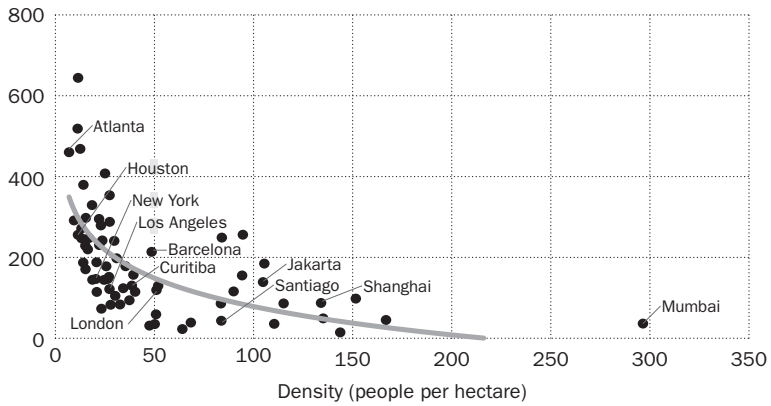
[7] In Germany, this includes incentives to purchase electricity from renewable sources, waste management, insulation standards in new and renovated buildings, and environmental standards in public procurement. In Sweden, urban policies combined energy facilities and encouraged mixed, and dense, land use. Deindustrialization also played a role.

High per capita energy use for transport in the United States and Western Europe can largely be explained by high incomes; in Middle Eastern countries this can be explained by generous fuel subsidies.

Recent research on urban form and density of cities reveals interesting patterns. The Neptis Foundation has produced figures emphasizing the urban form, density and transportation characteristics of 16 world cities (See Annex E). Compact cities, such as Vienna and Madrid, have significantly higher population density and higher public transport use than more sprawling cities, such as Atlanta and Houston. Spatial population density figures produced by Chreod Ltd. illustrate density distribution for 10 global cities (see Annex E). Population density is highest in the city core of compact Chinese cities, while spatial density variation is less pronounced in sprawling US cities. Tokyo offers an interesting example: with many dense city neighborhoods, Tokyo's population density distribution is relatively spatially consistent throughout the city.

Figure 14

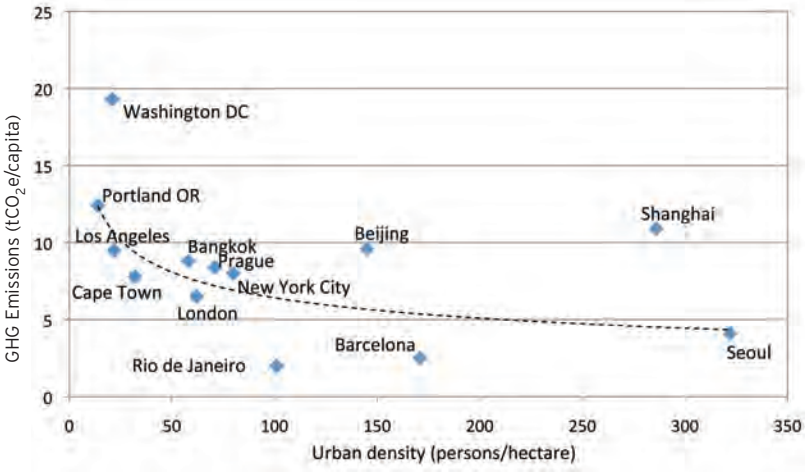
Transport-related Emissions, 1995 (per capita/Kg)



Source: World Bank 2009a.

Figure 15

City Densities and their Greenhouse Gas Emissions per Capita



Source: Density from Bertaud and Malpezzi 2003; GHGs from Kennedy et al. 2009b.

One of the biggest challenges for cities is the tendency to lock-in the form that they grow into. Infrastructure investments quickly become long-term sunk costs. The transportation system that a city develops largely defines the final shape of the city, as influenced by local geography. Roads and public transit lines are the bones of a city, with water, wastewater and power services fleshing out the city. Once buildings grow around transportation and service nodes, they are all but locked-in. Many newer U.S. cities are defined by the Interstate Highway system and their reliance on the automobile for most public travel. European cities tend to be more compact, with a greater reliance on public transportation. This variation in density and design is a major reason for the striking differences in per capita greenhouse gas emissions between newer cities in the United States and older cities in Europe. The urban form is also driven by lower fuel costs in the United States. This is a critical lesson for developing-country cities that still have an opportunity to influence the final shape of their cities.

Compact cities are more sustainable than sprawling cities. Urban form is important in determining land and energy use and the cost of infrastructure and municipal services. Denser cities use less energy for transportation, which lower transport-related emissions. They also provide access to services at lower cost and implement more energy efficiency measures. The relationship between urban density and greenhouse gas emissions per capita is shown in Figure 14, emphasizing that cities that are denser produce less emissions.

Sprawl Happens. As income increases, households choose larger living spaces, which leads to increased per-capita land consumption and low density form, especially as land tends to be cheaper on the outskirts of the city. This could be a worrying trend from a climate change perspective—as low density leads to higher greenhouse gas emissions for the same level of GDP and industrial activity—and from the point of view of service delivery efficiency.

Responding to climate change pressures, many local governments will encourage denser cities and greater reliance on public transportation. These efforts may seem to run counter to the traditional growth patterns of cities, especially in countries where land is available, fuel is relatively cheap, and the use of private owned transportation is well installed. It may also threaten the usual modes of land development and the regular stream of city revenues accruing from new land development and land transactions. Property taxes can influence sprawl as they can be levied on occupied space, and a policy of high floor area ratio can offset the impact of less land consumption per urban household. Hong-Kong, one of the densest cities in the world, depends heavily on property taxes.

Indeed, as climate change and quality of life considerations urge a more compact urban form, cities need to learn how to incorporate higher densities, higher floor area ratios (FARs), flexible zoning, and intelligent design—for example with high density poles along rapid transit corridors—as successfully used in major metropolises, such as Sao Paulo, Hong Kong, and Shanghai. However, it is never easy to change practices. In mature cities—such as in the United States, Canada, and Europe—land development is still an important source of revenue for local governments. In newer, rapidly developing cities, such as those in China, a more compact urban form is still possible; however, the current development charges and local revenue generation do not readily encourage this.

Naturally constrained cities, such as Portland, Seattle, Barcelona, and Vancouver, provide important lessons: Geography—oceans and mountains—limits the land available for development in these cities and has forced them to develop up in a high density mode that has led to an enhanced local quality of life and lower greenhouse gas emissions. However, artificial geographic constraints around cities, such as greenbelts, are a relatively crude instrument of land use policy, and by and large do not adequately constrain sprawl. Greenbelts can lead to leapfrog development as the pressure over city space is answered by land development outside the greenbelt.

Climate change may help limit urban sprawl, especially if local economies are to pay a high price for greenhouse gas emissions. Increasing agricultural productivity around a city, a critical aspect of climate change adaptation, can also help limit urban sprawl. A study of 120 representative cities showed that a doubling of the agricultural value added per hectare resulted in a 26 percent decline in land use for urban purposes (Angel 2005). Another area where cities can mobilize broad support from the community in responding to climate change is smart design and architecture. "Green cities" are manifested through many attributes but largely share a common theme of a supportive community and proactive local government. Better construction and management needs to be part of denser cities as a way to offset the corresponding concentration of risk and vulnerability.

Recent research suggests that simply increasing density in cities will not be enough. Gaigné et al. (2010) note that as density increases emissions may rise from traffic congestion and longer work-trips more than they are reduced from increasing efficiency in city-to-city transport. Hence, cities not only need to grow denser but also *smarter* through public transport networks, urban form and efficient water, wastewater, and solid waste systems.

Cities are already often overwhelmed by the magnitude of their service delivery requirements, especially in developing countries. Urban areas, because of their density, offer mass-targeting options that provide access to water, sanitation, and solid waste management more cost-efficiently than rural or suburban areas can. Infrastructure investments can be more cost effective when targeting urban beneficiaries. Latin America and the Caribbean and Eastern and Central Asia, with the highest urbanization rates,

have greater access to sanitation services. South Asia and Sub-Saharan Africa, with the lowest urbanization rates, have the least access (World Development Indicators, World Bank, 2006). Over 50 percent of the urban population in Sub-Saharan Africa and 40 percent of the urban population in South Asia still lack access to sanitation. With some 1.1 billion people living in slums today, progress toward the Millennium Development Goals related to improving basic service provision is slow (UN-HABITAT 2008; UN 2010). Cities offer the best opportunity to raise the most people out of poverty.

Urban Metabolism

One useful way to consider the impact of city activities on climate change has been the **lens of urban metabolism**—the paradigm that cities have functions and processes analogous to living organisms. The architect Frank Lloyd Wright exemplified this analogy in a classic 1904 speech, comparing streets to arteries and veins, sewers to intestines, and buildings to cellular tissue. Cities, as "fundamental economic units of the contemporary world" (Congress for the New Urbanism 2001) consume materials, water, and energy; they export products and expel waste. All flows in and out of the city should be considered. The metabolism concept is characterized as greater than the sum of its individual parts, therefore, it is in line with the general systems theory proposed by biologist Ludwig von Bertalanffy in 1928 that "Cities [be] regarded as complex living systems."

Just as the metabolism paradigm can describe environmental impacts of cities, it can be used to explain some social urban phenomenon as well. Bettencourt et al. (2007) have applied mathematical biology theories of collective organization and networks to urban systems. Infrastructure, for example, achieves important economies of scale: it can grow at a slower rate than population while maintaining service levels to the city. The opposite was found for social indicators: as population increases, social indicators such as connectivity increase faster. Social metabolism, or community connections, accelerates as cities grow, thereby making cities centers for ideas, connections, and innovation.

Urban metabolism and city-scalability are likely the two most important phenomenons needed as city planners design ways in which cities accommodate an additional two billion residents over the next 40 years.

Significant progress has recently been made toward developing a standard urban metabolism classification system. The system outlined in Figure 16 below was developed at an MIT workshop in January, 2010. The system integrates the EURO Stat material flow analysis framework, with methods

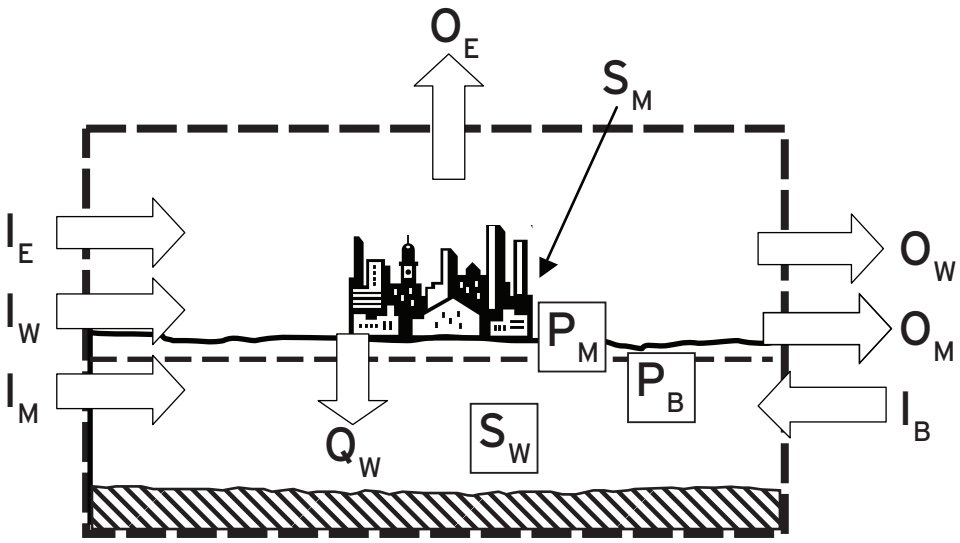


Figure 16
Urban Systems Boundary Broadly Showing Inflows (I), Outflows (O), Internal Flows (Q), Storage (S) and Production (P) of Biomass (B), Minerals (M), Water (W), and Energy (E).

Source: Kennedy 2010.

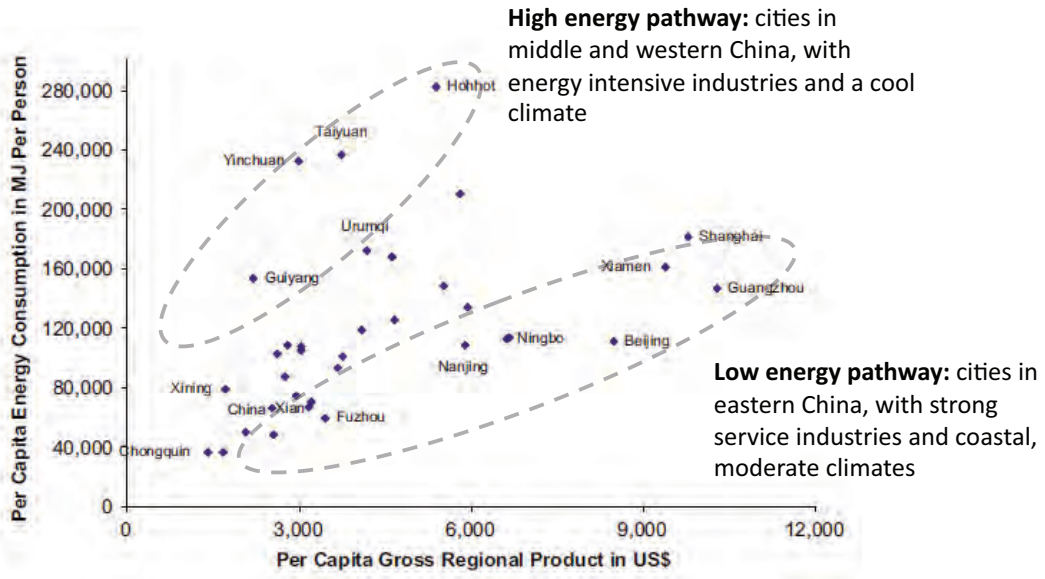


Figure 17
Varying Energy-economy Pathways within China's Cities

Source: Adapted from Dhakal 2009.

of water, energy, and substance flow analysis to include quantities that have typically been quantified in previous metabolism studies. The system boundary includes natural components (for example, solar radiation and groundwater flows) in addition to anthropogenic stocks and flows.

Building Better Cities

Today, urban areas of China represent 75 percent of the primary energy demand of the country; this is expected to rise to 83 percent as its urban population reaches 880 million by 2030. Use of this energy will contribute 85 percent of China's energy-related greenhouse gas emissions. A study of the development path for China's 35 largest cities highlights that the spatial form a city takes and adherence to energy efficiency can make a significant difference (Figure 17). China is a unique case in that 90 percent of its GDP is expected to be from urban areas in 2025, but many of the associated buildings and large-scale infrastructure have not yet been built.

Cities' energy sources matter. The China example above illustrates how the impact of energy consumption on greenhouse gas emissions depends both on the amount consumed but also on the mode of energy production and the consequent greenhouse gas emitted by those sources. For example, Cape Town has comparatively low per capita electricity consumption compared with Geneva but has a much higher greenhouse gas emissions because of South Africa's use of coal for 92 percent of its electrical generation, while Geneva mainly uses hydropower for its electricity.

Costs of delay. Ensuring the development of dense, efficient cities today could greatly reduce emissions from their projected trajectories, especially in rapidly urbanizing countries. The variation in per capita emissions in cities results from differences in wealth, sectoral specialization, energy sources, the general climate, and the structural efficiency of the urban form, which includes buildings and transport infrastructure.

The city of Toronto, for which some of the most comprehensive spatial data are now available, provides an important observation on spatial distribution of greenhouse gas emissions. Total residential emissions are for city-wide 9.5 tCO_2e, and metropolitan 11.6 tCO_2e. As highlighted in a review of Toronto neighborhoods, the low and high per capita greenhouse gas emissions range from 1.3 tCO_2e/capita to 13.3 tCO_2e/capita. This suggests

that what you buy is important, but where you live is much more important, especially if you take into account the weather conditions and the rigid patterns of emissions associated with urban form and buildings. Urban form may be the single largest determinant of a city's greenhouse gas emissions.

Can Pricing be Helpful?

Energy pricing and carbon markets have been put forward as two instruments that would help cities deal with energy intensive technologies. However, literature and experience show that in the short run, energy pricing may not work, especially once consumers have made their purchases of equipment or vehicles. Short-term elasticities for energy demand are actually relatively low (World Bank 2009b), because consumers are not influenced by price signals once they have locked in vehicle purchases and housing type and location, and often, location of employment. Long-run elasticities are more difficult to estimate and may underestimate the savings potential that result in changes in infrastructure systems, because of locked-in and long-lived capital investments.

Energy efficient cities, such as Hong Kong and Tokyo, have deliberately regulated individual car use and urban sprawl early on in their development. Without these efforts any reductions in energy consumption for transportation and household use resulting from price incentives would likely have been superseded by high income inelasticities for individual car use and high household energy consumption. Standard policy measures are not likely to lead to strong responses in greening cities, because elasticities for energy intensive activities, such as personal car ownership and housing location and type, are low. Infrastructure policies, which favor energy intensive housing or transport, have in fact reduced the responsiveness of citizens to fiscal and regulatory policies (Small and van Dender 2008).

A key aspect of a city's energy use involves societal norms and culture. Municipal officials will need to use education, social marketing, and global comparisons and cooperation to encourage lifestyle shifts toward a conserver ethic. Cities must prioritize their needs as they become more sustainable. Priorities vary globally across cities. With regard to climate change and sustainability, a priority for such cities as Denver, Los Angeles, and Cape Town are greenhouse gas emission reductions, whereas for such cities as Dhaka, Hanoi, and Jakarta strengthening adaptation capacity and municipal management are priorities, along with basic service provision to the poor.

Carbon markets, even if performing optimally, are not enough. A mechanism to include ancillary emissions in financial cost-benefit analysis is also required. Cities need upfront financing that can reflect potential long-term carbon revenues that may accrue. Similarly, mechanisms are needed to internalize other noncarbon externalities, for example, local air pollution, and to reduce such barriers as capacity and technology that currently favor higher-carbon investment options (Shalizi and Lecocq 2009).

In summary, cities are major contributors of greenhouse gas emissions. Measuring a city's emissions is an arduous but important challenge. Reducing emissions in cities relies on long-term planning largely around urban form and city efficiency.

