

3.4

Energy Consumption in Cities

The urban metabolism

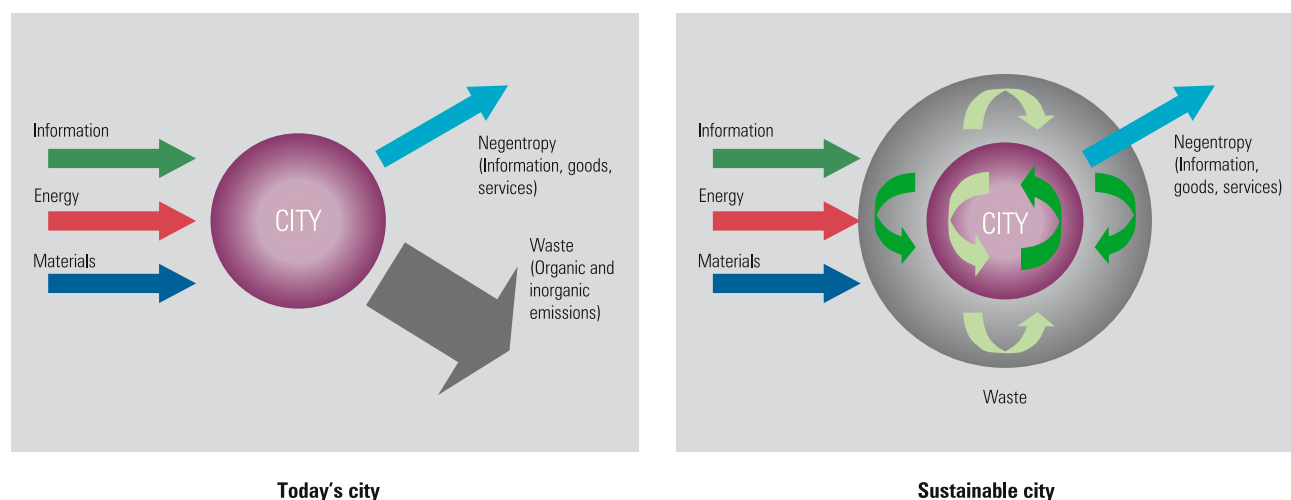
Energy consumption is the largest contributor to carbon dioxide (CO₂) emissions, the leading cause of climate change. It is important to understand which sectors consume the most energy to take appropriate remedial actions for emissions reduction. It is helpful to view cities as organic systems that have their own metabolism.¹ The metabolism of a city involves physical inputs – energy, water and materials – that are consumed and transformed, by means of technological and biological systems, into wastes and goods, or the city's outputs. Like any thermodynamic system, urban energy consumption can either be efficient or inefficient. An environmentally successful and energy efficient – or sustainable – city should ideally combine economic growth with social equity and minimum waste production (including greenhouse gas emissions).

To meet minimum waste standards, cities must fulfil two prerequisites: minimization of fossil fuel use and material

inputs; and maximization of recycling and reuse of energy, water and materials. The need for sustainable, or harmonious, urban development further requires cities to function with a circular, rather than a linear, metabolism. But first understanding how cities came to develop high-impact, linear metabolism systems is essential for knowing how to find effective means to make the shift to sustainable, circular metabolic systems.

The contribution of cities to global warming derives basically from combustion processes – from the production of energy. But energy also plays a vital role in sustaining the metabolism of cities. Agriculture, which sustains both rural and urban populations, for instance, also contributes to greenhouse gas emissions. Land use change (for urban development or for cultivation), and agriculture combined account for more than 30 per cent of global greenhouse gas emissions (Fig. 3.4.1).

