3.2
Cities and Climate Change

The earth's surface temperature has increased by between 0.74 and 1.8 degrees Centigrade since 1906. At least part of the global rise in temperature, we now know, is a result of human activity. The global atmospheric concentration of carbon dioxide – one of the greenhouse gases most directly responsible for the greenhouse effect and global warming – has risen by 35 per cent since the year 1750; more than 70 per cent of this rise can be attributed to the burning and consumption of fossil fuels – oil, gas and coal.[1]

In the last few decades, global warming has been exceptionally rapid in comparison to the changes in climate over the past two millennia. The Intergovernmental Panel on Climate Change (IPCC) notes that the rate of global temperature increase in the last 50 years has been twice that of the last 100 years. IPCC estimates that the earth's temperature will rise by between 1.8 and 4 degrees Centigrade over the course of the 21st century, if current levels of greenhouse gas emissions are not curbed.[2] Global warming will have severe impacts on the planet, including increased flood risk and reduced water supply; declining crop yields, especially in Africa; increase in vector-borne diseases, such as malaria and dengue fever; displacement of hundreds of millions of people from coastal cities and small islands; and significant changes in marine ecosystems.

Carbon dioxide (CO_2) comprises 77 per cent of global greenhouse gas (GHG) emissions, with fossil fuel consumption accounting for the bulk (nearly 60 per cent) of these emissions, while deforestation and land use conversion from natural to farmed or built areas account for the rest. Globally, agriculture is responsible for 13.5 per cent of other greenhouse gas emissions, mostly methane and nitrous oxide (N_2O) from agricultural soils, livestock and manure.[3]

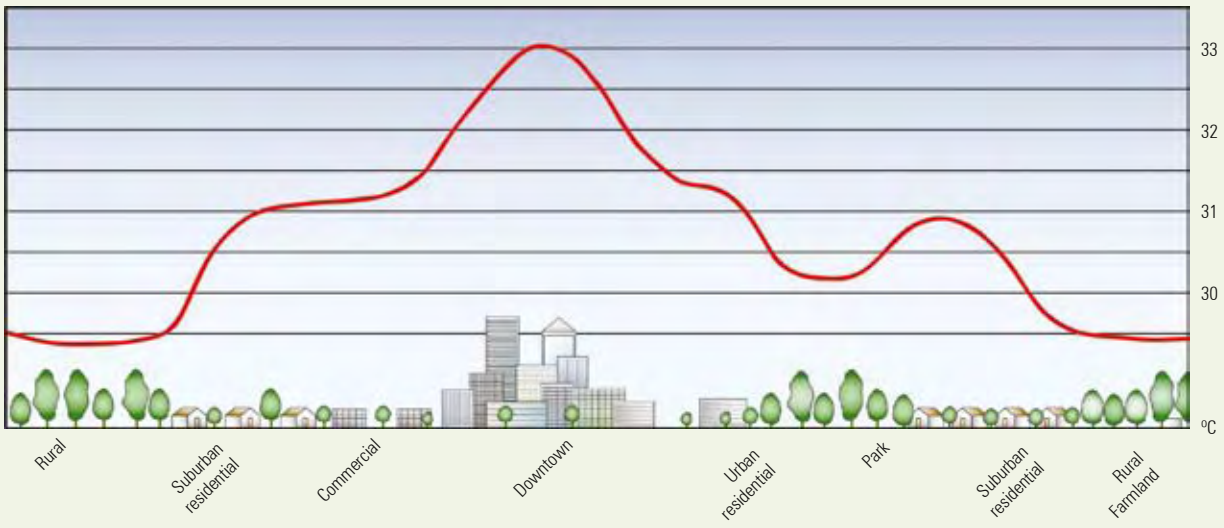
▲ It is estimated that the Earth's temperature will rise by between 1.8 and 4°C over the course of the 21st century.
©Clint Hild/iStockphoto

"Heat island" effect

Temperature distribution in urban areas is affected by the urban radiation balance. Solar radiation on urban surfaces is absorbed and transformed into heat. Walls, roofs and paved surfaces store heat and emit long-wave radiation to the sky, taking much longer to cool off than gardens, forests and fields. Areas with dense vegetation stay cooler because the sun's heat causes water held by soil and leaves to evaporate, and shading provided by plants keeps the ground cool. Because urban surfaces trap more heat than plants, urban areas have higher temperatures than surrounding rural areas. This phenomenon is known as the "heat island" effect.