PART IV
Benefits for Cities in Climate Change Action

Cities Have Much to Gain from Embracing the Low-carbon Agenda

Although climate change is a pressing issue, many local governments are reluctant or unaware of how to mainstream climate concerns into their political and development agenda, and how to address them in their investment plans and their city-wide strategic thinking.

There are at least four reasons why action on climate change is in the best interest of cities. First, the costs of inaction are very high. Rapidly growing cities will need to take urgent actions to guide building codes and practices, density, and connectivity infrastructure. Delay will result in a path that will increasingly diverge from the optimal high density, low-carbon trajectory and make mitigation increasingly expensive and inaccessible. Second, the cobenefits of green action often more than cover the costs. Reducing pollution has a direct impact on health, quality of living, attraction of private capital and human resources. Third, embracing such an important global cause helps cities to position themselves within a group of leaders, access information and technology, and learn by doing. Fourth, embracing and sharing global goods and practices is the best way to help small and poor cities to gain access to the best experiences available from around the world.

Costs of delaying action are very high. Although climate change mitigation and adaptation policies demand a high level of investment, the costs will be even higher, the longer the decision to act is delayed. This is particularly true for rapidly growing cities. A decision now to change building codes and practices, urge a more dense urban form, and build strong urban transport systems can save enormously in future energy costs (especially as energy costs are likely to increase faster than the general cost of living increases). Prompt action can also promote more pleasant cities and more inclusive and participatory societies.

Indirect impacts of climate change can cripple urban economic activity when economic activities, such as employment, transport, and communications are disturbed by weather events. Potential disruption in supply lines will also increase the cost of living in the city. But most economic loss will come in the form of hidden costs, such as the cost of rerouting traffic, lost productivity, relocation and retraining, and additional costs of insurance.

Cobenefits are substantial. They include public health improvements, cost savings through increased efficiency, and energy security. Policies to reduce GHG emissions through increasing energy efficiency can result in significant reductions in energy costs. These energy savings can compensate for the initial investment. A good example is Los Angeles where the city has retrofitted most of its public buildings. In three years, investment costs were recovered by savings in energy bills.

Low-carbon emissions and low pollution levels are essential components of the quality of life in cities. Competitive cities that are eager to attract human and financial capital to promote jobs and prosperity need to curb air pollution and ensure a healthy environment.

In addition, **urban policy can contribute to national targets.** OECD (Kamal-Chaoui 2009) suggests with its general equilibrium model (CGE) that such urban policies as higher spatial density and congestion charges can lead to reducing total global energy demand, and as a result, CO_2 emission. It also shows "that the overall abatement cost of meeting Kyoto emissions reduction can be reduced over time by complementing a global climate policy (e.g., a carbon tax) with urban densification policies and congestion charges" (Kamal-Chaoui 2009).

Cities are also good pilots for action on climate change and have key competencies to act on climate

change. Many cities are taking action on climate change—even without national pressure—to lower the potential trade-offs between growth and environmental priorities. This is happening among large cities, such as Seoul, Stockholm, Toronto, Copenhagen and New York, as well as in Mannheim, Germany, Nantes, France, and Boulder, United States.

Cities have authority over such urban sectors as land-use zoning, transport, buildings, waste management, and water services. Cities are well-positioned to develop policies that meet specific economic and social conditions. They are also in a good position to provide a laboratory setting. Cities can explore the positive synergies that occur when urban activities are planned together, and the city uses the opportunity to create a more inclusive and compassionate society. Strategic planning is a powerful tool to guide future action, identify implementing roles, and monitor outcomes.

Cities can promote green growth through their screening of investments in infrastructure and transport, financial and tax incentives, partnerships, regulation of energy suppliers, increased consumer awareness, and job training. They can also lead by example. Public-private partnerships leveraged by green infrastructure funds have a great potential to reduce the burden on local finances. In addition, cities can generate strong markets for efficient energy products and services. Cities can tap this fast growing market by including green safeguards in their infrastructure projects and dealings with utilities.

However, many cities are reluctant, or do not have access to necessary resources to address climate change.

Finance for Cities and Climate Change

Finance to address climate change is a critical concern for cities. This section highlights several of the most pressing aspects of climate change finance for cities, including the limited funding available, such as the Climate Investment Funds and carbon finance. A more detailed paper focused exclusively on finance for cities and climate change is in progress.

The current available funds for mitigation and adaptation, not limited to cities, only amounts to $9 billion per year. The maximum estimated available funding in the future for climate change through the UNFCCC and other funds is $100 billion per year (World Bank 2009b). This is a large sum, but many studies show that much more funding is needed; compared to an estimated $100 billion per year available, the need for mitigation and adaptation finance may be $275 billion per year (World Bank 2009b). By comparison, the estimated cost of attaining the Millennium Development Goals by 2015 is $40 to $60 billion per year (World Bank 2002).

In the current scenario of extremely limited funding, cities need to keep in mind that climate funding will certainly represent only a very small fraction of their overall budgets. The primary available funding sources for climate change in cities, both mitigation and adaptation, are briefly listed below. All of this international climate funding will be channeled through national governments, and city access to funding remains uncertain, especially as climate change activities are usually assigned to Ministries of Environment, which do not traditionally focus on urban issues.

The Least Developed Countries Fund ($223 million pledged) and the Special Climate Change Fund ($148 million) are, to date, small sources of adaptation funding for developing countries managed by the Global Environment Facility (GEF) (World Bank 2010a). The World Bank's Climate Investment Funds, with $6.3 billion pledged, provide a source of funding for clean technology, forest investment, renewable energy and other climate investment for developing countries (Climate Investment Funds 2010). These funds were multiplied several fold with matching funds. Such cities as Mexico City, Cairo and especially Bangkok highlight the possibilities of scaling up climate funds.

Carbon finance is another potential source of funding for climate change in cities. The World Bank operates more than 10 separate carbon funds that together manage $2.5 billion (World Bank 2010b). The Clean Development Mechanism (CDM), which allows developing countries to fulfill

BOX 6

Bangkok's Greenhouse Gas Emissions and the Clean Technology Fund

The Clean Technology Fund (CTF) Investment Plan for Thailand was approved in December 2009, and included a significant component for urban transformation in Bangkok. The CTF, one of the financing instruments under the Climate Investment Funds, invests in projects and programs that contribute to the demonstration, deployment, and transfer of low carbon technologies with a significant potential for long-term greenhouse gas emissions savings.

The CTF Investment Plan included a specific focus on Bangkok because of the city's unique position in the country. Thailand's energy consumption is concentrated in the Bangkok Metropolitan Region (BMR), and directly contributes to the city's greenhouse gas emissions. Moreover, Bangkok's urban form highlights the link between Thailand's overall greenhouse gas emissions and the urban setting.

On average, Bangkok is less dense than other East Asian cities, and its urban form is currently locked-in by its urban transportation system. Based on analysis undertaken as part of World Bank work on the international standard for city greenhouse gas emissions, it was found that at 10.6 tCO_2e, Bangkok's residents generate more greenhouse gas emissions per capita than the global average for city dwellers, within the highest tier for global cities.

Prior to the CTF Investment Plan, the Bangkok Metropolitan Administration (BMA) had already launched its Action Plan on Global Warming Mitigation, with a target to reduce the city's emissions by 15 percent. With the CTF, Bangkok was thus able to enhance its greenhouse gas mitigation program based on a credible and verifiable emissions baseline.

The CTF is providing $70 million for urban transformation in Bangkok to cofinance the development of a bus rapid transit (BRT) system for the city. CTF support is also cofinancing investments in energy efficiency for BMA facilities and public spaces, focusing on electrical appliances and air-conditioning.

These investments will create unique opportunities for replication. Within Bangkok, the energy efficiency investments in BMA facilities, for example, will serve as a model for commercial buildings. The success of BRT development in Bangkok would demonstrate viable low carbon transport solutions and models for replication to fast-growing secondary cities in Thailand that are facing increasing congestion.

A customized city investment plan was possible for Bangkok, because the city had already developed an urban transportation plan and a peer-reviewed greenhouse gas emissions baseline that can be used to highlight mitigation progress by the city. The lessons learned from Bangkok will also be useful for replication and scaling up of investments in other cities in Asia and other developing regions of the world.

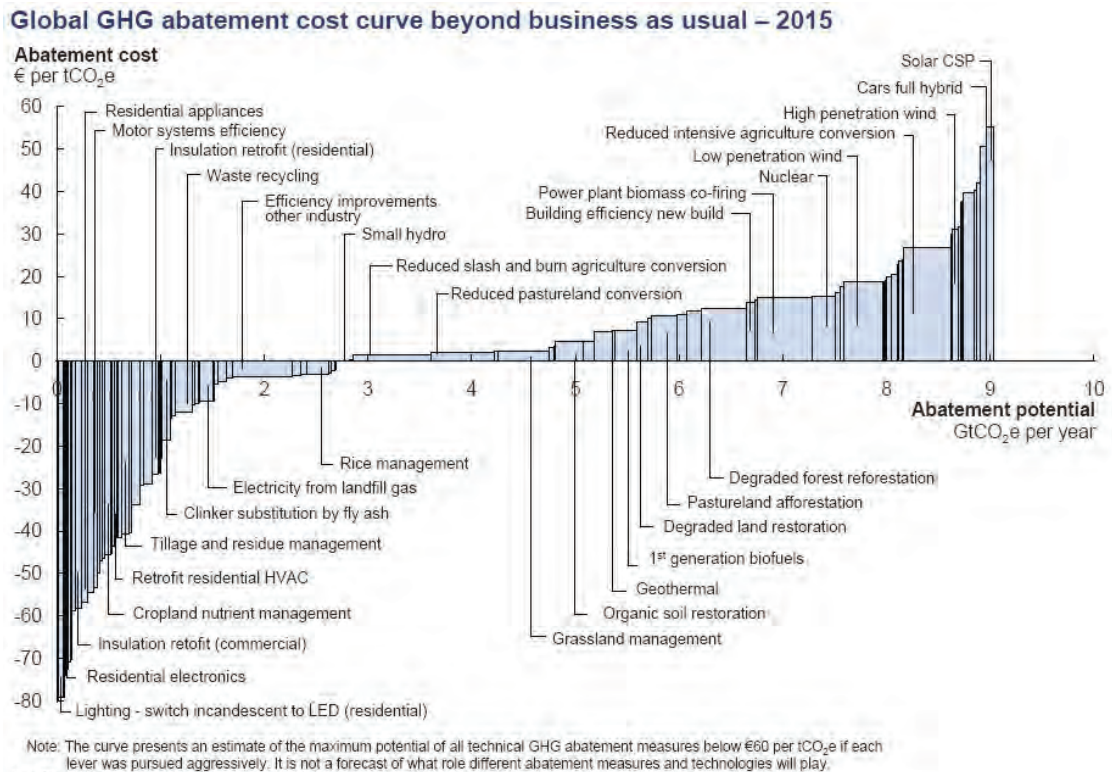
Source: Clean Technology Fund 2009.

emissions reduction requirements by carrying out projects, accrues saleable certified emission reduction (CER) credits. The Adaptation Fund, designed to finance adaptation projects in developing countries, receives 2 percent of the shares of CERs created under the CDM. The Adaptation Fund currently holds $135 million from the sale of CERs and the fund is projected to grow to $300–600 million by 2012 (World Bank 2010b).

Currently, cities have not been easily able to benefit from the ; less than 1 percent of current CDM projects are taking place through cities (World Bank 2010c). A new city-wide approach to carbon finance has recently been initiated by the World Bank to improve city access to market mechanisms for carbon finance. Under this approach, the CDM Program of Activities approach would include a Program of Activities for cities, under which cities could aggregate mitigation actions that fall under energy, transport, solid waste, water, and urban forestry to create a more sizeable number of Certified Emission Reductions (CERs). One of the current challenges of the CDM is that only projects with large mitigation potential and that will generate a large number of CERs are viable. By agglomerating mitigation actions within a city, this challenge would be overcome for cities. Work is underway to launch this methodology focusing on Amman, Jordan.

One way in which cities are taking the lead in climate finance is by initiating city level emissions trading programs (see Box 7). City level emissions trading systems (ETS) are increasingly being used for mitigation finance. Such finance tools as the ETS are powerful means of influencing behavior. When a real cost is associated with greenhouse gas production, as in the example of Tokyo's ETS, behavior can change drastically. This behavioral

Figure 18
Marginal Abatement Cost Curve (McKinsey 2009)



Source: Global GHG Abatement Cost Curve v2.0.

BOX 7

Tokyo's CO_2 Emissions Trading System (ETS)

As part of a suite of mitigation options, experience with ETSs already exists for greenhouse gases (such as the EU ETS) and other substances. However, city-level ETSs have hitherto had the primary objective of improving air quality, with some of the air pollutants covered happening to also be greenhouse gases.

The world's first city-level carbon dioxide cap and trade program, with the primary objective of mitigating climate change, was launched in Tokyo, Japan in April 2010. Tokyo's ETS covers energy-related CO_2, involving around 1,340 large installations, including industrial factories, public facilities, and educational institutions, as well as commercial buildings. With this ETS, the Tokyo Metropolitan Government (TMG) aims to reduce CO_2 emissions by at least six percent during the first compliance period (2010-2014), with the ultimate goal of a 25 percent reduction below 2000 levels by 2020.

A number of key enabling conditions in Tokyo were critical for the development and implementation of the city's ETS.

First, mandatory reporting of emissions from at least the year 2002 provided a rich data source and solid baseline for designing the ETS and setting compliance targets. This data was very detailed, in many cases down to individual energy consuming units of machinery or infrastructure. This enabled TMG and stakeholders to establish that energy efficiency targets are indeed possible, thus reducing resistance to the implementation of the ETS. A key feature of mandatory reporting in Tokyo has been its relative simplicity: the system relies on existing data from electricity and fuel bills and equipment inventory lists. Although this has the effect of limiting the target gases to energy-based CO_2, this was considered suitable in the case of Tokyo where the largest share of emissions comes for commercial buildings.

Second, a process of stakeholder consultations was part and parcel of the development of the ETS. In consultation with experts around the world and in Japan, TMG developed the core of the ETS proposal before opening it to public feedback. Stakeholders from the potential target institutions were then invited to participate in the development of the details of the ETS. Not only did this engagement with stakeholders provide a means of receiving feedback and technical inputs for strengthening the design and feasibility of the ETS, but it also helped to build confidence and increase acceptance of the ETS more widely.

Lastly, Tokyo's experience shows that it is difficult to achieve ambitious reductions without a conducive regulatory and legislative framework. Although TMG had initiated a program for voluntary reductions in 2002, this had a very limited effect in achieving actual emissions reductions, which then led TMG to introduce the mandatory ETS. The necessary legislative provisions for the ETS were enacted by the Tokyo Metropolitan Assembly, thus institutionalizing the ETS in a legally binding and enforceable framework.

Source: Cities and Climate Change Mitigation: Case Study on Tokyo's Emissions Trading System (report by PADECO Co. Ltd.).

response is common. Introducing congestion charges and direct fees for the amount of electricity or water used reduces consumption or pollution. A similar response occurs in solid waste management: waste production was reduced by nearly half when tipping fees were introduced in some communities (World Bank 1999).

Significant action by cities on climate change now will have positive economic returns in many cases. For example, action on renewable energy and energy efficiency in cities would reduce municipal service operating costs. The greenhouse gas abatement cost curve in Figure 18 clearly presents a number of profitable mitigation actions. Those listed below the median line are ones that will have positive returns and, thus, should be funded and undertaken immediately to reap the benefits. If city climate change actions are delayed, then future costs of mitigation and adaptation will increase significantly. Abatement cost curves specific to individual cities—with clear assumptions—are needed.

The World Bank is now working with partners to develop city-specific marginal abatement cost curves. A finer scale of differentiated actions, specific to key cities, will provide a powerful policy tool. Work will also proceed to develop analogous cost curves for adaptation, although this is expected to be more challenging since there is no unit for risk reduction similar to greenhouse gas abatement (that is, cost per ton reduced).

PART V
Support for Cities

A Call for Action

The 21st century has brought a double challenge to cities—a rapid increase in population and economic activity, and the urgency to reduce carbon dependency and move towards a zero-carbon world. The drama is that many developing cities are already facing overwhelming challenges to provide basic services to billions of people actually living in inadequate conditions today. Climate change adds a layer of urgency and complexity to an already crowded agenda. The skills and partnerships needed to respond to climate change in the urban sector are, however, the same skills needed to provide an improved quality of life for many of the world's poor: better city management, basic service delivery, equity, and good local governance with robust ties across all levels of government.

Climate change and urbanization are included in the strategies and reflections of most international finance institutions, think tanks, private sector partners, and government planning agencies, including the World Bank. Annex C includes a summary of urban climate change initiatives in which some of these organizations are involved. Reflecting the importance of the recently inaugurated 'Decade of the City', the World Bank's new Urban Sector Strategy was launched in November 2009 in Singapore. It recognizes the Bank's extensive experience in the sector and explicitly includes cities and climate change as an important component of the Bank's lending and analytical support to development.

The enormity of the task at hand calls for a broad coalition of partners among international agencies, cities, and communities at large. The World Bank can play an important role in coalescing efforts, building synergy and maximizing complementarities. In some cities, for example, there are more than 30 active World Bank-supported initiatives, and yet cities usually do not benefit from the coordinating aspects typically available to countries. Many World Bank client cities have a program of financial support and analytical services much larger than most countries. Sao Paulo, Jakarta, Mexico City, and Cairo have World Bank partnerships as comprehensive as most country assistance programs. A new city assistance strategy, similar to country assistance strategies, needs to evolve. For the World Bank, launching and coordinating this suite of support in receptive and proactive key cities is a priority.

The time is ripe to deepen the work being carried jointly with active partners. The World Bank is a strong member of the UNEP, UN-HABITAT, World Bank joint work program supported by Cities Alliance. Additional partnering is needed, including partnerships with the private sector, OECD, municipal associations such as C40, UCLG and ICLEI, the academic community, and leading-example cities. The private sector is emerging as a key partner in the climate change agenda. Such trade associations as the World Business Council for Sustainable Development, World Economic Forum, and individual firms with credible in-house urban research departments are developing innovative support programs with cities. The magnitude and urgency of climate change encourages an "all hands on deck" response.