FIGURE 3.4.1: LINEAR AND CIRCULAR URBAN METABOLISM



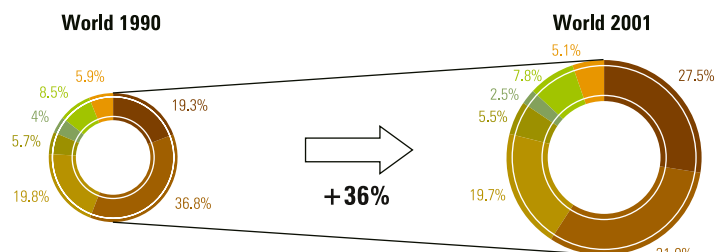
Source: Figure courtesy of F. Butera

Power lines against a stormy, cloudy sky
©iStockphoto

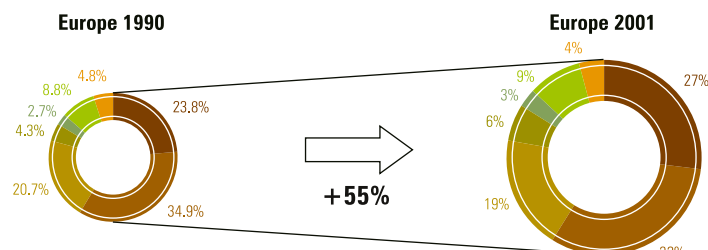




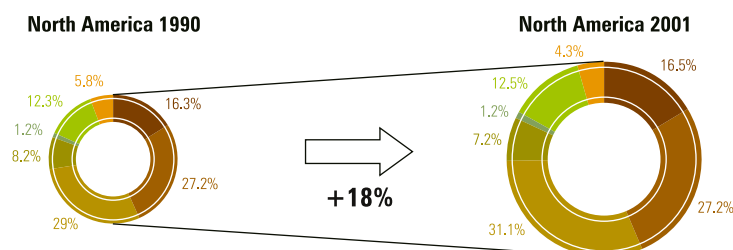
FIGURE 3.4.2: ENERGY CONSUMPTION BY REGION



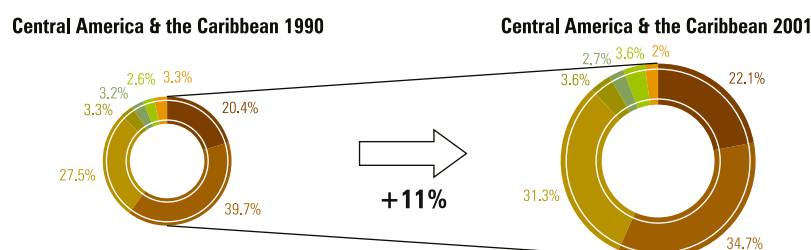
Total Final Consumption
5,566,234 (1000 metric toe a) Total Final Consumption
7,585,443 (1000 metric toe a)



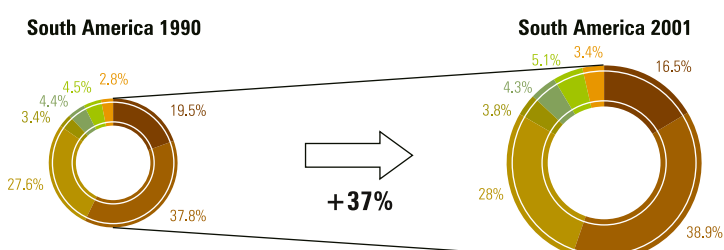
Total Final Consumption
1,198,340 (1000 metric toe a) Total Final Consumption
1,858,697 (1000 metric toe a)



Total Final Consumption
1,468,100 (1000 metric toe a) Total Final Consumption
1,725,599 (1000 metric toe a)



Total Final Consumption
125,054 (1000 metric toe a) Total Final Consumption
138,513 (1000 metric toe a)



Total Final Consumption
222,271 (1000 metric toe a) Total Final Consumption
304,536 (1000 metric toe a)

- Residential
- Industry
- Road Transport
- Other Transport
- Agriculture
- Commercial and Public Services
- Other

TECHNICAL NOTES:

Residential includes all energy used for activities by households except for transport.

Industry includes a combination of all industrial sub-sectors, such as mining and quarrying, iron and steel, and construction. Energy used for transport by industry is not included here, but is reported under transportation.

Road Transport includes all fuels used in road vehicles, including military, as well as agricultural and industrial highway use. The sector excludes motor gasoline used in stationary engines and diesel oil used in tractors.

All other transport refers to all fuel used for non-road transport except fuel used for international marine bunkers and ocean, coastal, and inland fishing. It includes transport in the industry sector and covers railways, air, internal navigation (including small craft and coastal shipping not included under marine bunkers), fuels used for transport of minerals by pipeline and non-specified transport.