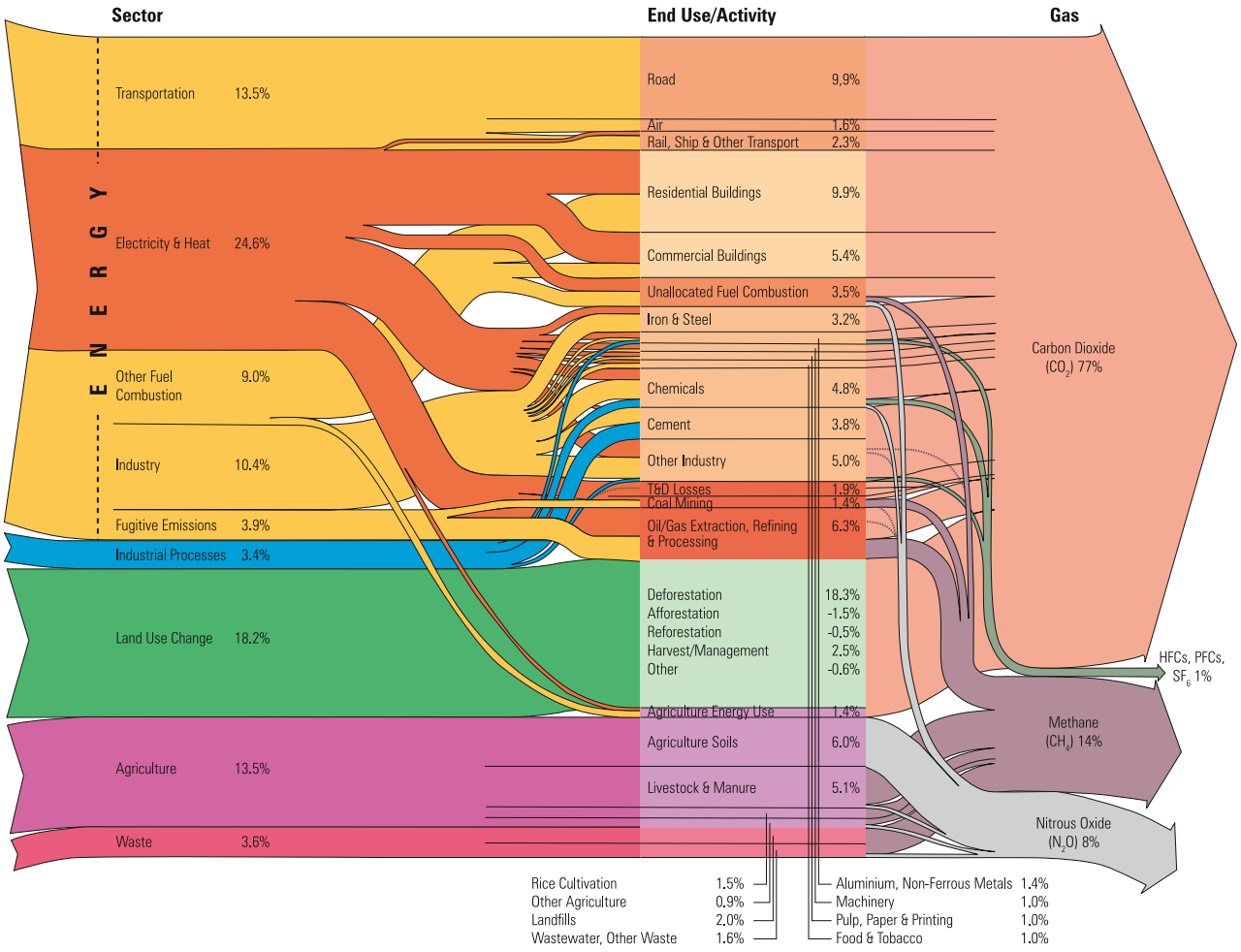
High temperatures in urban areas have a direct effect on the energy consumed by cooling appliances such as air conditioners. In large cities in the United States, the peak electricity load increases 3 to 5 per cent for a 1 °C increase in temperature. This is significant, considering that the average afternoon summer temperature in U.S. cities has increased from 1.1 to 2.2 °C in the last 40 years. It can be assumed that 3 to 8 per cent of the current urban electricity demand is used to compensate for the heat island effect alone. Hot air given off by air conditioning units also contributes to the urban temperature rise. A modelling study in Tokyo found that the waste heat emission from air conditioners is responsible for 1 °C warming in the summer. A similar study in Houston found that air conditioners account for a temperature increase of 0.5 °C during the day and 2.5 °C at night.