Climate change might be a sufficiently strong catalyst to bring several partners and programs together within receptive cities. The World Bank urges all agencies and businesses working on cities to use and encourage broad take-up of tools, such as the Global City Indicators Facility (GCIF), urban risk assessments, and a common greenhouse gas standard as part of a suite of urban metabolism indicators. Having common and standard metrics for urban areas and initiatives is extremely important and helpful in the long run for cities. Similarly, approaches from the private sector would benefit from a common, public good platform of shared information available to all cities.

Cities especially do not view a rigid a distinction between 'developing and developed' so where

practicable, tools, information sharing, and assistance to cities should be applicable to all cities.

Dealing with climate change at the city level is an integral part of city planning and management. It requires the implementation of tools that monitor local quality of life, the provision of basic services, and the assessment of whether city performance is in line with citizens' expectations. Although there is ample literature on city management and how mayors and city managers access toolkits for different purposes, a set of specific tools have been developed in the past two years with a focus on helping cities deal with climate change.

Initiatives and Tools

The World Bank and its key partners, such as UNEP, UN-HABITAT and Cities Alliance, offer a variety of tools to city managers, policy makers, and urban researchers. Some of the ongoing tools are described below.

(a) **Global City Indicators Program.** Responding to the need for cities to have a standard set of performance and quality of life indicators, the World Bank and key partners launched the Global City Indicators Program at the 4th World Urban Forum, November 2008 in Nanjing, China. The Program (www.cityindicators.org) provides an established set of 27 "core" and 26 "supporting" city indicators with a globally standardized methodology that allows for global comparability of city performance and knowledge sharing. The majority of these indicators are relevant to climate change. The city-led initiative enables cities to do the following: measure, report, and improve their performance and quality of life; facilitate capacity building; and share best practices through an easy-to-use web portal. The Program is being managed by the Global City Indicators Facility, based at the University of Toronto, which oversees the development of indicators and helps cities participate.

(b) **Greenhouse Gas Emissions Standard.** As mentioned above, cities need regular baseline estimates of total greenhouse gas emissions. These baselines need to be consistent with each country's national inventory. So far, city inventories are based on the availability of data and the common sense of the research agency. To facilitate city-to-city comparisons and eventually international emissions trading, standardized, credible greenhouse gas emission inventories are critical. In this context UNEP, and UN-HABITAT have launched an 'open-sourced,' harmonized protocol for quantifying city greenhouse gas emissions attributable to cities based on their own experiences. Now cities have a standardized means of measuring their greenhouse gas emissions and comparing them over time. The effort builds on the considerable experience of cities and organizations such as ICLEI and C40/CCI. It fosters rapid inventories and regular updating of all large cities (over 1 million people) and is supposed to offer a credible starting point of a critical mass of cities. The demand for data is straightforward and the methodology is simple. The inventory is seen as a minimal starting point and many cities have much more detailed breakdowns.

(c) **The Energy Sector Management Assistance Program (ESMAP).** ESMAP (www.esmap.org) is a global knowledge and technical assistance partnership managed by the World Bank. In 2008, ESMAP launched its *Energy Efficient Cities Initiative* (EECI) to help cities meet their energy challenges. The EECI is a flexible and demand-driven program that identifies innovative ways to improve energy efficiency in the delivery of city services and reduce the costs and environmental impacts of energy use. EECI, in turn, supports the development of the *Rapid Assessment Framework* (RAF), a practical tool to conduct rapid assessment in cities to identify and prioritize sectors. The RAF looks at energy efficiency in six sectors: buildings, transport, waste/wastewater, public lighting, solid waste, and power/heating. It is envisaged that the RAF will be completed by late 2010 and will provide a global framework to facilitate cross city comparison and sharing of best practices on energy saving initiatives in the six main sectors. In addition to the RAF, ESMAP has a project database of city case studies, which is publicly available.

Table 5

Policy Tools for Local-level Action on Climate Change

Policy Goals	Policy Tools	Policy Sector	Mode of Governance	Complementary Measures
REDUCE GHG EMISSIONS				
Increase density/ Improve city design	Restructuring land regulations to allow greater densities, reform zoning, review floor space ratio regulation	Land-use zoning	Regulatory	Increase mass transit use
	Mixed-use zoning to shorten trip distances	Land-use zoning	Regulatory	Discourage vehicle use Support nonmotorized use
Support mass transit/ Discourage private car ownership	Expanding mass transit service Reducing private motor vehicle use Improving quality of public transportation Linkages with multiple modes of travel Transit-oriented development zones	Land-use zoning	Regulatory	Enforce traffic management measures
	Tax-incentives to developers near public transportation	Land-use zoning	Regulatory	Increase mass transit use
	Improved quality of public transportation	Transportation	Service provision	Discourage vehicle use
Discourage vehicle use	Driving and parking restrictions in certain zones	Transportation	Regulatory	Improve quality of public transportation
Support nonmotorized means of travel	Traffic calming and increasing bike lanes	Transportation	Regulatory/ Service provision	Discourage vehicle use
Increase vehicle efficiency and alternative fuels use	Special parking privileges for alternative fuel or hybrid vehicles	Transportation	Regulatory	Enforce driving and parking restrictions in certain zones
	Purchase of fuel efficient, hybrid, or alternative fuel vehicles for city fleet	Transportation	Self-governance	–
IMPROVE ENERGY EFFICIENCY OF CITY BUILDINGS				
Increase building energy efficiency	Zoning regulation to promote multi-family and connected residential housing	Land-use zoning	Regulatory	Increase attractiveness of higher density developments Provide linkages with multiple modes of travel Expand mass transit service
	Energy efficiency requirements in building codes	Building	Regulatory	Coordination of public- private retrofitting programs Stringent enforcement policies
	Coordination of public- private retrofitting programs	Building	Service provision	Energy efficiency requirements in building codes
Increase share of renewable and captured energy generation	Building codes requiring a minimum share of renewable energy	Building	Regulatory	Technical support to developers and property owners
	District heating and cooling projects	Building	Regulatory/ Service provision	End requiring connection to district heating/cooling system
	Waste-to-energy programs	Waste	Service provision	Regulate incinerator emissions Remove recyclables from waste
REDUCE VULNERABILITY TO FLOODING AND NATURAL DISASTERS				
Reduce vulnerability to flooding and increased storm events	Zoning regulation to create more open space	Land-use zoning	Regulatory	Zoning regulation to promote multi-family and connected residential housing
	Retrofitting and improvements to mass transit systems to reduce potential damage from flooding	Transportation	Service provision	Improve quality of public transportation Provide linkages with multiple modes of travel
	Designation of open space as buffer zones for flooding	Natural Resources	Regulatory	Zoning regulation to create more open space Zoning regulation to promote multi-family and connected residential housing
	Building codes requiring minimum ground clearance	Building	Regulatory	Designation of open space as buffer zones for flooding
Reduce urban heat-island effects and vulnerability to extreme heat	Retrofitting and improvements to mass transit systems to reduce potential damage from extreme temperatures	Transportation	Service provision	Improve quality of public transportation Provide linkages with multiple modes of travel Expand mass transit service
	Tree-planting programs	Natural Resources	Service provision/Self Gov.	Increase attractiveness of higher density developments
	Building codes requiring design materials that reduce heat-island effects	Building	Regulatory	Energy efficiency requirements in building codes
	Building codes requiring "green roofs" with vegetation or white surfaces	Building	Regulatory	Energy efficiency requirements in building codes

Source: Kamal-Chaoui and Roberts 2009.

(d) **Urban Risk Assessment.** In partnership with UNEP and UN-HABITAT, and with the support of Cities Alliance, the World Bank is developing a standardized, cost-effective tool to carry out an urban risk assessment. It is intended to harmonize how information is gathered and analyzed related to disaster and climate risk at the city level, and to identify areas and populations that are most vulnerable, typically those living in informal settlements. The Urban Risk Assessment will provide a methodological framework for both qualitative and quantitative assessments that will enhance a local government's capacity to do the following:

- Identify primary and secondary hazards arising from disaster and climate change risks,
- Assess relative exposure and vulnerability of specific city assets and populations,
- Analyze institutional capacities and data availability, and
- Quantify city vulnerabilities through the application of a baseline-benchmarking approach to assess progress over time and space.

The tool will also provide a mapping of slum areas for prioritizing adaptation measures and identifying populations at greatest risk. See Section II for more details.

(e) **Urbanization Review.** Considering economic geography, spatial analysis, and the impact of growth on land and housing markets, the Urbanization Review supports governments' policies to help make urbanization more efficient and inclusive. The review will focus on outcomes and constraints faced by individual cities, as well as zoom out and consider interactions among cities and between cities and their peripheral rural and peri-urban areas. The diagnostics in the Urbanization Review will examine whether (a) institutions regulating factor markets and delivering basic services have laid the foundations for high quality urbanization; (b) extra and intra urban infrastructure are connecting places and amplifying production efficiency; and (c) targeted remedial and social interventions enhance livability and sustainability by offsetting government and market failures most visible in slum formation and environment degradation. The Urbanization Review will employ a fairly standardized suite of analytic tools based on quantifying economic efficiency and welfare losses from distortionary factor market regulations, infrastructure and service delivery shortfalls, and negative externalities associated with urbanization. It will be organized in three parts—descriptive, analytic, and prescriptive—and will be a multiyear programmatic effort to be carried out for countries, as well as subnational areas, such as provinces or metropolitan regions.

(f) **Eco^2 Cities: Ecological Cities as Economic Cities.** Eco^2 Cities is built on the foundation that Ecological Cities can be Economic Cities. Eco^2 Cities helps cities plan, design, invest, and manage integrated urban systems, moving away from single-purpose, short-term and sector-specific approaches to multi-purpose, long-term and integrated solutions. The Eco^2 framework is based on four key principles:

- A City Based Approach that enables local governments to take into account their specific circumstances
- An Expanded Platform for Collaborative Design and Decision Making that aligns the actions of key stakeholders
- A System Approach that enables cities to realize the benefits of integration by planning, designing, and managing the whole urban system
- An Investment Framework that values Sustainability and Resiliency by incorporating and accounting for life cycle analysis, the value of all capital assets (manufactured, natural, human, and social), and a broader scope of risk assessments in decision making

A regional program supporting Eco^2 in the East Asia and Pacific region, with specific sub-programs in Vietnam, Indonesia, the Philippines, and Laos is being launched in 2010 (see www.worldbank.org/eco2).

(g) **Green Buildings.** Following the lead of UNEP, the World Bank intends to support the green buildings program. These green building practices need to be integrated within similar forward planning efforts in transportation and urban planning practices.

(h) **Cap and Trade Program (Emissions Trading System).** A few global cities, such as Tokyo and Tianjin, are coming forward with plans for city-based cap and trade programs. The World Bank will support these efforts and try to expand them globally to enable these city-based programs to trade across cities, if sufficiently developed (Annex J).

(i) **Knowledge Platform.** Building on the success of Metropolis' Cisco-supported listing of city experience on mitigation and adaptation presented in December 2009, the Bank with program partners UNEP, UN-HABITAT and Cities Alliance will endeavor to build on this database and ensure a one-stop location for cities and climate change experience.

(j) **City-Wide Carbon Finance Methodology.** The World Bank's Carbon Finance Unit launched the city-wide methodology for carbon finance at Carbon Expo 2009. The methodology is based on a city-wide greenhouse gas inventory and supports a broad array of interventions designed to reduce greenhouse gas emissions. The pilot of the program is in Amman, Jordan. The World Bank will work to increase the number of cities that avail themselves of this new methodology.

(k) **A Sustainability Tool.** Several companies have developed proprietary software tools to measure the sustainability of a potential infrastructure investment or policy. An estimated 200 such tools now exist. The World Bank will support the global engineering community and their key partners to develop nonproprietary credible tool for cities and others.

Lending, Advisory Services, Client Partnerships

For more than 25 years, the World Bank has supported investment projects in greenhouse gas mitigation and energy efficiency. Recently, Development Program Loans (DPLs) specifically target policies for greenhouse gas mitigation. DPLs are expected to target a few select cities, and support policy reforms and activities directed at adaptation efforts. Infrastructure components in Sector Investment Loans will likely follow IFC practices and include a comprehensive assessment of total lifecycle greenhouse gas emissions from the investment. Feasibility and pre-feasibility studies for major infrastructure will need to incorporate aspects of robust decision making. For example, in long-lived infrastructure, particularly that which serves cities, a more comprehensive assessment in light of an uncertain climate will be required. A separate paper on climate finance for cities is under preparation (expected to be presented at the C40 conference in May 2011).

As highlighted through the GEF- supported low carbon growth review for Beijing, the World Bank will need to provide more assistance to cities on low carbon growth strategies, and green city development. Building on the Cities Alliance supported UNEP, UN-HABITAT, World Bank joint work program (see Annex C), the World Bank will review efforts to bring in additional partners, particularly the private sector and inclusion of sustainable city efforts. The Climate Investment Fund-supported Urban Transformation on greenhouse gas mitigation in Bangkok is an important example of financial assistance catalyzing a broad array of efforts. An amount of $76 million was allocated specifically to Bangkok for support of the six-part greenhouse gas mitigation strategy.

Two additional tools are being developed: the Mayors' Task Force on Urban Poverty and Climate Change and the Mayors' Handbook on Adaptation. The Mayors' Task Force was established at the Copenhagen COP 15 meeting December 2009 with the support of World Bank President Robert Zoellick (Box 3). City partners include Mexico City

(Chair), Dar es Salaam, Sao Paulo, and Jakarta: a comprehensive report is proposed to be presented at the C40 bi-annual meeting in Sao Paulo, Brazil, in May 2011. The Mayors' Handbook will outline proven strategies for cities to prepare for a changing climate.

Taking advantage of experience from Local Agenda 21, Climate Change-considerate City Development Strategies, Local Resilience Action Planning, and Eco^2, the Bank will work with more cities as they try to combine these programs and develop policy and investment strategies.

Finally, the World Bank will seek to establish special partnerships with three to six cities per region (about 25 to 30 cities in total). These cities would have a minimum 10-year partnership plan established. The Bank would endeavor to combine all activities within the partner city—ensuring maximum synergies. In some cities, such as Jakarta and Sao Paulo, the Bank has more than 25 ongoing activities at any one time. Better coordinating these and bringing in key development and private sector partners will provide considerable benefits. Climate change, with its broad city agenda, can be used to bring together several disparate programs.

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Glossary

All definitions are from IPCC documents, available at http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf (accessed April 2010).

Adaptability
See *Adaptive capacity*.

Adaptation
Adjustment in natural or *human systems* to a new or changing environment. Adaptation to *climate change* refers to adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Adaptation costs
Costs of planning, preparing for, facilitating, and implementing *adaptation* measures, including transition costs.

Adaptive capacity
The ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Climate
Climate in a narrow sense is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables, such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the *climate system*.

Climate change
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or *external forcings*, or to persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *United Nations Framework Convention on Climate Change* (UNFCCC), in its Article 1, defines "climate change" as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes. See also *climate variability*.

Climate model (hierarchy)
A numerical representation of the *climate system* based on the physical, chemical, and biological properties of its components, their interactions and *feedback* processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity—that is, for any one component or combination of components a "hierarchy" of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical *parametrizations* are involved. Coupled atmosphere/ocean/sea-ice *general circulation* models (AOGCMs) provide a comprehensive representation of the climate system. There is an evolution towards more complex models with active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual *climate predictions*.

Climate sensitivity
In IPCC assessments, "equilibrium climate sensitivity" refers to the equilibrium change in global mean surface temperature following a doubling of the atmospheric (*equivalent*) CO_2 concentration. More generally, equilibrium climate sensitivity refers to the equilibrium change in surface air temperature following a unit change in *radiative forcing* (°C/Wm-2). In practice, the evaluation of the equilibrium climate sensitivity requires very long simulations with coupled *general circulation models*. The "effective climate sensitivity" is a related measure that circumvents this requirement. It is evaluated from model output for evolving non-equilibrium conditions. It is a measure of the strengths of the *feedbacks* at a particular time and may vary with forcing history and climate state. See climate model.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, and others) of the *climate* on all *temporal and spatial scales* beyond that of individual weather events. Variability may be due to natural internal processes within the *climate system* (internal variability), or to variations in natural or *anthropogenic external forcing* (external variability). See also *climate change*.

Equivalent CO_2 (carbon dioxide)
The concentration of *carbon dioxide* that would cause the same amount of *radiative forcing* as a given mixture of carbon dioxide and other *greenhouse gases*.

Inertia
Delay, slowness, or resistance in the response of the *climate*, biological, or *human systems* to factors that alter their rate of change, including continuation of change in the system after the cause of that change has been removed.

Maladaptation
Any changes in natural or *human systems* that inadvertently increase *vulnerability* to climatic *stimuli*; an *adaptation* that does not succeed in reducing vulnerability but increases it instead.

Mitigation
An *anthropogenic* intervention to reduce the *sources* or enhance the *sinks* of *greenhouse gases*.

Mitigative capacity
The social, political, and economic structures and conditions that are required for effective *mitigation*.

Rapid climate change
The *nonlinearity* of the *climate system* may lead to rapid climate change, sometimes called abrupt events or even surprises. Some such abrupt events may be imaginable, such as a dramatic reorganization of the *thermohaline circulation*, rapid deglaciation, or massive melting of *permafrost* leading to fast changes in the *carbon cycle*. Others may be truly unexpected, as a consequence of a strong, rapidly changing, forcing of a nonlinear system.

Resilience
Amount of change a system can undergo without changing state.

Sensitivity
Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related *stimuli*. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding because of *sea-level rise*). See also *climate sensitivity*.

Sequestration
The process of increasing the carbon content of a carbon *reservoir* other than the *atmosphere*. Biological approaches to sequestration include direct removal of *carbon dioxide* from the atmosphere through *land-use change*, *afforestation*, *reforestation*, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing *fossil fuels* to produce hydrogen- and carbon dioxide-rich fractions and long term storage in underground in depleted oil and gas reservoirs, coal seams, and saline *aquifers*. See also *uptake*.

Uptake
The addition of a substance of concern to a *reservoir*. The uptake of carbon-containing substances, in particular *carbon dioxide*, is often called (carbon) *sequestration*. See also *sequestration*.

Urbanization
The conversion of land from a natural state or managed natural state (such as agriculture) to cities; a process driven by net rural-to-urban migration through which an increasing percentage of the population in any nation or region come to live in settlements that are defined as "urban centers."

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its *sensitivity*, and its *adaptive capacity*.