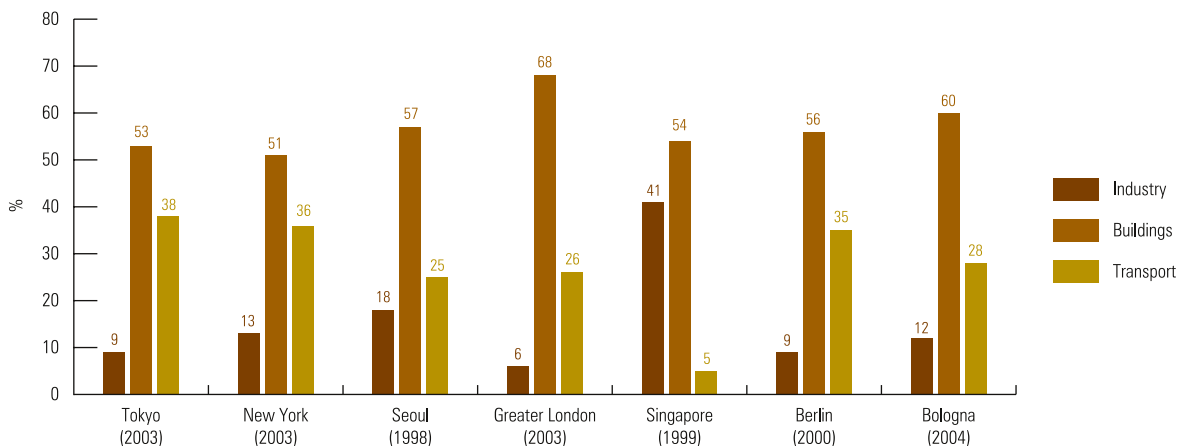
Agriculture includes all activities defined as agriculture, hunting, and forestry. The sector therefore includes energy consumed by ocean, coastal and inland fishing in addition to the energy consumed by traction, power, and heating.

Commercial & Public Services includes, for example, wholesale and retail trade; the operation of hotels and restaurants; post and telecommunications; real estate, renting and business activities; the collection, purification and distribution of water; maintenance and repair of motor vehicles and motorcycles; financial intermediation, except insurance and pension funding; computers and related activities; sewage and refuse disposal; public administration and defence; education; and other community, health, social and personal service activities.

Non-energy Uses and "other" includes the use of petroleum products such as white spirit, paraffin waxes, lubricants, bitumen and other products. It is assumed that these products are used exclusively for non-energy purposes. This category also includes the non-energy use of coal (excluding peat) and fuel inputs for the production of ammonia and methanol. All fuel use not elsewhere specified is included here.

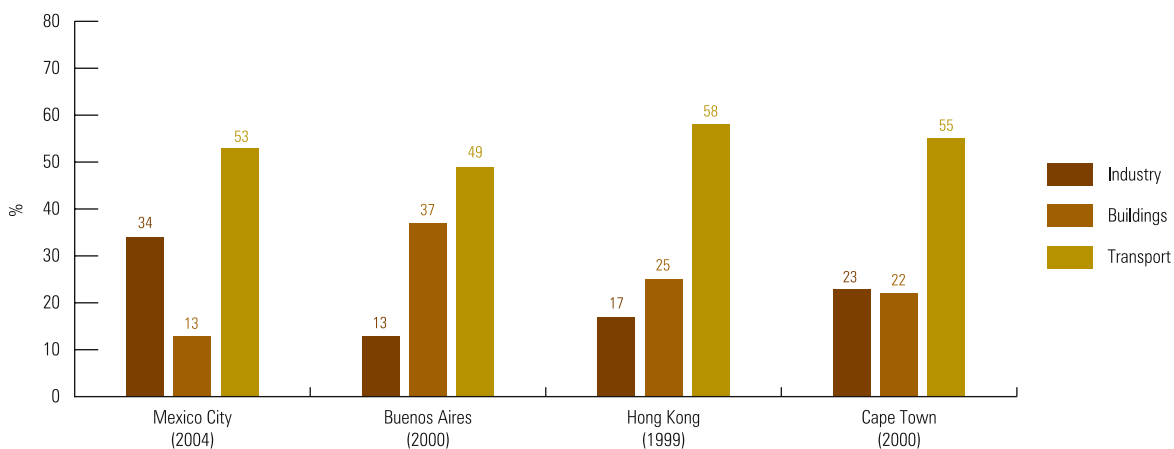
Source: Prepared by International Energy Agency, reported in World Resources Institute, Earthtrends, www.earthtrends.wri.org