Rows of air conditioners on a building in Tokyo
©Holger Mette/iStockphoto



Source: F. Butera (2008), "Towards the renewable built environment", in: Urban Energy Transition, Elsevier.

FIGURE 3.2.1: **WORLD GHG EMISSIONS FLOW CHART**



Source: World Resources Institute (WRI) - Climate Analysis Indicators Tool (CAIT) http://cait.wri.org/

While cities are not the only generators of greenhouse gas emissions, there is no doubt that built-up areas consume more energy, and therefore produce more emissions than undeveloped areas. Energy for heating and lighting residential and commercial buildings generates nearly a quarter of greenhouse gas emissions globally, while transport contributes 13.5 per cent, of which 10 per cent is attributed to road transport (Figure 3.2.1).

In the EU-15,[4] mainly comprising countries in Western Europe, buildings account for approximately one-third of the total energy-related CO_2 emissions; on average, between 1980 and 1990, CO_2 emissions from buildings in the region have increased by 1.7 per cent per annum.[5] In 2002, homes generated the majority (77 per cent) of greenhouse gases emitted by buildings in the region, while the remaining 23 per cent originated from non-residential or commercial buildings,[6] the latter concentrated in cities. Because disaggregated data is not available, it is it not clear what proportion of the overall emissions is generated in urban areas, although since most buildings and transport networks are located in cities, urban areas are most likely responsible for a large proportion of these emissions. However, as the following chapters will show, emission levels are linked much more closely to consumption patterns and levels of income than to levels of urbanization or the size of built-up areas.

Energy for electricity, heating, transport, industry and other uses combined generates more than 60 per cent of greenhouse gases worldwide. Land use change, in the development of large-scale agriculture or infrastructure, has also had a significant impact on levels of CO_2 emissions. Machinery and materials used to convert greenfields – land not previously developed – to built or farmed areas contribute almost as much to worldwide greenhouse gas emissions as residential and commercial buildings, which are the most prominent global source of GHG emissions.

Emissions at the city level

It is no coincidence that global climate change has become a leading international development issue precisely at the same time and virtually at the same rate as the world is becoming urbanized. Cities are key players in the carbon emissions and climate change arenas because most human and economic activities are concentrated in urban areas. Cities generate a large share of most nations' gross domestic product (GDP), which typically translates into high levels of energy consumption for industrial processes compared to non-urban areas. Built-up areas in cities also consume a large amount of the world's energy, which contributes to global warming. Urban areas also influence patterns of energy and land use in the surrounding and more distant areas that affect the livelihoods and quality of life of people who live outside city boundaries.[7] At the same time, however, an increasing number of cities are becoming centres of innovation in alternative energy, developing resources that may reduce our dependence on fossil fuels and make our societies more sustainable.

Rich cities tend to produce more CO_2 emissions than poor cities. Increased incomes lead to changes in lifestyles that tend to increase consumption and energy dependence. North American cities, especially expanding cities in which residents are heavily dependent on private cars as the main mode of transport, typically produce exceptionally high levels of emissions. In the case of the United States, heavy dependence on motorized transport and urban sprawl have emerged as factors contributing to that country's high rate of urban emissions. For example, San Diego in the United States produces more emissions per capita than Tokyo, partly because residents of the latter are less dependant on private motorized transport. In Europe, emissions are lower, even though GDP per capita is similar to that of North America. This difference could be explained by the existence of environmentally friendly policies that promote the use of clean energy, lower electricity consumption, compact urban forms as well as the more prevalent use of public transport in European cities.

Urban sprawl and expansion, combined with widespread use of motorized transport, are significant contributors to levels of emissions in North American cities. Between 1970 and 1990, the total area of the 100 largest urban areas in the United States increased by 82 per cent. Population growth accounted for only half of the increase in land area, indicating that, in many cities around the country, people are living farther from the city centre and spending more time commuting. One study found that the number of miles driven by the average United States resident has increased by 25 per cent in the last 10 years; the amount of time Americans spend in traffic, though, has increased by 236 per cent. Time and fuel lost in heavy auto traffic is worth roughly US$78 billion to the American economy.[8]