List of Abbreviations and Acronyms

AFOLU	Agriculture, Forestry, and Other Land Use change
BOD	Biochemical Oxygen Demand
C40	Climate Leadership Group-"Large cities committed to tackling climate change"
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
COP15	Conference of Parties
DHW	Domestic Hot Water
EIG	Environmental Integrity Group
EPA	U.S. Environmental Protection Agency
ESMAP-EECI	Energy Sector Management Assistance Program- Energy Efficient Cities Initiative
GCIF	Global City Indicators Facility
GDP-PPP	Gross Domestic Product at Purchasing Power Parity
GEF	Global Environment Facility
GHG	Greenhouse Gas(es)
ICLEI	International Coalition for Local Environmental Initiatives
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LECZ	Low-Elevation Coastal Zones
LPG	Liquefied Petroleum Gas
OECD	Organisation for Economic Co-operation and Development
T&D	Transmission and Distribution
tCO_2e	Tons of Carbon Dioxide Equivalent
US (or USA)	United States
UCLG	United Cities and Local Governments
UN	United Nations
UNEP	United Nations Environment Programme
UNEP-SBCI	United Nations Environment Programme-Sustainable Buildings and Climate Initiative
UNFCCC	United Nations Framework Convention on Climate Change
UN-HABITAT	United Nations Human Settlements Programme
UR	Urbanization Review
WRI	World Resources Institute

ANNEX A
International Standard for Measuring Greenhouse Gas Emissions Standard

The international standard for determining greenhouse gas emissions for cities, presented at the June 2009 Urban Research Symposium in Marseille by Kennedy et al.[8] and proposed by UNEP, UN-HABITAT, World Bank, recommends that emissions are reported from four categories: energy (including emissions from electricity consumption, heating and industrial fuel use, ground transport, and aviation and marine transport); industrial processes and product use; agriculture, forestry, and other land use change (known as AFOLU); and waste. Kennedy et al. also suggest reporting emissions embodied in fuel, water, food, and building materials as additional items. Research conducted by Hillman and Ramaswami[9] demonstrated that including Scope 3 emissions in eight U.S. city case studies increase urban inventories by an average of 45 percent. The following reported items are recommended: emissions produced in the geographical boundary of the city (Scope 1); emissions released outside the geographical boundary of the city that enable energy, including electricity and district heat, to be consumed in the city (Scope 2); and emissions from waste, aviation, and marine transport, and embodied in fuel, food, building materials, and water used in the city (Scope 3).

Although data can be difficult to obtain, the reporting of upstream emissions provides the most comprehensive view of the urban system for decision makers. Upstream emissions may be used to inform systemic consequences of climate change actions. Some actions that reduce climate change in cities may increase emissions in rural areas; for example, exporting cement manufacturing to rural areas removes emissions from cities but increases emissions associated with transportation. Described in Kennedy et al., Ramaswami's Scope 3 analysis of Denver[10] led to the adoption of green concrete policies, reducing upstream emissions in new construction projects. As cities create strategic plans for mitigation, it is important to consider these upstream impacts.

Four standardized tables provide a consistent reporting format for emissions: 1) community information (Table A.1); 2) greenhouse gas emissions by sector (Table A.2); 3) greenhouse gas emissions by fuel or activity type (Table A.3); and 4) upstream (embodied) greenhouse gas emissions (Table A.4).

[8]Kennedy C., A. Ramaswami, S. Carney, and S. Dhakal. 2009. "Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions." *Proceedings of the 5th Urban Research Symposium* Marseille, France: June 28-30, 2009.

[9]Hillman, T. and A. Ramaswami. 2009. "Greenhouse Gas Footprints and Energy Use Benchmarks for Eight US Cities." ***Env. Sci. & Tech.*** 44(6): 1902-10.

[10]Ramaswami, A., T. Hillman, B. Janson, M. Reiner, and G. Thomas. 2008. "A Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories." ***Env. Sci. & Tech***. 42(17): 6455-61.

Table A.1.
Community Information

Name of city or local region	
Country	
Inventory year	
Reporting date	
Population (year-round residents)	
Land area (sq. kilometers)	
Urbanized area (sq. kilometers)	
Name, status, and address of reporter	
Name, status, and address of third party verifier (if applicable)	
Other information, e.g., websites of fuller inventory report or emissions reduction program	

Table A.2.

Greenhouse Gas Emissions by Sector

	SCOPE	CO	CH4	N2O	HFCs	PFCs	SF6s	TOTAL
Units		kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.
ENERGY								
a) Stationary Combustion								
Electricity (incl. T&D losses)	1,2,3							
District energy and CHP	1,2							
Energy from waste	1							
Commercial & Institutional	1							
Residential	1							
Manufacturing Industries & Construction	1							
Other	1							
b) Mobile Combustion								
Road transportation: vehicles	1							
Road transportation: trucks	1							
Railways	1							
Domestic aviation	3							
International aviation	3							
Domestic marine	3							
International marine	3							
Other	1							
c) Fugitive Sources								
INDUSTRIAL PROCESSES								
Mineral industry	1							
Chemical industry	1							
Metal industry	1							
Electronics industry	1							
Other	1							
Solvent and product use	1							
AFOLU	1							
WASTE								
Solid waste disposal on land	1,3							
Wastewater handling	1,3							
Waste incineration	1,3							
TOTAL								

Table A.3.

Greenhouse Gas Emissions by Fuel or Activity Type

II.	Activity Data			Emissions Factor[xiii,xiv]			Total GHGs
	Value	Units	Tier[xv]	Value	Units	Tier	t CO_2 e
ENERGY							
Electricity (on-site renewable)		GWh	N/A	0	t CO_2 e / GWh	N/A	0
Electricity (grid)		GWh			t CO_2 e / GWh		
Natural gas		TJ			t CO_2 e / TJ		
Fuel oil		TJ			t CO_2 e / TJ		
Coal		TJ			t CO_2 e / TJ		
Gasoline		TJ			t CO_2 e / TJ		
Diesel		TJ			t CO_2 e / TJ		
Jet Fuel		TJ			t CO_2 e / TJ		
Marine Fuel		TJ			t CO_2 e / TJ		
<add fuels as appropriate[xvi]>		TJ			t CO_2 e / TJ		
INDUSTRIAL PROCESSES							
<add industrial products as appropriate>		kt			t CO_2 e / kt		
WASTE							
Solid waste disposal on land		kt			t CO_2 e / kt		
Wastewater handling		kt BOD			t CO_2 e / kt BOD		
Waste incineration		kt			t CO_2 e / kt		
AFOLU							
<add AFOLU activity data as appropriate>							

Notes on Tables A.2 and A.3

[iv]This category is for emissions from the generation of electricity consumed in the city, regardless of whether the generation occurs inside or outside of the city boundaries; it includes emissions associated with transmission and distribution losses, but excludes electricity generated by combined heat and power (CHP).

[v]May include district energy systems or heat pipes for which emissions occur outside of the city boundaries.

[vi]Aviation emissions should be determined from fuel loaded onto planes within the boundaries of the city.

[vii]See iii.

[viii]Marine emissions should be determined from fuel loaded onto vessels within the boundaries of the city.

[ix]See v.

[x]This includes emissions from residential, commercial, and industrial waste that are emitted inside or outside of the city boundaries.

[xi]May include emissions from wastewater handling that occur outside of the city boundaries.

[xii]Excludes emission from energy generation.

[xiii]Where the emissions factor for a fuel depends on the application or sector, then the fuel may be entered multiple times in this table. For example, the emissions factor for stationary combustion vary for energy industries, manufacturing industries, the commercial sector and the residential sector (see Tables 2.2 to 2.5 of Volume 2 of the 2006 IPCC Guidelines).

[xiv]The calculation of emissions from combustion of some fuels may not be as straightforward as multiplying a single activity level by a single emissions factor. For example, with road transportation, emissions of CO_2 depend on the quantity of fuel consumed, while emissions of CH_4 and N_2O also depend on driving characteristics, vehicle type and emissions control technology. In such cases, a weighted averaged emission factor should be reported in the table.

[xv]The IPCC's Tiers (1, 2, or 3) provides an indication of the accuracy and complexity of approach used to determine activity levels or emissions factors. In some cases there may only be one Tier. When a city is unable to use an IPCC tier approach, e.g., due to lack of data, then any alternate method used should be recorded in a footnote to the table.

[xvi]Other fuels such as CNG/LPG, biofuels, etc. should be added here where they are used in significant quantities. Emissions factors are available in the IPCC guidelines or national inventories.

Table A.4.

Upstream (Embodied) Greenhouse Gas Emissionsxvii

III.	Activity Data		Emissions Factor		Total GHGs
	Value	Units	Value	Units	t CO_2 e.
ENERGY					
Electricity (on-site renewable)		GWh		t CO_2 e / GWh	
Electricity (grid)		GWh		t CO_2 e / GWh	
Natural gas		TJ		t CO_2 e / TJ	
Fuel oil		TJ		t CO_2 e / TJ	
Coal		TJ		t CO_2 e / TJ	
Gasoline		TJ		t CO_2 e / TJ	
Diesel		TJ		t CO_2 e / TJ	
Jet Fuel		TJ		t CO_2 e / TJ	
Marine Fuel		TJ		t CO_2 e / TJ	
<add fuels as appropriate>		TJ		t CO_2 e / TJ	
WATER		ML		t CO_2 e/ ML	
BUILDING MATERIALS					
Cement		Kt		t CO_2 e / kt	
Steel		Kt		t CO_2 e / kt	
Bricks		Kt		t CO_2 e / kt	
<add building materials as appropriate>					
FOOD					
Cereals		Kt		t CO_2 e / kt	
Fruits		Kt		t CO_2 e / kt	
Meat		Kt		t CO_2 e / kt	
Seafood		Kt		t CO_2 e / kt	
Dairy		Kt		t CO_2 e / kt	
Other		Kt		t CO_2 e / kt	

Notes on Table A.4

[xvii]While the use of physical units (e.g., TJ or kt) rather than monetary units is encouraged for this table, some of the emissions factors may be derived from Environmental Input Output (EIO) models. Multiregional EIO tables are available for many parts of the world, see for example: http://www.feem-project.net/exiopol/ and https://www.gtap.agecon.purdue.edu/databases/v7/default.asp. The source of emissions factors should be reported as a footnote to the table.

ANNEX B.
Footnotes Linked to Table 4

i Value includes emissions from aviation and marine sources.

† Value for Denver is available, including embodied emission in food and cement: 25.3 tCO_2e/cap, see Ramaswami, A., T. Hillman, B. Janson, M. Reiner, and G. Thomas (2008), "A Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories." *Environmental Science and Technology*. Vol. 42 No. 17. pp 6455-6461.

1 Values provided by ICLEI.

2 City of Sydney (2008), "Local Government Area Greenhouse Gas Emissions", Available: http://cityofsydney.nsw.gov.au/Environment/GreenhouseAndAirQuality/CurrentStatus/GreenhouseGasEmissions.asp, [Accessed March 2010].

3 Kennedy C., Ramaswami A., Carney S., and Dhakal S. (2009), "Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions", Proceedings of the 5th Urban Research Symposium, Marseille, France, June 28-30, 2009.

4 City of Toronto (2007), *Greenhouse Gases and Air Pollutants in the City of Toronto* (2004). Available: http://www.toronto.ca/teo/pdf/ghg-aq-inventory-june2007.pdf. [Accessed March 2010].

5 Kennedy C., J. Steinberger, B. Gasson, Y. Hansen, T. Hillman, M. Havranek, D. Pataki, A. Phdungsilp, A. Ramaswami, and G. Villalba Mendez (2009), "Greenhouse Gas Emissions from Global Cities." *Environ. Sci. Technol.*, 43, 7297–7302.

6 City of Vancouver (2007), *Climate Protection Progress Report*. Available: http://vancouver.ca/sustainability/documents/Progress2007. pdf. [Accessed March 2010].

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9 Sugar, L. (2010), *Amman's Greenhouse Gas Emissions*. The World Bank.

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14 The Center for Neighborhood Technology (2008), *Chicago's Greenhouse Gas Emissions: An Inventory, Forecast and Mitigation Analysis for Chicago and the Metropolitan Region*. Chicago Climate Action Plan. Available: http://www.cnt.org/repository/CNT_Climate_Research_Summary_9.17.08.pdf. [Accessed March 2010].

15 City & Borough of Juneau (2009), *City & Borough of Juneau Greenhouse Gas Emissions Inventory for 2007*. Available: http://www.juneau.org/clerk/boards/Sustainability/Agendas_and_Minutes/Agendas/documents/Juneau_Report_GHG_Inventory_DRAFT_2-4-09_with_updated_links131.pdf. [Accessed March 2010].

16 City of Menlo Park, *Greenhouse Gas Emissions Analysis – 2005 Community Emissions Inventory & 2005 Municipal Operations Emissions Inventory*. Available: http://www.menlopark.org/departments/env/ggeir_208.pdf. [Accessed March 2010].

17 Air Quality Division (2005), *District of Columbia Greenhouse Gas Inventories and Preliminary Projections*. District of Columbia Department of Health, Air Quality Division.

ANNEX C
Cities and Climate Change Activities in Key Organizations

All information below was provided by the organization listed, unless otherwise indicated.

C40

(Information from www.c40cities.org)

C40 is involved in two primary cities and climate change activities. 1) Carbon Finance Capacity Building, in partnership with the World Bank Carbon Finance Unit, the Clinton Climate Initiative (CCI), and others, helps megacities in the global south gain access to carbon finance opportunities. 2) The C40 Urban Life program, in partnership with CCI and Arup, uses Arup's 'sustainable integrated development' approach to help cities plan carbon reduction programs. C40 also hosts events and workshops to discuss cities and climate change issues.

Carbon Disclosure Project

(Information from www.cdproject.net)

The Carbon Disclosure Project collects information on greenhouse gas emissions and carbon reduction plans for 2,500 organizations throughout the world, including cities. When organizations voluntarily disclose their carbon inventory, they can gain important baseline information and gain knowledge for planning carbon reduction plans.

CDP issued a publication on cities and emissions in 2008: "Carbon Disclosure Project: Cities Pilot Project 2008". This report was prepared in partnership with ICLEI.

Cities Alliance

Cities Alliance is supporting five primary activities in cities and climate change.

1) A Joint Program on Cities and Climate Change in partnership with the World Bank, UNEP, and UN-HABITAT was established to produce a greenhouse gas inventory for cities, develop a city risk assessment, a cities and climate change clearinghouse, a handbook for mayors on climate change, and a climate change position paper.

2) Cities Alliance supported the first Urban Climate Change Research Network (UCCRN) Assessment Report on Climate Change, a report that informs city decision makers on climate risk reduction through adaptation and mitigation.

3) Cities Alliance supports a joint project with the World Bank and UN-HABITAT to strengthening climate adaptation and disaster risk management in Latin American & Caribbean cities. This project will increase awareness and understanding of climate change risks and impacts on mid-sized cities among urban planners and/or mayors of such cities in the region.

4) Cities Alliance and the Global Facility for Disaster Risk Reduction (GFDRR) are working on a project to support cities and disaster management (focused on the Philippines, Senegal, and Burkina Faso). This project supports local governments in adopting more systematic and durable mechanisms to prevent and respond more effectively to disasters, risks and vulnerabilities, both climate, and nonclimate related. It also mobilizes and engages local governments and their associations to work in alignment with national governments when addressing the challenges posed by disasters.

5) Cities Alliance is supporting IIED in producing publications that share knowledge and learning about cities to ensure that city decision makers are informed about the basic concepts that link climate change and urban management.

Clinton Climate Initiative (CCI)

The William J. Clinton Foundation launched the Clinton Climate Initiative (CCI) to create and advance solutions to the core issues driving climate change. Working with governments and businesses around the world to tailor local solutions that are economically and environmentally sustainable, CCI focuses on three strategic program areas: increasing energy efficiency in cities, catalyzing the large-scale supply of clean energy, and working to measure and value the carbon absorbed by forests. In each of these programs, CCI uses a holistic approach to address the major sources of greenhouse gas emissions and the people, policies, and practices that impact them.

As the delivery partner of the C40, CCI works with some of the world's largest cities to help develop large-scale, emissions reducing projects. CCI has helped initiate more than 250 building retrofit projects in more than 20 different cities. Many of these projects have begun or completed construction, including the following: public buildings in Houston, London, and Seoul; commercial buildings such as the Empire State Building in New York, large shopping centers in India and Southeast Asia, and large department stores in Korea as well as others; universities in Mexico City and Hong Kong; and housing developments in New York, Chicago, and Toronto. In Los Angeles, CCI is helping the city to replace 140,000 streetlights with light-emitting diode (LED) fixtures, which will cut CO_2 emissions in the city by 40,500 tons and save the city up to $10 million each year in energy and maintenance costs. CCI has also helped Delhi to launch the first integrated waste management system in India, which will handle 1,200 tons of waste per day, create over 1,000 jobs, and prevent the release of 96,000 tons of carbon dioxide into the atmosphere each year.

In collaboration with the U.S. Green Building Council, CCI is setting new standards for large-scale property developments in cities around the world. Through the Climate Positive Development Program, CCI is working with 18 urban developments across 10 countries that have committed to reduce their greenhouse gas emissions to below zero.

For more information, visit http://www.clinton-foundation.org/cci.

Energy Sector Management Assistance Program (ESMAP)

The Energy Sector Management Assistance Program, a global, multi-donor technical assistance program administered by the World Bank Group, launched its Energy Efficient Cities Initiative (EECI) in December 2008, following a round-table discussion about ongoing initiatives, barriers, and opportunities, to further scale up energy efficiency impacts with representatives from client countries and partner organizations.

EECI is a flexible, cross-cutting, and demand-driven program that identifies innovative ways to improve energy efficiency in the delivery of city services across six sectors—buildings, water, transport, public lighting, solid waste and heating and power—and reduce the costs and environmental impacts of energy use. EECI is building upon existing work through broad consultation and leveraging sustainable energy investments in cities through existing, and possibly new, financing instruments, and fostering global partnerships to successfully respond to the needs of cities.

EECI has a full range of available support, from upstream market assessments to project design to program monitoring and dissemination. The five main components include the following: (i) analytical work, including tools; (ii) direct technical assistance to cities to help influence their city development strategies; (iii) a city energy efficiency case study database and innovation awards; (iv) mobilization of financing; and (v) outreach and partnerships.