FIGURE 3.4.3: ENERGY CONSUMPTION IN SELECTED CITIES IN HIGH-INCOME, INDUSTRIALIZED ECONOMIES



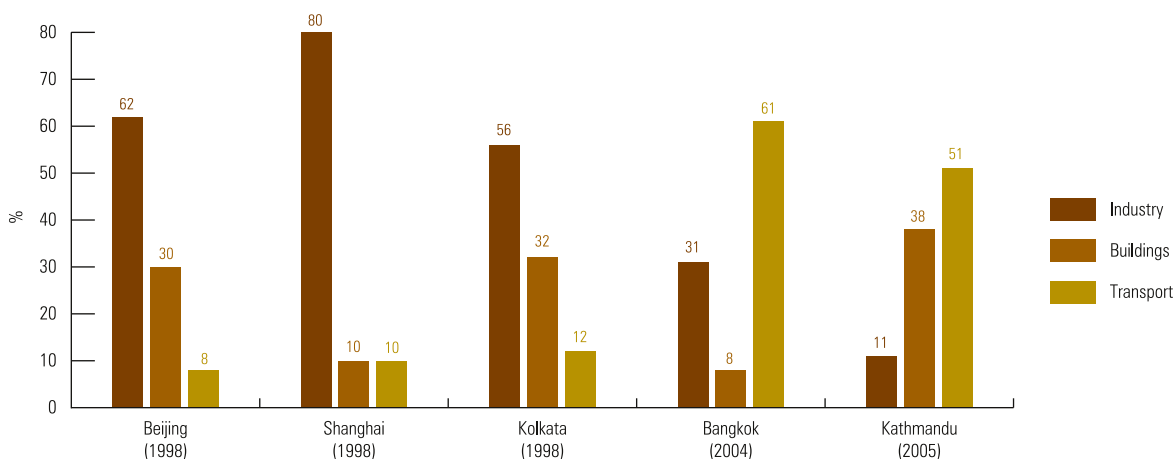
Source: UN-HABITAT Global Urban Observatory 2008
 Note: Data from various sources, 1999-2004

FIGURE 3.4.4: ENERGY CONSUMPTION IN SELECTED CITIES IN MIDDLE-INCOME COUNTRIES



Source: UN-HABITAT Global Urban Observatory 2008
 Note: Data from various sources 1999-2004

FIGURE 3.4.5: ENERGY CONSUMPTION IN SELECTED ASIAN CITIES



Source: UN-HABITAT Global Urban Observatory 2008
 Note: Data from various sources, 1998-2005

Energy consumption by sector

In the early phase of industrialization, European cities looked like the cities of today's emerging economies, with heavy industries running on coal, producing high levels of urban air pollution and emissions. The amount of energy used to produce one unit of gross domestic product (GDP) was very high, due mainly to the high energy consumption of the industrial and construction sectors. In developed, industrialized cities, energy is consumed primarily through the maintenance and operation of built-up infrastructure, rather than on industry.

In the wealthier cities in the industrialized world, most energy is used to heat and light residential and commercial buildings; transport and industry follow as the second and third greatest consumers of energy. As Figure 3.4.3 shows, residential and commercial buildings account for more than half of the energy consumed in cities such as London, Bologna and Tokyo, while the transport sector consumes between 25 and 38 per cent of energy, with the exception of Singapore, which has successfully made urban mobility

more energy efficient. Industry consumes less than 10 per cent of energy in cities such as Berlin and Tokyo because economic activities in there have moved away from industry to services.

Transport is the highest consumer of energy in cities such as Mexico City, Hong Kong and Cape Town, followed by residential and commercial buildings and industry (see Figure 3.4.4). Cities in the developing world show different energy end-use distribution according to their size and their stage of economic development. In megacities such as Beijing, Shanghai and Kolkata, industries consume more than 50 per cent of total energy uses, reflecting the fast growth of Chinese and Indian economies, while in large cities of countries whose economies are growing at a slower pace, the transport sector consumes more than half of the total energy used. Some industries in Chinese cities are voracious consumers of energy. Shanghai's industrial sector, for instance, consumes as much as 80 per cent of energy, compared to 10 per cent consumed by transport.



▲ Tokyo skyline at dusk: Residential and commercial buildings account for more than half of the energy consumed in Tokyo.
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Ecological footprint

The ecological footprint is a measure of how much productive land and water an individual, a city, a country, or the whole global population require to produce all the resources they consume and to absorb all the waste they generate, using the prevailing technology.² The total ecological footprint of a given place or people is the sum of cropland, forest, grazing land, fishing ground, built-up land, and carbon and nuclear energy footprints required to sustain them and to absorb their outputs.³ The world ecological footprint is measured in hectares (1 ha = 10,000 m²) of biologically productive space with world-average productivity.