Intra-city income inequalities also have a carbon- and climate-relevant dimension. The wealthy generally consume more than the poor and produce more solid waste (a source of methane) than the poor. However, because there is no global database on CO_2 emissions at the city level, it is difficult to correlate affluence and emissions. Furthermore, across high-income cities for which there is more information, CO_2 emissions per capita vary considerably. However, when explaining cities' energy use and greenhouse gas emissions, we need to bear in mind not only the size of a country's economy, its transport and household consumption patterns, but other factors as well, namely:

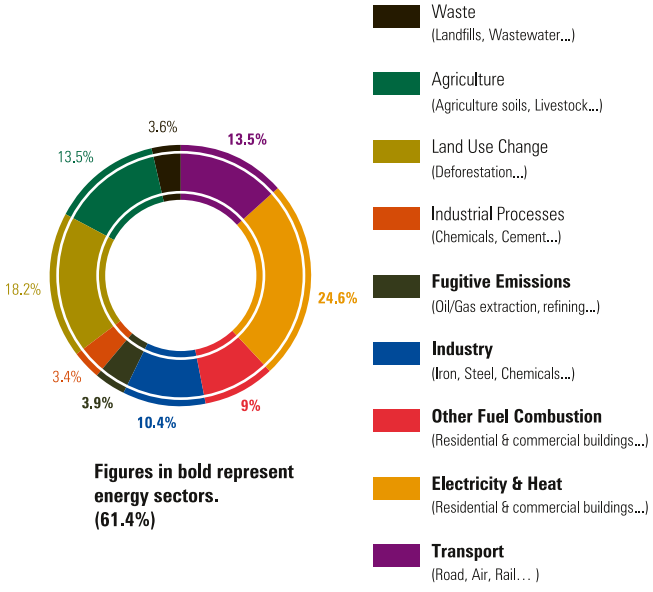
a) the sectoral and total carbon intensity of the city as measured by tonnes of CO_2 per unit of US$, determined by the fuels and technologies used;

b) the total and sectoral energy intensity as measured by the energy input/ economy output, determined by the fuels and technologies used;

c) the form and structure of the city, whether it is compact (dense) or scattered (urban sprawl), and its transport mode; and

d) the management structures of the city.

FIGURE 3.2.2: **GLOBAL GREENHOUSE GAS EMISSIONS IN 2000, BY SOURCE**



Source: World Resources Institute.
Notes: All data is for 2000. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41,755 $MtCO_2$ equivalent. Land use change includes both emissions and absorptions.

Emissions at the global and regional level

At the global level, 25 countries with the most greenhouse gas emissions account for approximately 83 per cent of global emissions; in the year 2000, they collectively represented 70 per cent of the global population and 87 per cent of global gross domestic product (GDP)[9]. The United States, China, the European Union, Russia, and India together contribute approximately 61 per cent of global emissions. In the developing world, Eastern Asia was the biggest emittor of CO_2 emissions (5.6 billion metric tonnes) in 2004 nearly three times the emissions produced by Southern Asia (2 billion tonnes) and four times the emissions produced by Latin America and the Caribbean (1.4 billion tonnes). Northern and sub-Saharan Africa produce the least amount of CO_2 emissions, 0.5 billion tonnes and 0.7 billion tonnes respectively.