Global Environment Facility (GEF)

Established in 1991, the Global Environment Facility (GEF) unites 179 member governments and 10 Implementing Agencies to address global environmental issues. As an operating entity of the financial mechanism of the UN Framework Convention on Climate Change, the GEF provides grants to developing countries and economies in transition to adapt to climate change and to mitigate their greenhouse gases emissions through energy efficiency, renewable energy, and low carbon transport and urban systems.

The GEF's portfolio on low carbon transport and urban systems now includes 75 cities all around the world, impacting the daily life of 250 million people. An amount of $200 million was committed to these projects, leveraging $2.5 billion. Through this portfolio, to date mainly focused on sustainable transport initiatives, the GEF has helped globally avoid the emission of nearly 60 million tons of CO_2. The publication "Investing in Sustainable Urban Transport: The GEF Experience" summarizes the GEF achievements in this area. See http://www.thegef.org/gef/node/1541 for more information.

During its fifth replenishment period (2010-2014), the GEF will build upon these achievements and further expand its scope to include integrated approaches to promoting energy efficient, low-carbon cities. Emphasis will be placed on comprehensive low-carbon urban planning for transport, energy efficiency, and renewable energy, covering housing, transport, public utilities, and commercial development. To achieve this objective, strong commitments from the local as well as the national governments will be particularly important, and greater attention will have to be given to measuring and quantifying global environmental benefits.

Global Facility for Disaster Risk Reduction (GFDRR)

With the support of Cities Alliance, GFDRR is working on a project on cities and disaster management focused on the Philippines, Senegal, and Burkina Faso. This project supports local governments to adopt more systematic and durable mechanisms to prevent and respond more effectively to disasters, risks, and vulnerabilities, both climate and nonclimate related. It also mobilizes and engages local governments and their associations to work in alignment with national governments when addressing the challenges posed by disasters.

Global City Indicators Facility (GCIF)

The Global City Indicators Facility (GCIF) provides a credible, internationally recognized city indicator reporting standard to enable city managers, investors, citizens, and stakeholders to measure and compare a city's performance, track trends, and have a basis for sound decision-making. The GCIF currently has several environment related indicators and is in the process of developing a number of environmental indices, including cooperation with colleagues on a Greenhouse Gas Index. The Global City Indicators Facility provides cities with a standardized web-based relational database that allows cities to enter city data and draw comparability between and among cities globally. The comprehensive web-based database enables cities to measure, report, and improve their own performance in the areas of city services and quality of life.

Indicators on climate change at the city level can inform city officials and support their existing, and indeed potentially far-reaching powers of planning, aimed at climate change adaptation and mitigation. For example, cities have the power to pass legislation related to greenhouse gas emissions; cities have the capacity to encourage participation and engage with related governmental agencies and local corporate organizations on climate change mitigation; cities can build more inclusive institutions for achieving environmental objectives; cities have the power to plan and design transportation systems that support access by all citizens and rational choices on where to live and work that is in keeping with a climate change agenda for the city; cities have the power to ensure strong and robust local economic development patterns that build economic opportunity for all citizens while addressing climate change; cities have the power to address land tenure and land rights in the city and can thereby adopt a pro-poor set of policies governing access to and environmentally safe use of land in the city; cities have important powers over building codes and zoning by-laws and can adopt flexible standards governing safer construction of housing, buildings, and infrastructure that are more resilient to climate change risk and to adopt standards on greener buildings; and cities have the power to develop creative financing tools for mobilizing investments that help to overcome climate-related threats derived from a lack of basic infrastructure and environmental amenities for all, and especially the poorest urban residents in cities.

Many of the indicators collected are highly relevant to cities and climate change: greenhouse gas

emissions measured in tons per capita, PM10 Concentration, total electrical use per capita, total residential electrical us per capita, percentage of the city's solid waste that is disposed of in an incinerator or burned openly/open dump/sanitary landfill/other means, Km of high capacity public transit system per 100,000 population, Km of light passenger transit system per 100,000 population, number of personal automobiles per capita and green area (hectares) per 100,000 population.

ICLEI-Local Governments for Sustainability

ICLEI is working in three main areas on cities and climate change:

1) The Cities for Climate Protection (CCP) Campaign, started in 1993, is the first international initiative that aims to facilitate emissions reduction of local governments through a five milestone process of measurement, commitment, planning, implementing, and monitoring. The CCP Campaign assists cities to adopt policies and implement quantifiable measures to reduce local greenhouse gas emissions, improve air quality, and enhance urban livability and sustainability. More than 1,000 cities worldwide are participating in this Campaign; each regional campaign is supported by governmental and intergovernmental institutions, including United States Agency for International Development (USAID), the European Commission and the British High Commissioner. All relevant publications can be found at www.iclei.org/index.php?id=10828 .

2) ICLEI Adaptation initiatives follow the interpretation of the five milestone process of the CCP Campaign in urban climate resilience concept, supported by a number of guidebooks and toolkits. In 2009, ICLEI became a partner of the UNFCCC Nairobi Work Programme on Adaptation and was recognized as the first local government network in this field. Resilient Cities 2010—the first World Congress on Cities and Adaptation to Climate Change—is the first Action Pledge of ICLEI to the UNFCCC Nairobi Work Programme.

3) ICLEI Climate Advocacy: The 1st Municipal Leadership Summit held at the UN Headquarters in New York in 1993 yielded the establishment of Cities for Climate Protection (CCP) Campaign. Based on the success of intensive efforts on mitigation projects at the local level since the first UNFCCC Conference of Parties (COP) in 1995 in Berlin, ICLEI became the focal point for local government and municipality authority's constituency at the UNFCCC Secretariat. Through this opportunity, hundreds of mayors and local government representatives took part in Municipal Summits that were held in parallel to official COP events and necessary interventions were delivered at high level segments. Between 2007 and 2009, the Local Government Climate Roadmap, as the coalition of local government networks, advocated for a better recognition and empowerment of cities and local governments in the new global climate regime in the post-2012 period. In 2009, ICLEI became the first local government network that has been accredited as an observer organization to the Intergovernmental Panel on Climate Change (IPCC).

Institut du développement durable et des relations internationales (IDDRI)

"Urban Fabric: Sustainable urban development" is a program of activities set up by IDDRI to address urban development and sustainability. Specifically related to cities and climate change, IDDRI is involved in seven main activities.

1) Transition to low-carbon buildings in Chinese cities: This research project aims to examine possible paths to low carbon cities in emerging countries by focusing on the buildings sector in Chinese cities. It seeks to establish a dynamic link between the energy performance of new buildings constructed today and the financial capacity in investing in new technologies to decarbonise the energy supply in cities tomorrow. Barriers and opportunity and policy tools of managing carbon emissions in the building sector in China will be investigated.

2) Climate Change Mitigation and Adaptation Challenges and Initiatives in California: (In

partnership with Department of City and Regional Planning and the Global Metropolitan Studies program at University of California, Berkeley) The objective of this research is to examine the challenge of finding a balance between mitigation and adaptation at the local level, to assess the policies that aim to tackle these issues, and to determine how a territorial approach—integrating transport and land uses—could be part of the answer.

3) A Task Force Energy Efficiency and Urban Development works on policy recommendations to the China Council for International Cooperation on Environment and Development (CCICED). The general objective of the Task Force is to address the energy dimensions of urban development in China from the perspective of sustainability. Case studies on the development of several cities in China and abroad investigated the relations between urban density, urban design, lifestyles, and household energy consumption. Surveys on households' lifestyles and behaviors were carried out.

4) Task Force Global Climate Change Policy and the Increasing Role of Cities: (in partnership with the Centre for European Policy studies [CEPS]) This Task Force constitutes a unique forum of representatives from the European Commission (DG Environment, DG Transport & Energy, and other DGs), Members of the European Parliament, officials from member states, representatives from cities, local government and their organizations, business and industry (i.e., energy supply companies, energy-intensive industries, traders, equipment suppliers, and project developers), small consumer associations, NGOs, international organizations and other stakeholders of energy regulators to facilitate an in-depth discussion and provide background research.

International Development Research Centre (IDRC)

IDRC is a Canadian Crown corporation that works in close collaboration with researchers from the developing world in their search for the means to build healthier, more equitable, and more prosperous societies.

IDRC has two major projects with regard to climate change research and cities.

1) **Climate change and Water Program**
Climate change is having a significant effect on the environment, especially on the quality and availability of water resources. Changing rainfall patterns, river hydrology and drought, and the decline of important ecosystems are certain to have a negative impact on the poor. The focus of this five-year Climate Change and Water Program is to support applied, policy-relevant research to help people adapt to the water-related impacts of climate change.

   By providing grants and technical guidance, the program will encourage the development of specific research tools to cope with climate-related water stress and of the research capacity needed to estimate and respond to risks created by climate change. The program will explore certain emerging areas, such as the links between climate change, energy, and water, to identify useful avenues of investment. Research will also be carried out on how information and communication technologies support climate change adaptation.

2) **Climate Change Adaptation in Africa**
The *Climate Change Adaptation* in Africa (CCAA) research and capacity development program aims to improve the capacity of African countries to adapt to climate change in ways that benefit the most vulnerable. The program is jointly funded by Canada's International Development Research Centre and the UK Department for International Development.

To better prepare Africa's urban settlements for climate variability and change, the Climate Change Adaptation in Africa (CCAA) program invited combined research and capacity building proposals that addressed the vulnerabilities of Africa's urban centres to climate change, and helped urban stakeholders work together in developing adaptation options.

Following CCAA's call for proposals on urban vulnerabilities to climate change in September 2008, nine project proposals have been developed and funded. See www.idrc.ca for more information.

International Institute for Environment and Development (IIED)

IIED's staff and partners have been engaged with climate change adaptation in urban areas for many years, including staff contributions to the Third and Fourth Assessments of the Intergovernmental Panel on Climate Change (IPCC), and to setting the scope for the planned Fifth IPCC Assessment. They have produced a large body of work on the scale and range of environmental hazards and risks in urban areas. This has been strengthened through the long-established partnership between IIED's Human Settlements and Climate Change Groups, and the publication through IIED of a considerable proportion of all the published literature to date on this topic (through IIED Briefs and working papers, over 20 papers published in IIED's journal *Environment and Urbanization*, and a book titled *Adapting Cities to Climate Change* published in June 2009). IIED staff have also advised many international agencies on climate change and cities including the UNFCCC, OECD Development Assistance Committee, Rockefeller Foundation, UNDP, UN-Habitat, United Nations International Strategy for Disaster Reduction (UN-ISDR), United Nations Population Fund (UNFPA), United Cities and Local Governments, ICLEI-Local Governments for Sustainability, the International Federation of the Red Cross, and the World Bank.

Over the last two years, IIED has been engaged with a network of 15 researchers in low-income countries (12 in Africa and 3 in Asia) to produce city vulnerability and adaptation reports through the CLACC (Capacity Strengthening in the Least Developed Countries for Adaptation to Climate Change) programme. The maps and reports from this activity represent one of the first substantial attempts to document climate vulnerability in urban areas in low-income countries, to assess the potential for adaptation strategies, and to provide the necessary information for communities and local governments to address climate change adaptation.

IIED's current research activities involve expanding knowledge on effective interventions for climate change adaptation that meet the needs of low-income urban residents. This is achieved through supporting research partners in low-income countries to conduct, document, and present their research findings in a range of forums. IIED's current practical interventions on climate change and cities are based on strengthening linkages between climate change NGOs and local organizations supporting low-income residents in accessing land, shelter, and basic infrastructure. Key locations for this activity are Zimbabwe and Tanzania. IIED staff are also engaged in training and capacity strengthening of various kinds, including the delivery of a postgraduate module on "Adapting Cities to Climate Change" at the Development Planning Unit, University College London, and supporting authors from the global south in preparing peer-reviewed publications on cities and climate change that can be used as supporting documentation for the IPCC Fifth Assessment Report.

International Society for Industrial Ecology (ISIE)

Many members of the International Society for Industrial Ecology (ISIE) are working on issues of urban sustainability and in particular the development of low carbon cities. The ISIE has a worldwide membership of about 500 leading scientists and engineers broadly concerned with the technical foundations of sustainable development. The membership, from academia, industry and government, has expertise in the technological development and societal progression towards human and industrial systems that are compatible with the functioning of natural ecosystems. Members working on sustainable cities apply methods of industrial ecology, e.g., life cycle assessment, material flow analysis, complex systems theory, and applied thermodynamics, to better understand the urban metabolism and ways that it can be managed for a low carbon future.

As an example, a recent study of greenhouse gas emissions from ten global cities (Los Angeles County, Denver City and County, Greater Toronto, New York City, Greater London, Geneva Canton,

Greater Prague, Barcelona, Cape Town, and Bangkok) was primarily undertaken by members of the ISIE (Kennedy et al., 2009a,b). The study identified the geophysical factors (climate, access to resources and gateway status) and technical factors (power generation, urban design, and waste processing) that determine the greenhouse gases attributable to cities. ISIE members are continuing to expand the study of urban greenhouse gas emissions to other cities (e.g., Hillman and Ramaswami, 2009; Kennedy et al. 2009c).

One of the ISIE's immediate goals is to create a network of developing world academics with the skills to calculate greenhouse gas (GHG) emissions for cities, so as to assist in their low carbon development. The ISIE would welcome the opportunity to work with other agencies on this initiative.

Organisation for Economic Co-operation and Development (OECD)

The OECD, an intergovernmental organization representing 30 member countries committed to common principles to support economic development including social and environmental protection, helps governments to improve their collective and individual performance of climate change policies through peer reviews, dialogue, and shared policy assessment. A number of projects at the OECD are advancing the understanding of the roles that cities can play to respond efficiently and effectively to climate change.

- ***Competitive Cities and Climate Change***
  This activity focuses on urban governance, planning, and land use, as well as intergovernmental collaborations that link national and regional strategies to local actions. An international conference held in Milan, Italy, in October 2008, and a follow-up workshop on Greening Cities: New Approaches to Local Climate Change Actions held in June 2009, in Las Palmas, Spain built on this theme. A new OECD report "Competitive Cities and Climate Change" assesses the relationship between urbanisation and CO_2, and identifies key opportunities for action to reduce cities' contribution and vulnerability to climate change, including complementary urban planning and sectoral policies, "greening" of fiscal policies, financing options, and opportunities to boost green innovation and jobs.

- ***Cities, Climate Change and Multilevel Governance***
  The OECD has also begun to identify a multilevel governance framework to explore linkages between national, regional, and local policies, and to explore the ability to strengthen multilevel, regional, and urban governance to more effectively address the problem of climate change. A recent report highlights progress made to advance principals of good practice, including participatory governance; the existence of a strong analytical foundation for short and long-term planning; cost-effectiveness and economic efficiency; consideration of distributional consequences and procedural equity; use of a long term planning horizon; and policy coherence and feasibility.

- ***Cities and Green Growth***
  Having strengthened their role as drivers of innovation and entrepreneurship, cities play an increasingly important role in identifying policies and approaches that can shift production and consumption towards a clean, low-carbon and sustainable economy. How cities grow spatially greatly impacts the degree to which economic growth can also be considered green.

- ***Enhancing Local Benefits of Adaptation & Mitigation Policies***
  This activity focuses on assessment of climate policy benefits at local scale, in particular on how policy can limit or avoid climate impacts on urban infrastructure, people, and economies. A first priority is to explore the local scale economic impacts of climate change in the face of urban development, including the impacts of projected changes in extreme weather events. Several working papers are available: a literature review on impacts and adaptation at city scale; a conceptual framework for impact and benefit assessment at urban scale; a ranking of the world's large cities most exposed to coastal flooding today and in the future; and an in-depth case study on coastal flood risk in Copenhagen.

- ***Adaptation to Climate Change***
  On the adaptation dimension, related work is investigating how to better integrate adaptation at city scale in development co-operation and planning in developing countries.

- ***Transportation and Climate Change***
  The International Transport Forum (ITF) is engaged in many aspects of transport-related climate research and policy-making, including urban travel. In May 2008, the forum organized the world's largest transport summit around the theme of "Transport and Energy: the Challenge of Climate Change." Key policy and research findings highlighted the need for a strategic package of policy measures including the following: technology development, strengthened research into new technology and fuels, increased use of information technology and integrated mobility management as well as a wide variety of nontechnology tools with potential to improve economic efficiency and reduce emissions.

Rockefeller Foundation

The Asian Cities Climate Change Resilience Network (ACCCRN) aims to catalyze attention, funding, and action on building climate change resilience for poor and vulnerable people by creating robust models and methodologies for assessing and addressing risk through active engagement and analysis of various cities. Through the actions of the Asian Cities Climate Change Resilience Network, it is anticipated that by 2012 a network of cities in Asia will have developed robust plans to prepare for, withstand and recover from the predicted impacts of climate change. To accomplish this, ACCCRN must test and demonstrate a range of actions to build climate change resilience in cities; build a replicable base of lessons learned, successes and failures; assist cities in the development and implementation of a climate change resilience building process; and help cities continue activities that build climate change resilience.

ACCCRN is being implemented in 4 phases:
Phase 1 (completed): City Scoping and Selection. *Selected cities in India*: Surat, Indore and Gorakphur. Selected cities in Viet Nam: Da Nang, Quy Nhon and Can Tho. *Selected Cities in Thailand*: Chiang Rai and Hat Yai. *Selected Cities in Indonesia*: Bandar Lampung and Semerang.
Phase 2: City-level engagement and capacity development
Phase 3: Implementation of effective urban resilience building projects
Phase 4: Replication

This project is carried out with many partners, including Institute for Social Environmental Transition (ISET), Arup International Development, ICLEI, APCO Worldwide, TARU Leading Edge, Gorakhpur Environmental Action Group (GEAG), Thailand Environment Institute (TEI), Asian Disaster Preparedness Center (ADPC), Mercy Corps, Urban and Regional Development Institute (URDI), Challenge to Change (Vietnam), National Institute for Science and Technology Policy and Strategy Studies (NISTPASS).

For more information see: http://www.rockefellerfoundation.org/news/publications/acccrn-responding-urban-climate.

The Climate Group

The Climate Group has worked with cities since the organization was founded in 2004. The Climate Group launched the C10 initiative in 2005, which was spun off to become the C40 under the Clinton Global Initiative.

The Climate Group is a member of the HSBC Climate Partnership, launched in 2007. Through this partnership The Climate Group works in Hong Kong, London, Mumbai, New York, and Shanghai to help citizens, business, and government to make smarter, cleaner choices.

In 2009, The Climate Group partnered with the City of Chicago and the Chicago 2016 Olympic Bid Committee to create a new type of public-private partnership that engaged leading Chicago-area businesses and nonprofit organizations to help the city achieve its greenhouse-gas emissions reduction targets, "green" the bid for the Olympic and Paralympic Games, and leave an environmental legacy for all Chicago residents.

In 2009, The Climate Group began its Market Transformation work. Three of the focus areas aim

to increase demonstration projects of low carbon technologies in cities—LED Street Lighting, Information and Communications Technologies (ICT) and Electric Vehicles (EVs). These three programmes will run through 2013.

The goal of The Climate Group's ICT sector work is to facilitate proof-of-concept pilots, performance tracking, financing and policy for scaling ICT solutions in transport, buildings and electricity grid that could save up to 15 percent of global emissions in 2020 (according to the SMART 2020 report, June 2008). In 2009, The Climate Group partnered with Cisco's Connected Urban Development programme to develop a set of activities to achieve programme goals, and will officially announce and call for new partners during the Shanghai World Expo in June 2010.

In 2009, The Climate Group launched LightSavers, an international program to transform how we light the world by bringing low-energy LED lighting to commercial scale. LightSavers has launched a global trail to test the efficacy and cost savings of outdoor LED lights in cities, starting in New York, Hong Kong, London, Adelaide, Kolkata, Mumbai, Tianjin, and Toronto. By 2020, The Climate Group's goal is for 25 percent of all outdoor lights to be replaced with high quality LEDs that are available on the commercial market. Initial results show that LED lights use half as much energy as existing lighting.

UCLG/Metropolis

In the realm of cities and climate change, Metropolis is working on a range of projects and knowledge products including the following.

- **Seminar on Cities and Information Technology, New Delhi, India**
  This seminar is dedicated to local officials of major cities in India. It is jointly organized with CISCO.

- **Field study on Chicago Climate Plan and Success Stories, Chicago, USA**
  This field study follows the publication released by Metropolis International Institute: *Climate Change: Cities in Action*. It aims to demonstrate actions and innovations at the local level to reduce greenhouse gas emissions.

- **Urban Design and Landscaping for Sustainable Tourism, Mashhad, Iran**
  This course is dedicated to local Middle East officials and aims to help them to enhance the urban environment and increase tourism in respect to the principles of sustainable development.

- **Field study on City and Quality of Life for the Citizens, Songpa, South Korea**
  Songpa is a district of 650,000 inhabitants in the Seoul Metropolitan Government area. In 2008, Songpa has won a UNEP reward for its quality of life and actions for the environment. This field study is a showcase for the participants to local actions.

- **Urban Transportation Policy, Seoul, South Korea**
  Transportation is an important sector for the greenhouse gas reduction and achieving the national and local targets. Also, Seoul Metropolitan Government is innovating in transportation. This course will allow officials working in the transportation sector to learn how Seoul achieved its very good results.

- **Urban Environment Policy, Seoul, South Korea**
  Seoul is well known as an attractive city that has developed an efficient environment policy and actions (greening, water protection, energy efficiency, etc.). This course will allow the participants to exchange with their counterparts on mechanisms of achieving good results in this field.

- **Environmental Friendly Infrastructure, Cairo, Egypt**
  This course will be delivered to African and Middle East local officials.

- **Infrastructure and Project Management for Informal Areas, Cairo, Egypt**
  This course will be delivered to African and Middle East local officials.

- **African Cities and Climate Change, Ouagadougou, Burkina Faso**
  This seminar will be jointly organized with the UEMOA (Union of the West African States). This is under discussion and it will be offered depending on the available funding.

Additionally, Metropolis is updating and translating its *Climate Change: Cities in Action* publication and developing an online portal dedicated to knowledge on cities and climate change. Metropolis will host a forum on cities and climate change in the framework of the 16th Conférence de Montréal.

UNEP

In joint partnership with UN-HABITAT and the World Bank, UNEP is working on several projects on cities and climate change. Joint work program outputs include the following: an online catalogue to facilitate access to current information on cities and climate change; integrating climate change into city development strategies; developing a city greenhouse gas inventory and standard; and a handbook for mayors on climate change.

UN-HABITAT

The United Nations Human Settlements Programme (UN-HABITAT) promotes the role of local leadership in mitigating and adapting to climate change in urban areas. The agency has adopted a Cities and Climate Change Strategy, to focus its efforts in this important area. This Strategy includes thematic focus areas on the following: urban governance, planning and management; land and housing; disaster risk reduction; and environmentally sound infrastructure. Cities and Climate Change is also the theme of the next edition of the agency's main flagship publication, the *2011 Global Report on Human Settlements*.

Spearheading UN-Habitat's response in this area is its cross-divisional Cities and Climate Change Initiative (CCCI). CCCI is working at the national and local level in a number of countries. To date, CCCI has carried out detailed climate change assessments, and has begun to support follow-on action planning, in Kampala (Uganda), Maputo (Mozambique), Sorsogon City (Philippines), and Esmeraldas (Ecuador). It recently expanded to include several new cities in Africa: Mombasa (Kenya), Kigali (Rwanda), Walvis Bay (Namibia), St. Louis (Senegal), and Bobo Dioulasso (Burkina Faso). The Initiative plans further expansion in the near future in Asia. CCCI is sharing lessons from those experiences via the Climate Action Map, in partnership with Local Government Denmark (see www.climateactionmap.org), as well as by means of presentations at fora and articles in professional publications.

Internationally, UN-Habitat is developing several capacity-building tools that address cities and climate change, including one on developing local climate action plans and one on carbon finance for cities. The Initiative is promoting green building practices in Africa by encouraging the formation of green building councils and via other appropriate mechanisms. CCCI has supported the Local Government Climate Change Roadmap process. In partnership with the World Bank, the United Nations Environment Programme (UNEP) and Cities Alliance, UN-Habitat is promoting a common standard for methodologies for city-level inventories of greenhouse gas emissions, developing a comparative vulnerability assessment methodology for cities, and undertaking other initiatives. For further information on CCCI, please go to www.unhabitat.org/ccci.

Veolia Institute

The Institut Veolia Environnement is a nonprofit organization created and sponsored by Veolia Environnement. The Institute aims to nurture reflection on future environmental trends by proposing a forum for dialogue within academia, institutions, and different actors in society. Its research agenda, conducted in partnership with universities or research organizations aims to contribute to public debate on an international scale.

Main activities related to Cities and Climate Change

1) GHG accountability: With the College of Europe, the Institute has conducted research on the methodological challenges of GHG monitoring at local level to give an overview of current practices. Questions addressed were as follows: How do the methodologies which underlie different GHG inventory tools differ? What are the critical variables explaining differences between inventories? Can different GHG inventory tools be compatible — and/or interoperable— and under which conditions? This overview identified critical variables and concluded that local GHG inventories differ substantially and their result can hardly be compared. This study also gave research and policy recommendations towards greater comparability and sketched the requirements of an

international protocol on urban GHG inventories.

The study is available at: http://www.institut.veolia.org/ive/ressources/documents/2/491,Final-report-Comparative-Analysis-of.pdf

2) Estimating Carbon Footprint of urban energy use in India and China: In the context of the growing energy demand of urban areas, this study recognized the need (1) to understand the energy consumption patterns of the urban population in developing countries, (2) develop a tool to measure its impacts and (3) propose this indicator to policy makers to conceive of energy strategies for the urban areas. In partnership with The Energy Research Institute (TERI, Delhi), the Energy Resource Institute (ERI, Beijing) and Tsinghua University (Beijing), primary surveys of households were conducted and the energy consumption profiles of Jaipur, India, and Shijiazhuang, China, were established.

3) S.A.P.I.EN.S issue on Cities and Climate Change: S.A.P.I.EN.S is a new international, peer-reviewed, open access multidisciplinary journal focused on integrating scientific knowledge for sustainability. The special issue *Cities and Climate Change* gathers critical state of the arts and science based opinions, on all multidisciplinary aspects of this burning issue. The journal is available at http://sapiens.revues.org/index835.html.

World Bank

The World Bank is undertaking a wide variety of work in cities and climate change, all of which is outlined in the above paper. Activities include the following: the Mayor's Dialogue on Urban Poverty and Climate Change; a City-wide Approach to Carbon Finance; Mayors' Handbook on climate change adaptation; 5th Urban Research Symposium on Cities and Climate Change; Greenhouse Gas Emissions Standard; Urban Risk Assessment; Eco^2 Cities; and the Urbanization Review.

World Bank Institute

Climate Change Group

The climate change group within the World Bank Institute works to enable cities to play more active roles in integrating climate risks, low carbon strategies, and innovative climate finance into their development planning. The climate group is very active in cities and climate change and is working on an array of activities around this theme.

1) A learning program on Carbon Finance for Urban Areas comprising courses on cities and climate change, CDM, energy, transport, solid waste, and water management.

2) A carbon finance capacity building program for emerging megacities.

3) A city twinning program on carbon finance to bring together cities from the north and south for structured peer-to-peer exchange of knowledge.

4) A visioning scenario for urban leaders to enhance the capacity of various stakeholders to integrate considerations of climate change risks and adaptation options into development action plans and policies in the context of urban planning in Asia with pilot experience in Hanoi, Vietnam.

5) A CTF on Urban and Carbon Finance to provide technical advice and coordination in developing a CTF program.

6) A Mayor's Task Force beginning January 2010 to provide a platform to facilitate knowledge exchange among mayors.

Urban Group

The "Sustainable Land Use Planning" course that The World Bank Institute is currently developing is relevant to cities and climate change. The course considers climate change as one key environmental challenge and explores tools and policies that help mainstream climate change mitigation and adaptation strategies into the land use planning process. For example, through 1) planning of compact urban form and public transport, pedestrian based movement systems, 2) a wide spectrum of risk-reduction regulatory and economic instruments to identify (or relocate residents from) hazard-prone areas, protect agricultural, open space and water source, construct flood/storm management infrastructure, and others, 3) cross-jurisdiction coordination in river basin management and others.

ANNEX D.
a) Population, GDP, and GHG Emissions for 50 Largest Cities and Urban Areas in the World

Combined, the 50 largest cities and urban areas are home to 500 million people, have a total GDP of $9,564 billion, and emit 2.6 billion tonnes of CO_2e per year.

City/ Urban Area	Country	Population (Millions)	GDP (US$bn)	Total GHG ($MtCO_2e$)	Total GHG (tCO_2e/cap)	GHG per GDP ($ktCO_2e$/US$bn)
Tokyo	Japan	35.53	1191	174	4.9	146
Mexico City	Mexico	19.24	315	55	2.8	173
Mumbai (Bombay)	India	18.84	126	25 (est)	1.3 (est)	198
New York	USA	18.65	1133	196	10.5	173
São Paulo	Brazil	18.61	225	26	1.4	116
Delhi	India	16.00	93	24	1.5	258
Calcutta	India	14.57	94	16	1.1	171
Jakarta	Indonesia	13.67	98	24 (est)	1.8 (est)	245
Buenos Aires	Argentina	13.52	245	52	3.8	211
Dhaka	Bangladesh	13.09	52	8	0.6	159
Shanghai	China	12.63	139	148	11.7	1063
Los Angeles	USA	12.22	639	159	13.0	249
Karachi	Pakistan	12.20	55	16 (est)	1.3 (est)	298
Lagos	Nigeria	11.70	30	27 (est)	2.3 (est)	893
Rio de Janeiro	Brazil	11.62	141	24	2.1	173
Osaka, Kobe	Japan	11.32	341	122 (est)	10.8 (est)	357
Cairo	Egypt	11.29	98	23 (est)	2.0 (est)	233
Beijing	China	10.85	99	110	10.1	1107
Moscow	Russia	10.82	181	167 (est)	15.4 (est)	922
Metro Manila	Philippines	10.80	108	16 (est)	1.5 (est)	147
Istanbul	Turkey	10.00	133	51 (est)	5.1 (est)	384
Paris	France	9.89	460	51	5.2	112
Seoul	South Korea	9.52	218	39	4.1	179
Tianjin	China	9.39	45	104	11.1	2316
Chicago	USA	8.80	460	106	12.0	230
Lima	Peru	8.35	67	20 (est)	2.5 (est)	305
Bogotá	Colombia	7.80	86	30 (est)	3.8 (est)	348
London	UK	7.61	452	73	9.6	162
Tehran	Iran	7.42	88	49 (est)	6.6 (est)	560
Hong Kong	China	7.28	244	25 (est)	3.4 (est)	102
Chennai (Madras)	India	7.04	38	9 (est)	1.3 (est)	246
Bangalore	India	6.75	45	9 (est)	1.3 (est)	199
Bangkok	Thailand	6.65	89	71	10.7	799
Dortmund, Bochum	Germany	6.57	234	76 (est)	11.6 (est)	327
Lahore	Pakistan	6.57	28	9 (est)	1.3 (est)	316
Hyderabad	India	6.34	38	8 (est)	1.3 (est)	221
Wuhan	China	6.18	38	21 (est)	3.4 (est)	554
Baghdad	Iraq	6.06	22	N/A	N/A	N/A
Kinshasa	Congo	5.89	10	6 (est)	1.0 (est)	598
Riyadh	Saudi Arabia	5.76	80	58 (est)	10.1 (est)	726
Santiago	Chile	5.70	91	22 (est)	3.9 (est)	243
Miami	USA	5.48	231	65	11.9	282
Belo Horizonte	Brazil	5.45	65	23 (est)	4.2 (est)	349
Philadelphia	USA	5.36	312	60	11.1	191
St Petersburg	Russia	5.35	85	83 (est)	15.4 (est)	971
Ahmadabad	India	5.34	32	6	1.2	200
Madrid	Spain	5.17	188	36	6.9	190
Toronto	Canada	5.16	209	60	11.6	286
Ho Chi Minh City	Vietnam	5.10	38	6 (est)	1.2 (est)	158
Chongqing	China	5.06	35	19	3.7	535

Notes:
- "The 2006 population figures are based on censuses carried out between 2000 and 2005 and adjusted to take account of average annual population changes." Available: www.citymayors.com.
- GDP figures are for cities and their surrounding urban areas for the year 2005 based on research conducted by PricewaterhouseCoopers. Available: www.citymayors.com.
- GHG per capita values are from the "City GHG Emissions per Capita" table (available: www.worldbank.org/urban). GHG per capita values presented in italics (est) are national values, as city values are unavailable. The corresponding GHG emissions should be considered GHG indications, not specific city values.

ANNEX D.
b) Population, GDP, and GHG Emissions for C40 cities

Combined, the C40 cities are home to 393 million people, has a total GDP of $8,781 billion, and emits 2.4 billion tons of CO_2e per year. The urban agglomerate associated with each C40 city is used in calculations for consistency.

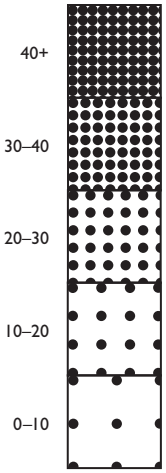
City/ Urban Area	Country	Population (Millions)	GDP (US$bn)	Total GHG ($MtCO_2e$)	Total GHG (tCO_2e/cap)	GHG per GDP ($ktCO_2e$/US$bn)
Tokyo	Japan	35.53	1191	174	4.9	146
Mexico City	Mexico	19.24	315	55	2.8	173
Mumbai	India	18.84	126	25 (est)	1.3 (est)	198
New York	USA	18.65	1133	196	10.5	173
Sao Paulo	Brazil	18.61	225	26	1.4	116
Delhi NCT	India	16.00	93	24	1.5	258
Jakarta	Indonesia	13.67	98	24 (est)	1.8 (est)	245
Buenos Aires	Argentina	13.52	245	52	3.8	211
Dhaka	Bangladesh	13.09	52	8	0.6	159
Shanghai	China	12.63	139	148	11.7	1063
Los Angeles	USA	12.22	639	159	13.0	249
Karachi	Pakistan	12.20	55	16 (est)	1.3 (est)	298
Lagos	Nigeria	11.70	30	27 (est)	2.3 (est)	893
Rio de Janeiro	Brazil	11.62	141	24	2.1	173
Cairo	Egypt	11.29	98	23 (est)	2.0 (est)	233
Beijing	China	10.85	99	110	10.1	1107
Moscow	Russia	10.82	181	167 (est)	15.4 (est)	922
Istanbul	Turkey	10.00	133	51 (est)	5.1 (est)	384
Paris	France	9.89	460	51	5.2	112
Seoul	South Korea	9.52	218	39	4.1	179
Chicago	USA	8.80	460	106	12.0	230
Lima	Peru	8.35	67	20 (est)	2.5 (est)	305
Bogota	Colombia	7.80	86	30 (est)	3.8 (est)	348
London	UK	7.61	452	73	9.6	162
Hong Kong	China	7.28	244	25 (est)	3.4 (est)	102
Bangkok	Thailand	6.65	89	71	10.7	799
Philadelphia	USA	5.36	312	60	11.1	191
Madrid	Spain	5.17	188	36	6.9	190
Toronto	Canada	5.16	209	60	11.6	286
Sydney	Australia	4.45	172	115 (est)	25.8 (est)	666
Houston	USA	4.39	235	62	14.1	263
Hanoi	Vietnam	4.22	28	5 (est)	1.2 (est)	178
Rome	Italy	4.00	123	37 (est)	9.3 (est)	303
Melbourne	Australia	3.71	135	96 (est)	25.8 (est)	708
Johannesburg	South Africa	3.44	79	34 (est)	9.9 (est)	432
Warsaw	Poland	3.35	48	35 (est)	10.5 (est)	730
Berlin	Germany	3.33	75	39 (est)	11.6 (est)	516
Caracas	Venezuela	3.30	28	27 (est)	8.1 (est)	949
Athens	Greece	3.25	73	34	10.4	463
Addis Ababa	Ethiopia	3.15	7	3 (est)	0.8 (est)	378

Notes:
- "The 2006 population figures are based on censuses carried out between 2000 and 2005 and adjusted to take account of average annual population changes." Available: www.citymayors.com.
- GDP figures are for cities and their surrounding urban areas for the year 2005 based on research conducted by PricewaterhouseCoopers. Available: www.citymayors.com.
- GHG per capita values are from the "City GHG Emissions per Capita" table (available: www.worldbank.org/urban). GHG per capita values presented in italics (est) are national values, as city values are unavailable. The corresponding GHG emissions should be considered GHG indications, not specific city values.