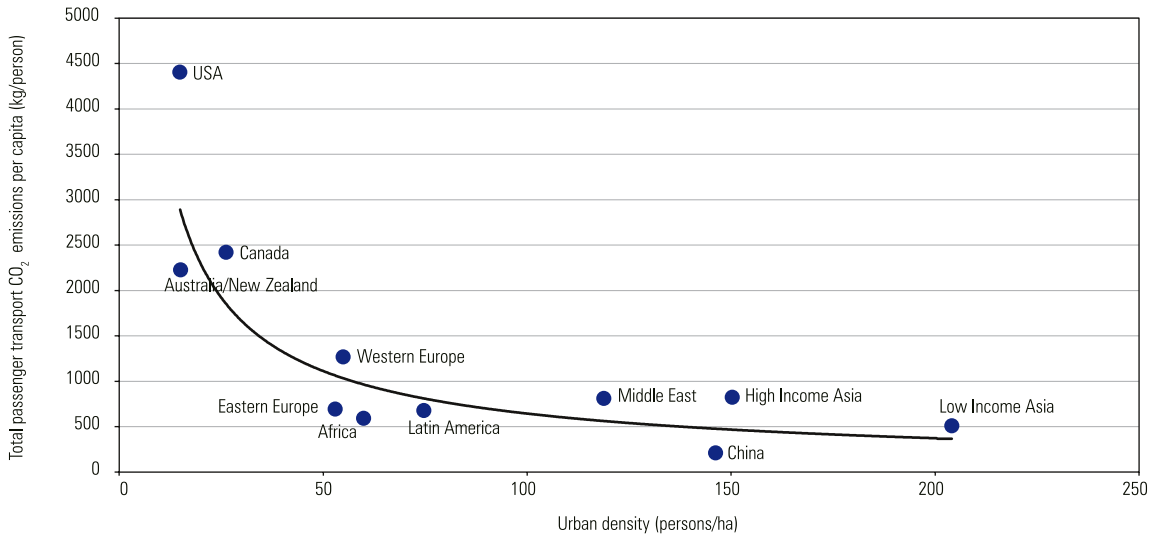
While Latin American cities generally produce low CO_2 emissions, individual countries in the region, such as Brazil, are among the top 20 emittors of CO_2 globally. In 2000, Latin America was responsible for 12 per cent of global CO_2 emissions, with land use change and deforestation accounting for nearly half of these emissions. The level of greenhouse gas emissions in Brazil is relatively high (337 million metric tonnes in 2004), largely resulting from deforestation in the Amazon basin. Regional methane emissions from anthropogenic sources (mainly livestock farming and the production and consumption of fossil fuels) represent 9.3 per cent of the world total. Brazil, Mexico, Venezuela, Argentina, Colombia, and Peru are responsible for more than 80 per cent of greenhouse gas emissions in Latin America and the Caribbean.[10] Large cities in the region, as well as many medium-sized cities, also emit greenhouse gases, mainly generated by motorized transport and industrial production.

On a global scale, a relationship is evident among emissions, population and GDP rankings, reflecting the importance of population and economic growth as emission drivers. For instance, in the year 2000, 8.7 per cent of the world's population was located in Latin American and Caribbean countries, which emitted 5.8 per cent of global CO_2 emissions, and had the following average GDP per capita: US $637 (low-income nations), US $1,799 (lower middle-income nations) and US $4,795 (upper middle-income nations). In contrast, North America had a GDP per capita of US $28,910 and 5.2 per cent of the global population, but contributed 13.7 per cent of the global emissions in 2000, more than twice that of Latin America and the Caribbean. In contrast, an individual in sub-Sahara Africa accounts for less than a tenth of the CO_2 produced by an average person in the developed world.

In newly industrializing countries, the combined impact of population growth, urbanization, motorization and increased energy use act as drivers of emissions. These factors are particularly significant in countries such as China and India. In 2007, China surpassed the United States as the leading emitter of greenhouse gases; the increase has been attributed mainly to increased coal consumption, industrial processes and changing lifestyles.[11] China's emissions are significantly larger than those of India, even though both countries have roughly similar economic growth rates and population sizes.

Evidence suggests that if current trends continue, climate change may eventually damage national and urban

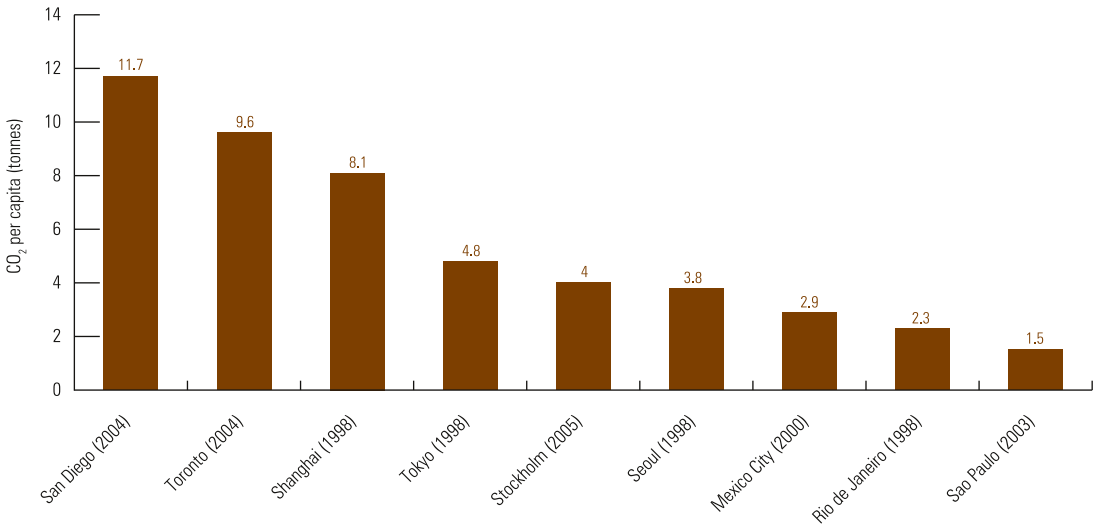
FIGURE 3.2.3: **RELATIONSHIP BETWEEN URBAN DENSITY AND CO_2 EMISSIONS**



Source: Adapted from Kenworthy 2003

Remains of burnt trees in the Amazon: Deforestation is a significant contributor to global CO_2 emissions.
©iStockphoto