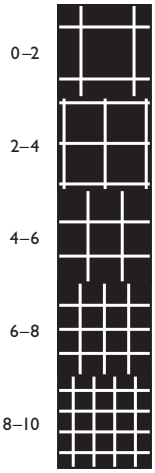
ANNEX E.
Visualizing Urban Form and Density.

METROPOLITAN INDICATORS

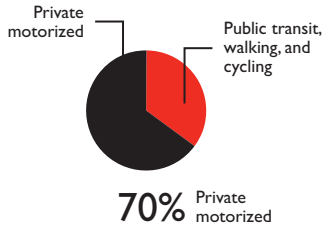
Urban density
(population / hectare)



Road length per capita
(metres / person)

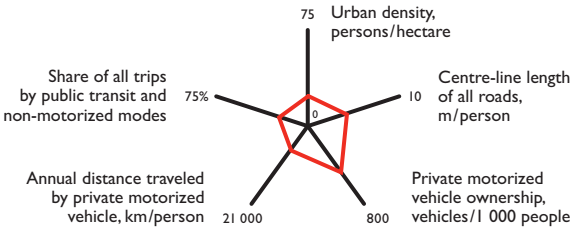


Transportation mode share



70% Private motorized

Metropolitan profile



The pie diagrams indicate the proportion of all trips made by private motorized vehicle (mostly cars, trucks, and motorcycles) and public transit, walking, and cycling. The star-shaped Metropolitan Profile diagrams graphically display the transportation orientation of the urban regions using five variables. If a city's red polygon is shifted toward the upper left, as seen in some European cities, it is more oriented toward public transit, walking, and cycling. If a city's red polygon is shifted toward the bottom right, it is more automobile oriented. The numbers at the end of each arm indicate each scale's maximum value.

Urbanized area of the metropolitan region

Limited-access expressway

Differing definitions and data make international comparisons of metropolitan regions difficult. Each region's urbanized area map is based on a minimum population density and the contiguity of the built-up urban area, and adjusted to accommodate differences in settlement patterns. Only limited-access expressways are shown. Other roads and transit facilities such as subways and commuter railways are not mapped due large variations in their levels of service. For a complete description of data sources and mapping methodology, visit http://www.neptis.org/atlas/show.cfm?id=60&cat_id=29.

Data sources

INDICATORS

Transportation mode share, centre-line road length, annual distance traveled by private motorized vehicle, and vehicle ownership statistics are from the *Millennium Cities Database 2001* by J. Kenworthy and F. Laube, published by the International Association of Public Transport.

EXPRESSWAYS

Expressways are compiled from local road atlases and checked against satellite imagery.

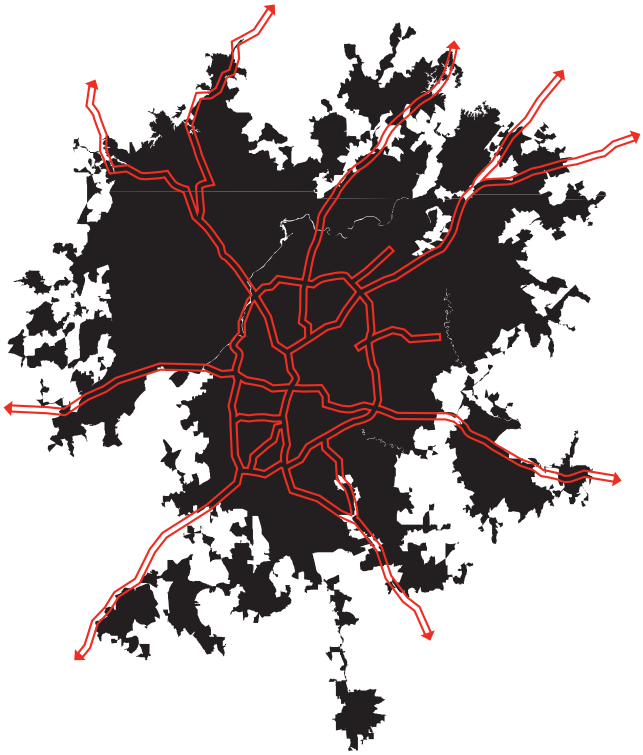
URBANIZED AREA DEFINITION

The urbanized area for each city is generated from government data sources. For the European cities, the definition is based primarily on land uses that constitute the built-up urban fabric of a region. The extent of a European region is limited to those local municipalities that are contiguous to the central municipality and have a minimum population density of 4 people per hectare, a threshold employed by the US census bureau. For the U.S., Canadian and Australian cities, the definition is based on the urban area definitions employed by each country's census bureau, a combination of population density measured within census geographic units and the contiguity of those census units. Some alterations were made to the urbanized area shapes to make them more comparable in area and extent. For the Canadian cities, the census-defined 'urban area' was used as a base and large, green spaces and agriculture reserve land at the edge were removed using local data sources. For the U.S. and Australian cities, census-defined 'urban area' and 'urban centre-locality' were not altered since comparable density thresholds and fine-grained census units were employed in the rule base.

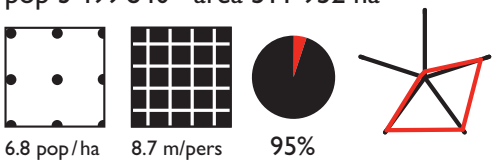
Sources: **EUROPE** *Urbanized area & population:* Corine land cover 2000 seamless vector database (CLC2000) in the form of Urban Morphological Zones with associated area and population data, European Environment Agency. *Municipal boundaries:* GfK MACON. **AUSTRALIA** *Urbanized area & population:* 2001 Urban Centre-Locality Structure, Australian Standard Geographical Classification, Australian Bureau of Statistics. **CANADA** *Urbanized area & population:* 2001 Urban Area, 2001 Census Dictionary, Statistics Canada; Green Zone, map in Greater Vancouver Regional District Livable Region Strategic Plan; vacant and urbanized spaces and decreed agricultural zones, map 5 in Planning Framework and Government Orientation for Montreal Metropolitan Region, 2001. **USA** *Urbanized area & population:* 2000 Urban Area Criteria, Federal Register, Volume 67, 51, March 15, 2002, US Bureau of Census and Department of Commerce.

Created by André Sorensen and Paul Hess, Department of Geography, University of Toronto
with Zack Taylor & Marcy Burchfield (The Neptis Foundation) and Byron Moldofsky & Jo Ashley (The Cartography Office)

Current research on urban form and density of cities reveals interesting patterns. The Neptis Foundation has produced the following figures emphasizing the urban form, density and transportation characteristics of 16 world cities. Compact cities, such as Vienna and Madrid, have significantly higher population density and higher public transport use than more sprawling cities, such as Atlanta and Houston. Spatial population density figures produced by Chreod Ltd. illustrate density distribution for 10 world cities. Population density is highest in the city core of compact Chinese cities, while spatial density variation is less pronounced in sprawling U.S. cities. Tokyo offers an interesting example; with many dense city neighborhoods, Tokyo's population density distribution is relatively spatially consistent throughout the city.

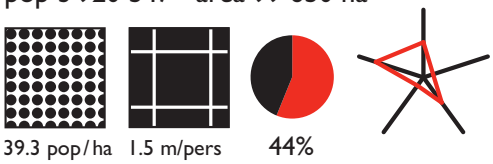


ATLANTA
pop 3 499 840 area 511 952 ha

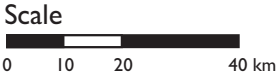


Scale

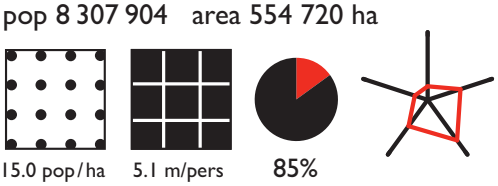
BERLIN
pop 3 920 547 area 99 650 ha



Scale



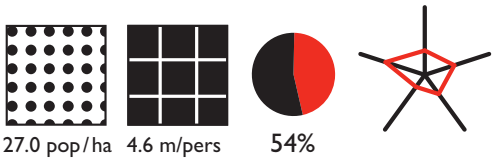
CHICAGO
pop 8 307 904 area 554 720 ha



Scale

COPENHAGEN

pop 1 385 259 area 51 368 ha

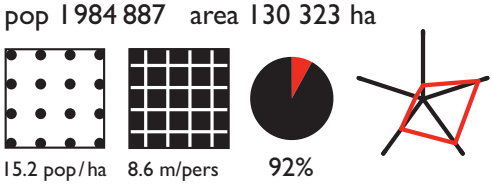


Scale

0 10 20 40 km

DENVER

pop 1 984 887 area 130 323 ha

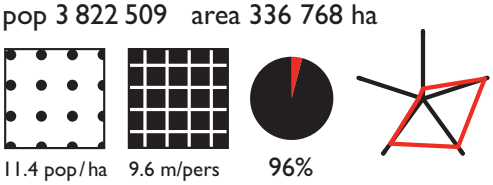


Scale

0 10 20 40 km

HOUSTON

pop 3 822 509 area 336 768 ha

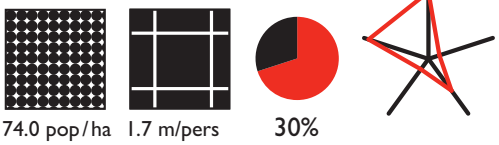


Scale

0 10 20 40 km

M A D R I D

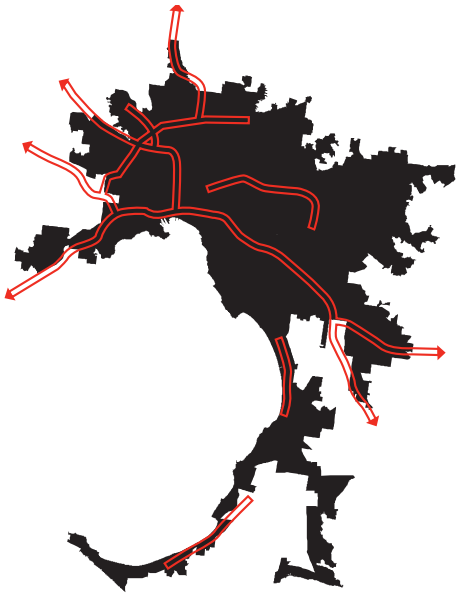
pop 4 652 379 area 62 865 ha



74.0 pop/ha 1.7 m/pers 30%

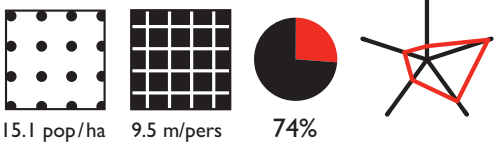
Scale

0 10 20 40 km



M E L B O U R N E

pop 3 132 806 area 208 135 ha



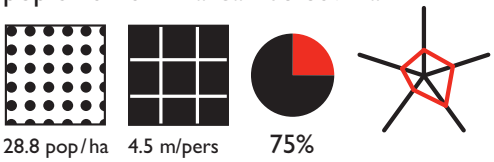
15.1 pop/ha 9.5 m/pers 74%

Scale

0 10 20 40 km

M O N T R E A L

pop 3 131 622 area 108 837 ha



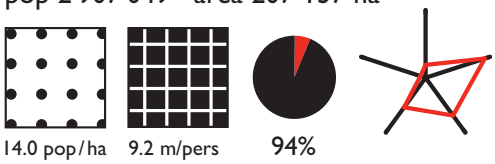
28.8 pop/ha 4.5 m/pers 75%

Scale

0 10 20 40 km

PHOENIX

pop 2 907 049 area 207 137 ha

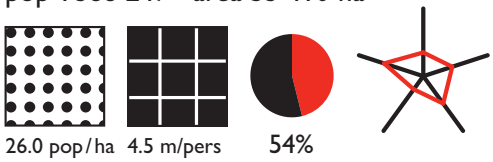


Scale

0 10 20 40 km

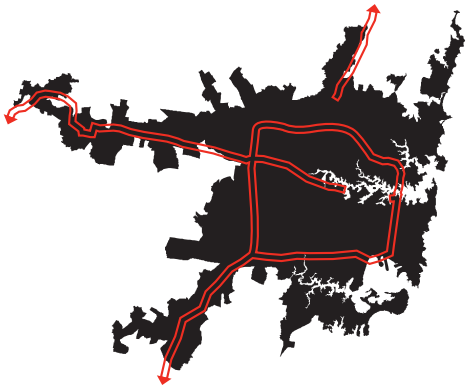
STOCKHOLM

pop 1 388 247 area 53 410 ha



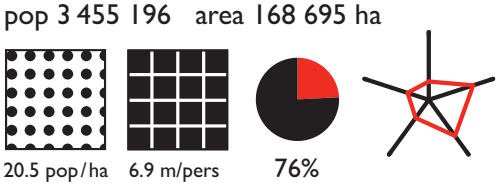
Scale

0 10 20 40 km



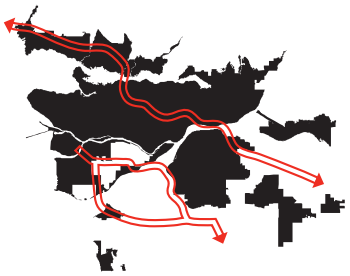
SYDNEY

pop 3 455 196 area 168 695 ha

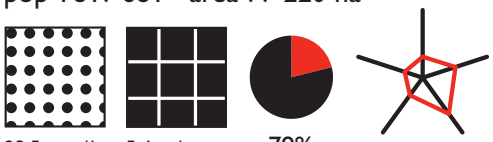


Scale

0 10 20 40 km



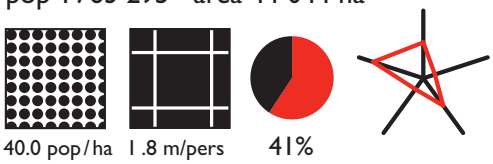
VANCOUVER
pop 1817 681 area 77 220 ha



Scale

0 10 20 40 km

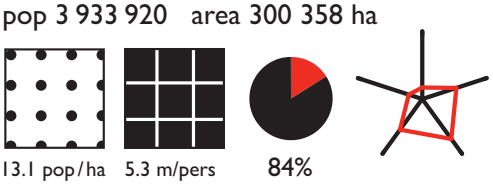
VIENNA
pop 1763 295 area 44 044 ha



Scale

0 10 20 40 km

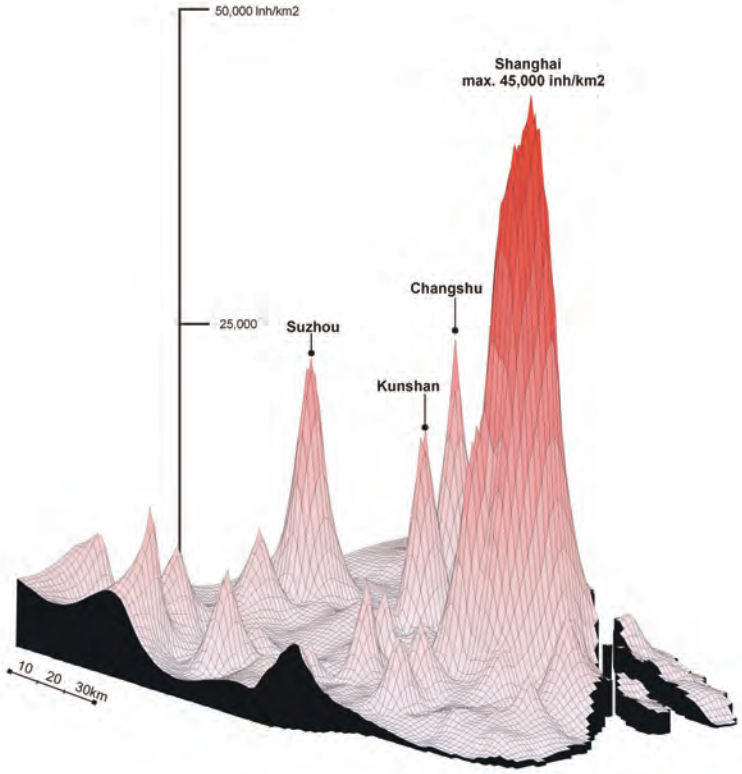
WASHINGTON D. C.
pop 3 933 920 area 300 358 ha

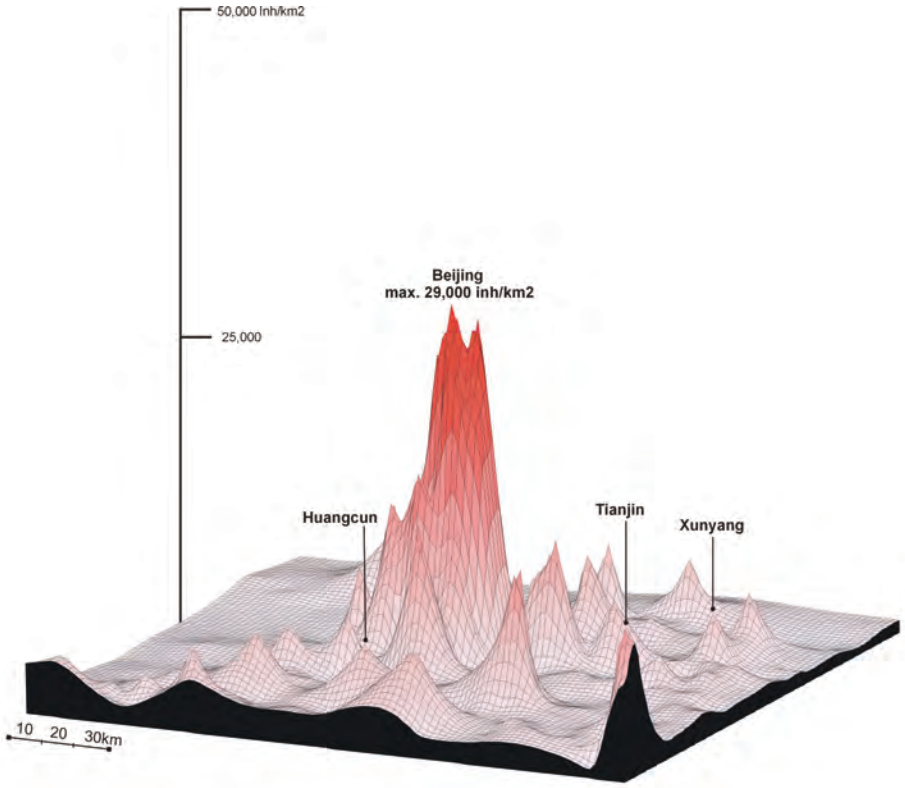


Scale

0 10 20 40 km

Population Densities of Selected Metropolitan Regions, 2000





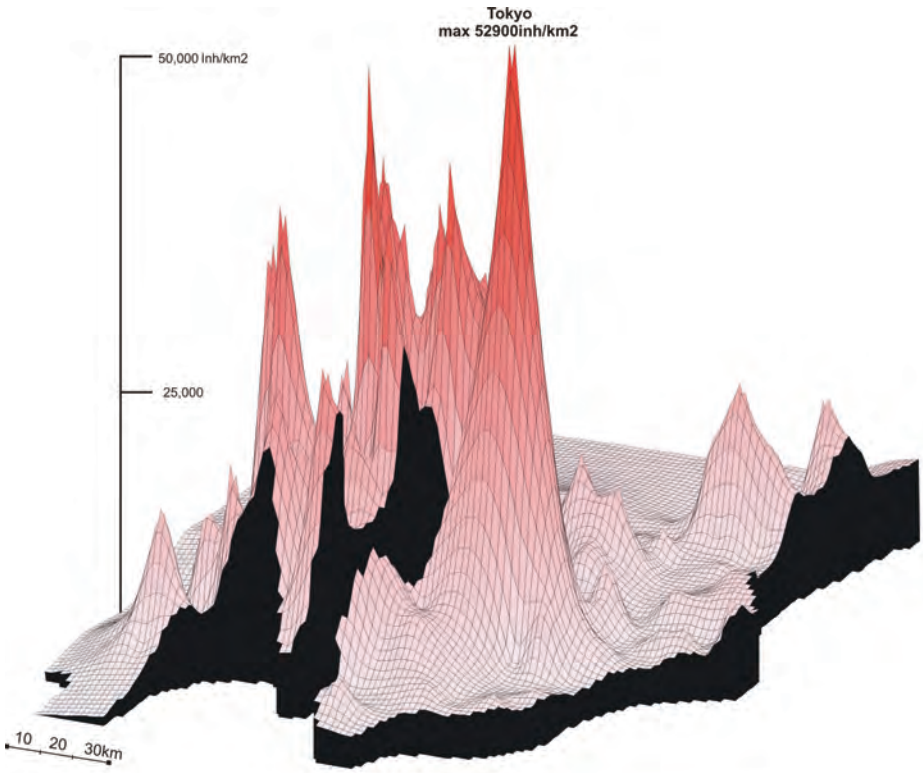
Chreod Group Inc.