FIGURE 3.2.4: **PER CAPITA CO_2 EMISSIONS IN SELECTED CITIES**



Source: UN-HABITAT Global Urban Observatory2008
Note: Data from various sources, 1998-2005

economies. Economic losses will emanate from declining agricultural production and increased heat waves, extreme weather, droughts, flooding, biodiversity loss, disease, and soil erosion. It is estimated that abrupt and large-scale climate change could lead to an average loss of 5 to10 per cent in global GDP, with poor countries suffering costs in excess of 10 per cent of GDP. This scenario has been described by former World Bank economist Nicholas Stern as "the greatest and widest ranging market failure ever seen."[12]

A report commissioned by the U.K.[13] in 2006 concluded that tackling climate change is a pro-growth strategy in the long term, as it reduces the risk of disrupting social and economic activities on a massive scale. Efforts to mitigate climate change effects should not, however, hinder productivity or reduce the quality of urban life. The challenge is to find ways to reduce emissions and vulnerability in an environment of equity, prosperity and harmony.

TABLE 3.2.1: **GHG EMISSIONS ON A REGIONAL SCALE**

Greenhouse Gas Emissions Diagnostic for OECD and Latin American

	Population (million)	GDP (2000$b)	CO_2 emissions (Mt CO_2)	Electricity consumption (kWh per capita)	CO_2 emissions per capita (t CO_2 per capita)
OECD	1,154	26,792	12,794	8,044	11.08
Latin America	432	1,443	850	1,601	1.97
World	6,268	33,391	24,983	2,429	3.99

Source: International Energy Agency (IEA), 2005, cited in Simms and Reid, 2006.

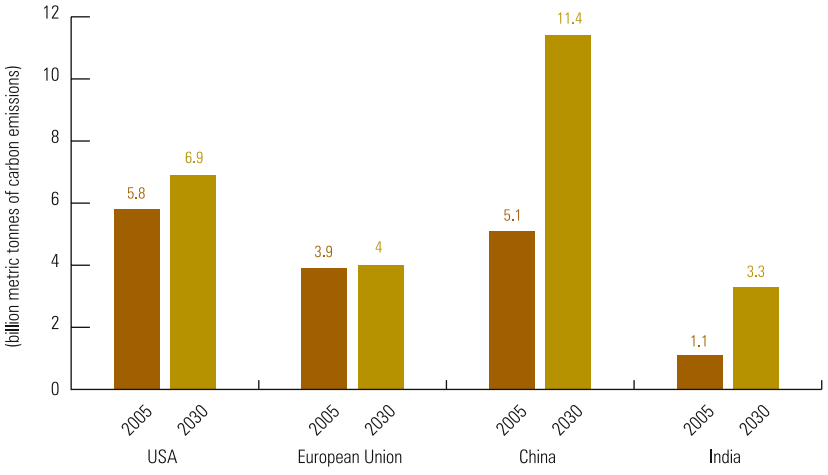
Urban responses to climate change

Many countries and cities have managed to urbanize without placing a huge environmental burden on the world's resources, thereby mitigating climate change. The challenge for cities is to implement policies that encourage lower energy consumption and emissions and to reduce vulnerability of urban populations.

World Bank estimates indicate that in urban metropolitan areas, the transport sector accounts for a third or more of total greenhouse gas emissions. The growing energy needs that countries face in the transport sector, especially in urban transport in developing countries, present major challenges in terms of energy security and the environmental externalities associated with emissions. The growth of secondary cities and urban sprawl contribute to the pressure on existing urban transport networks. A moderate increase in per capita vehicle ownership could lead to a long commute time, changes in land use, and more transport-related air pollution. The trend toward increased motorization, in all its forms, leads to longer travel times for surface public transport (buses)—which in turn induces more auto and taxi use—and to poor traffic safety, the economic inefficiency of increased fuel use, and degradation of the urban quality of life.