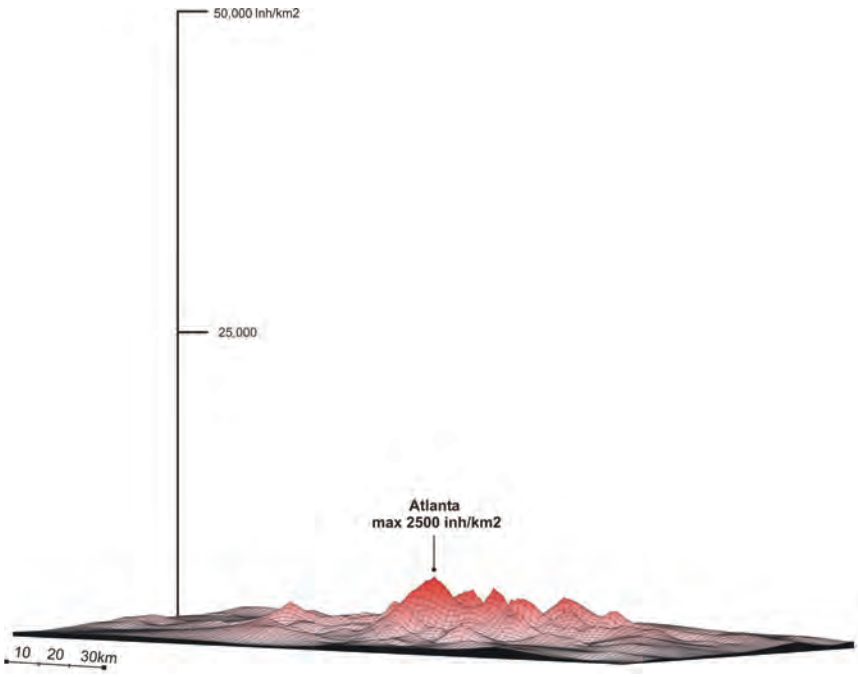
7 February 2010

The following pages show three-dimensional representations of population densities (night-time) in selected metropolitan regions. Data are for 2000 and, in some cases, 2001. Densities were calculated using 3D-Field software using geo-referenced, small-area population point data at the census tract scale.

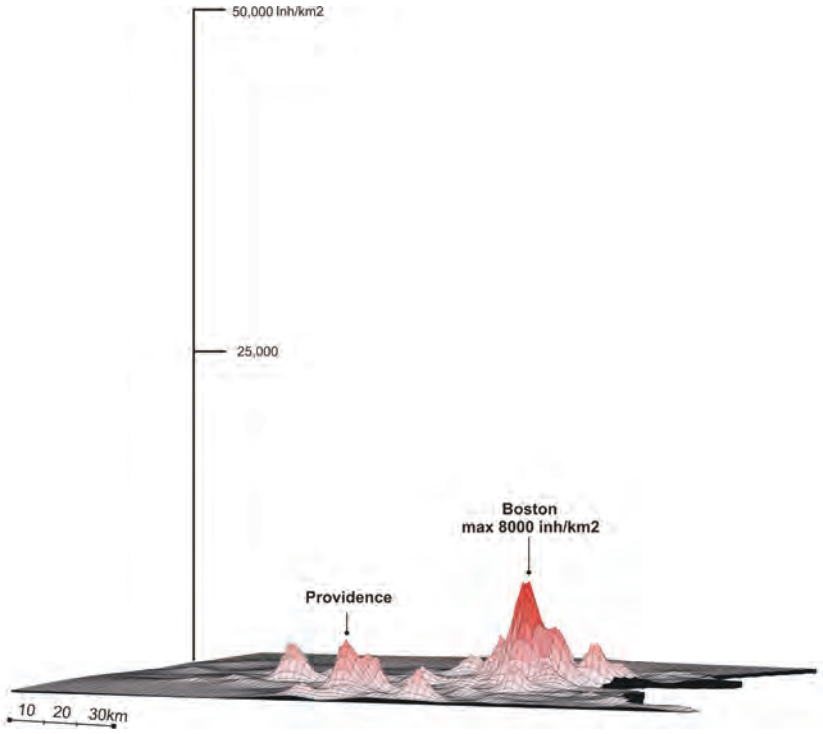
SHANGHAI AND BEJING

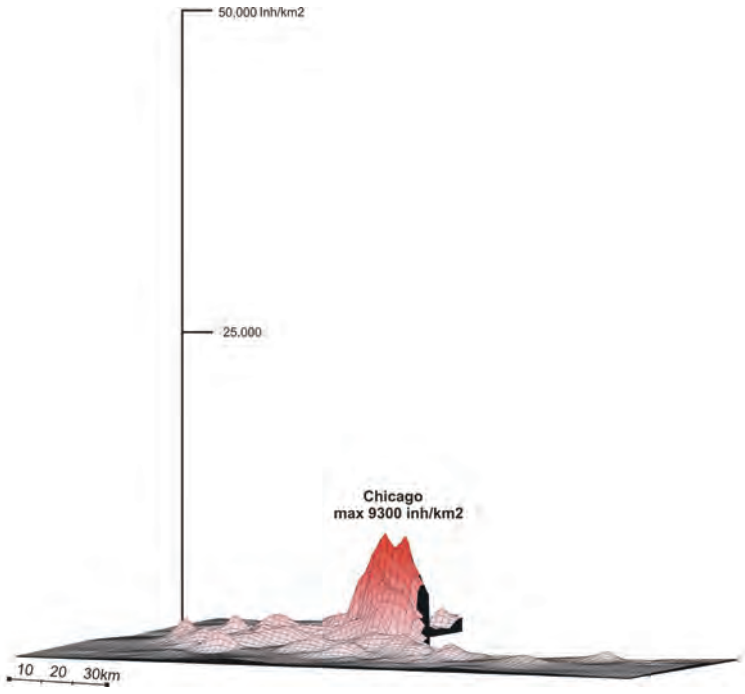
TOKYO and ATLANTA



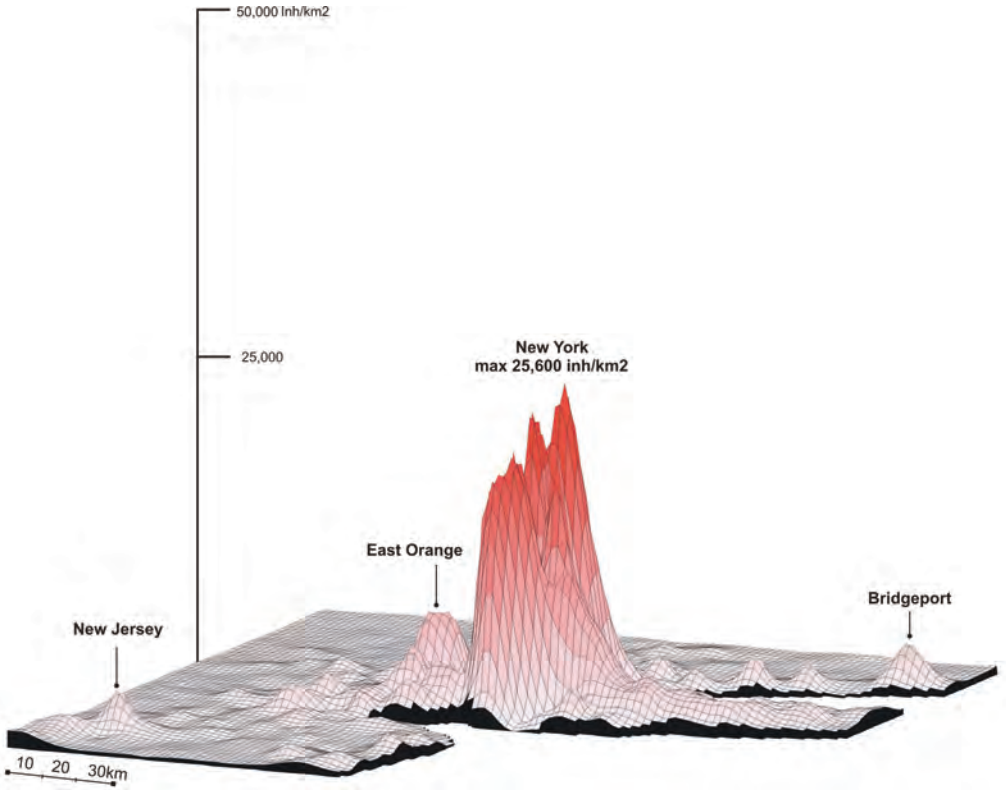


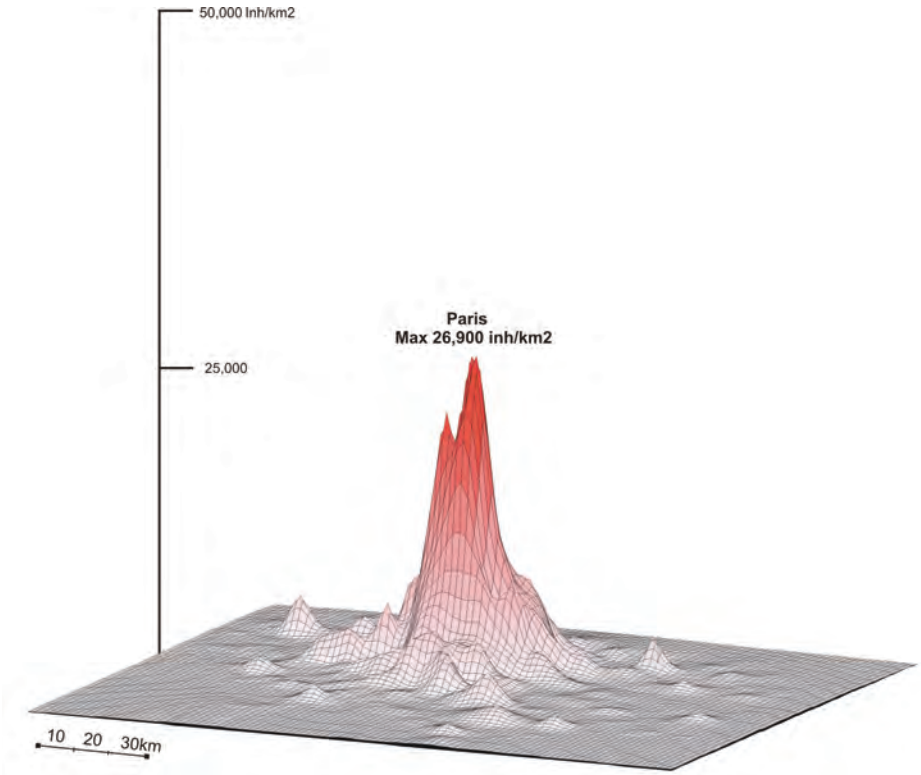
BOSTON and CHICAGO



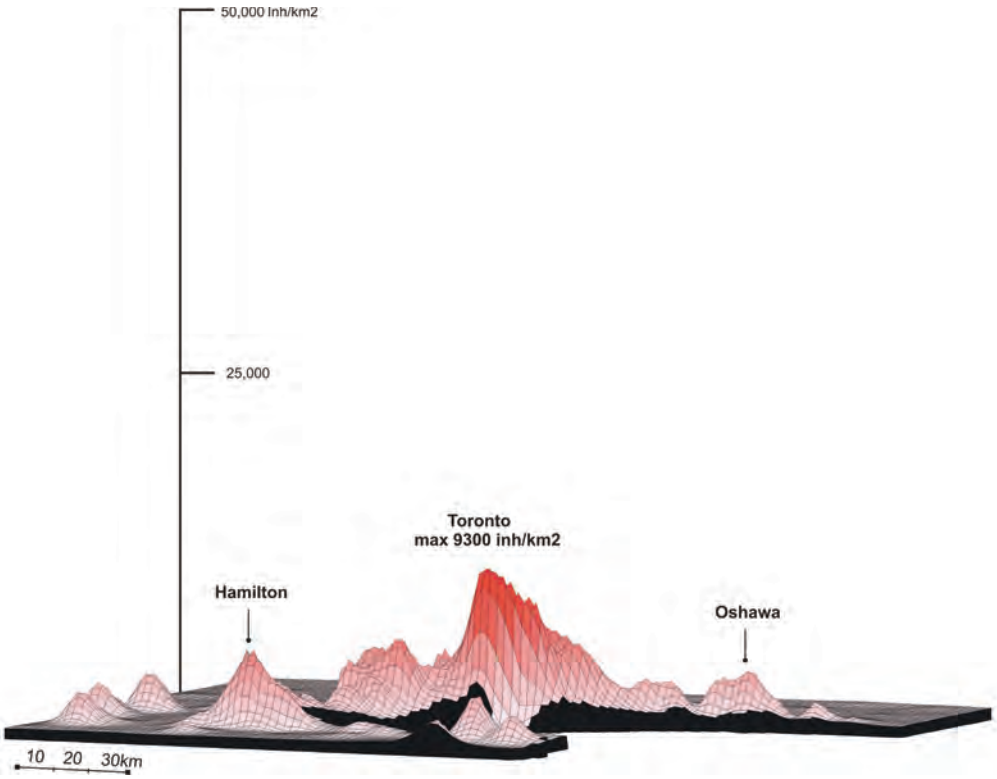


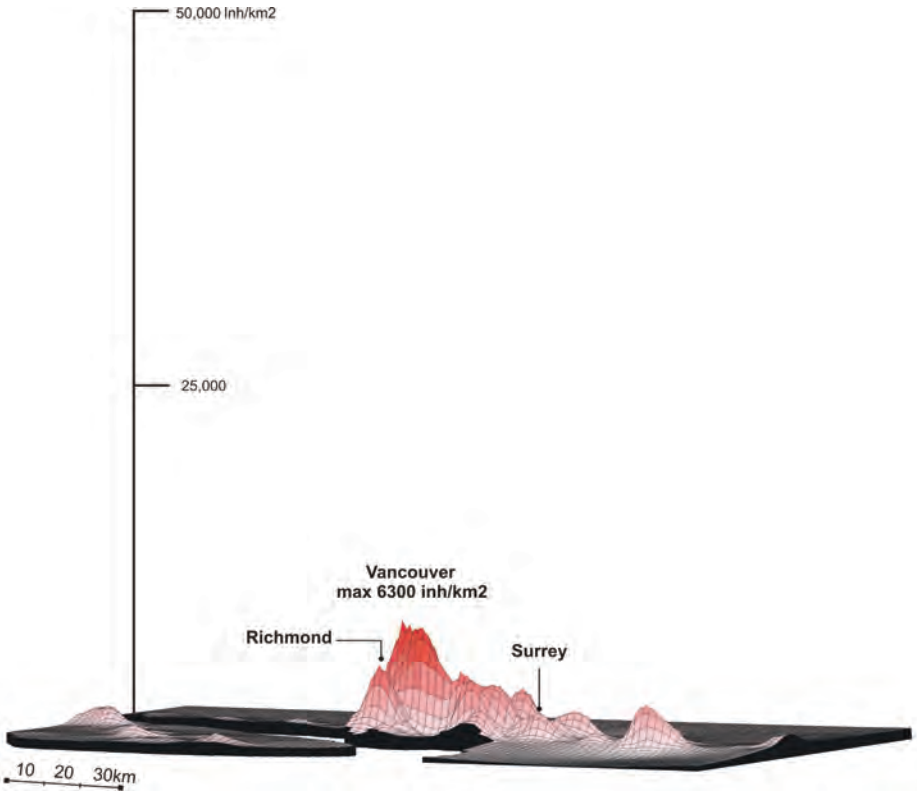
NEW YORK and PARIS





TORONTO and VANCOUVER





THE WORLD BANK

URBAN DEVELOPMENT
& LOCAL GOVERNMENT