Promotion of non-motorized public transport options, is therefore, key to reducing emissions in cities. Reducing consumption of electricity and shifting to cleaner sources of energy would also go a long way in reducing emissions. Several cities have already put in place energy-efficient policies and practices, for example, in 1989, Toronto became the first city to adopt a greenhouse gas reduction target. Since the adoption of the Kyoto Protocol in 1997, several other cities have joined forces to address global warming and reduce emissions, as highlighted below:[14]

FIGURE 3.2.5: **CARBON EMISSIONS IN USA, EUROPEAN UNION, CHINA AND INDIA, 2005 AND 2030**



Urbanization levels

	2005	2030
USA	80.8%	87.0%
Europe	72.2%	78.3%
China	40.42%	60.3%
India	28.7%	40.7%

Source: Carbon emissions: International Energy Agency 2007
Urbanization rate: UN Population Division, World Urbanization Prospects 2005

Solar panel installation in Barcelona, Spain
©Snezana Negovanovic/iStockphoto

- The city of Calgary, Canada, is achieving significant electricity savings and reducing greenhouse gas emissions with the EnviroSmart Retrofit Project. Most of Calgary's residential streetlights are being changed to more energy-efficient flathead lenses. Streetlight wattage is being reduced from 200W to 100W on residential local roads and from 250W to 150W on collector roads.

- On 5 November 1999, Vienna City Council adopted the city's Climate Protection Programme (KLIP) as a framework for its Eco-Business plan. The plan was introduced to help enterprises operate and generate profits through eco-friendly practices that benefit both the enterprises and the environment. The initiative is a partnership among the city administration, interest groups, private companies, and management consultants. It promotes environmental protection strategies, efficient use of resources, sustainable development, information exchange, and effective relationships between the city administration and the private sector. To date, 527 enterprises have participated in the Eco-Business plan, implementing more than 9,000 environmental projects. These enterprises have been able to generate savings totalling approximately 30 million Euros. The city has also seen reductions in, solid waste output, by 109,300 tonnes; toxic solid wastes, by 1,325 tonnes; and carbon dioxide emissions, by 42,765 tonnes. Energy savings total 138.7 million Kwh, and 1,325,000 cubic meters of drinking water has been saved. The Eco-Business plan is now being implemented in Chennai, India, and Athens, Greece.

- The city of Johannesburg, South Africa, is guided by an integrated Environmental Management Policy, the goal of which is to improve the quality of the urban environment. Mitigation measures in place are retrofitting of council buildings, energy savings in water pump installations, and methane gas recovery.

- The Spanish city of Barcelona has addressed the energy-efficiency issue through the Barnamil Campaign, the goal of which is to install solar panels for heating domestic hot water in urban residential areas. Since 2006, Barcelona has made solar panel installation mandatory for all new and renovated buildings to supply at least 60 per cent of the energy needed to heat water.

- In 1997, the municipality of Guangzhou in southern China initiated a five-year Action Programme for improving the living environment to maintain and enhance Guangzhou's attractiveness both as a place to live and do business. The strategic urban plan of Guangzhou provided the overall framework for implementation and resulted in substantial improvements in traffic

management, urban greening, sanitation, pollution control, and conservation of natural resources and cultural heritage. The action plan is been replicated in other cities in China, such as Hangzhou, Nanjing, Jinan, Xiamen, Changsha and Chengdu.

- In the U.K., the Leicester Environment Partnership has developed a Climate Change Strategy for the city to stimulate public debate, raise awareness and initiate a plan of action to minimize impacts and effects of climate change. The Climate Change Strategy builds on the 1994 Leicester Energy Strategy and puts in place an integrated approach to the mitigation of climate change across the city. Its objectives are: assessing the city's contributions to climate change; forecasting change in the next 80 years; reviewing progress on targets contained within 1994 Leicester Energy Strategy; identifying how to reduce greenhouse gas emissions; providing a framework for an action programme; and setting up a monitoring framework to assess progress towards targets.

- In the U.S.A., more than 710 cities have joined forces to undertake local actions to meet or beat the Kyoto Protocol target (i.e. 7 per cent reduction in emissions from 1990 levels by 2012) through actions ranging from anti-sprawl land-use policies to urban forest restoration projects. U.S. cities are also partnering with businesses to meet their environmental goals. More than 50 private firms are taking part in the ClimateWise Program, in which cities offer free assessments of a firm's energy, water, solid waste, transport, and recycling, then offer guidance on becoming more energy efficient. The city of Chicago also awards grants for rooftop gardens that help to improve air quality, conserve energy and reduce storm water runoff. And Seattle recently began a programme in which businesses assess and cut greenhouse gas emissions and encourage their workers, customers and suppliers to do the same. Participating cities are encouraged to work with the global ICLEI Local Governments for Sustainability's Cities for Climate Protection Programme to assist them in tracking progress. To support all these efforts, an umbrella body called the World Mayors and Local Governments Climate Protection Agreement was officially launched at the United Nations Climate Change Conference in Bali, Indonesia, in December 2007.

TABLE 3.2.2: **ADAPTATION STRATEGIES**

Sector	Adaptation option/strategy	Policy
Water supply/water hazards	Water storage and conservation techniques; incentives for water conservation; water reuse; water recycling; desalination; increase water use efficiency; public education; flood risk map; public participation flood adaptation and mitigation programs; greater investment in water supply systems; controlled use of urban and rural groundwater.	Urban water policies and integrated water resources management; water-related hazards management; integrating climate change into public policy; policy to control groundwater extraction.
Infrastructure/ settlement (including cities in the coastal zones)	Cleaning drainage system and replacement of primary sewer system; encourage infiltration and increasing depression and street detention storage; re-designing structures; relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of wetlands as buffer zone against sea level rise and flooding; protection of existing natural barriers; maintaining defensible space around each building/neighborhood.	Design standards and codes; regulations; integrate climate change considerations into design; land use policies; insurance; financial incentives; public education regarding risk of living in hazard prone areas.
Human health	Heat-related public health action plans; emergency medical services; access to public 'cooling centers'; improved climate sensitive disease surveillance and control; access to safe water and improved sanitation; greater ingovernmental coordination and cross-boundary coordination.	Public health policies that recognize climate risk; strengthen health services; intergovernmental, regional and international cooperation; greater investment in health services.
Urban transport	Environmentally friendly transport system; energy efficient cars; car pooling; efficient public transportation system; new design standards and planning for urban roads, rail, etc., to cope with warming and drainage; fuel substitution.	Integrating climate change considerations into urban transport policy; investment in research and development; incentives for energy efficient car industry.
Energy	Strengthening of overhead transmission and distribution lines; underground cabling for utilities; increasing energy efficiency; emphasis on renewable resources.	Sustainable urban energy policies; regulations; fiscal and financial incentives to encourage use of green energy and building; incorporate climate change in design standards and codes.

Source: Extract from Mirza 2007.

Poverty reduction as an adaptation strategy

The Stern Review on the Economics of Climate Change (2006), commissioned by the Government of the United Kingdom, is unusual among discussions on climate change in its explicit recognition that climate change adaptation in low- and middle-income countries has to reduce the vulnerability of the urban poor. If cities and countries had been more successful in the last five decades in reducing poverty, upgrading slums and providing infrastructure and services to low-income settlements, adaptation costs would be much lower. The deficiencies in infrastructure, housing and services in slums and informal settlements means that the cost of adaptation includes not only putting in place the necessary infrastructure but improving the durability of housing and expanding the scale of public service provision. The report notes key areas of action that could help reduce vulnerability to the effects of climate change: improving food security and overcoming the structural causes of famine; building robust education and health systems; better urban planning that includes provision of services and infrastructure to the most vulnerable groups; and gender equality.

Source: Satterthwaite et al., 2007

▲
Nanjing, China.
©City of Nanjing

NOTES

1 Intergovernmental Panel on Climate Change, 2007.
2 UNEP, 2007b.
3 Data drawn from the World Resources Institute's Climate Analysis Indicators Tool, online database version 3.0.
4 Eu-15 comprise the following 15 European countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, and the U.K.
5 Constantinos et al., 2007.
6 Petersdorff, et al., 2004.
7 Hardoy, Mitlin & Satterthwaite, 2004.
8 Knaap, 2008.
9 Baumert, Herzog & Pershing, 2005.
10 UNEP Regional Office for Latin America and the Caribbean and SEMARNET (Secretaria de Medio Ambiente y Recursis Naturales), 2006.
11 Netherlands Environmental Assessment Agency, 2007.
12 Stern, 2006.
13 Stern, 2006.
14 City examples from UN-HABITAT Best Practices database, www.bestpractices.org and other sources.