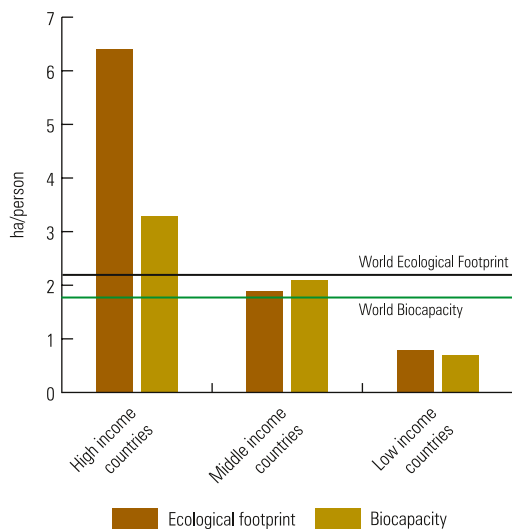
Today, humanity's ecological footprint is 2.2 ha per person – over 21 per cent greater than the earth's biocapacity (1.8 ha), or its capability to regenerate the resources used. In other words, it now takes more than one year and two months for planet Earth to regenerate what we, its inhabitants, use in a single year.

Middle- and low-income countries, on average, do not contribute to the global over-consumption of resources, but exceptions include China and India, whose ecological footprints are twice their biocapacity. There are exceptions in the high-income countries too, such as New Zealand and Canada, whose ecological footprints are less than half their biocapacity.

The total ecological footprint can be subdivided into specific categories of consumption and waste production. The **carbon footprint** is calculated as the area of forest that would be required to absorb CO₂ emissions from fossil fuel combustion, excluding the proportion absorbed by the oceans. The **biomass fuel footprint** is calculated as the area of forest needed to grow wood and other forest products used as fuel. The hydropower footprint is the area occupied by hydroelectric dams and reservoirs. The **energy footprint** – of both carbon-based and nuclear-generated energy sources – accounts for more than half of the total world ecological footprint. At the city scale, the energy footprint is even more dominant.

Ecological footprints of cities are usually higher than those of their countries, but there are exceptions. For instance, as shown in Figure 3.4.8, the ecological footprints of Berlin and Wellington are smaller than those of Germany and New Zealand, respectively. In general, richer cities have larger footprints than poorer cities. The figure highlights the width of the gap in natural resource use between high-income North American cities and poor cities of developing countries, but also between cities in the United States and in the rest of the world, including Canada. This shows that the same quality of life can be achieved with very different environmental impacts.

FIGURE 3.4.6: ECOLOGICAL FOOTPRINT OF COUNTRIES BY INCOME (2003)*



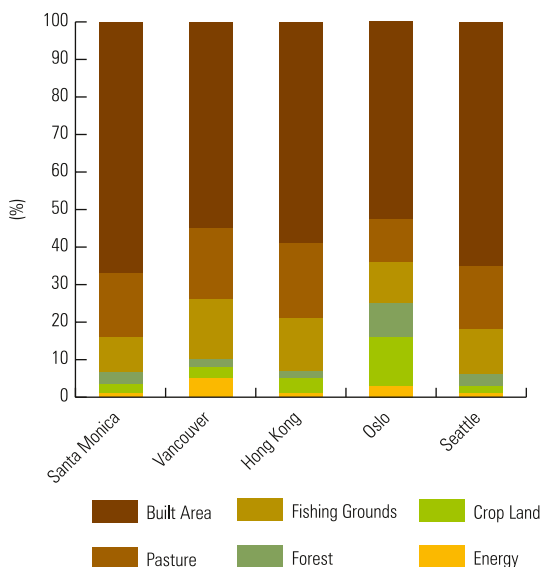
***High-Income Countries:** Australia, Austria, Belgium & Luxembourg, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea Republic, Kuwait, Malta, Netherlands, New Zealand, Norway, Portugal, Saudi Arabia, Slovenia, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States of America.

Middle-Income Countries: Albania, Algeria, Angola, Argentina, Armenia, Azerbaijan, Belarus, Bolivia, Bosnia Herzegovina, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Cuba, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Gabon, Georgia, Guatemala, Honduras, Hungary, Indonesia, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Latvia, Lebanon, Libya, Lithuania, Macedonia, Malaysia, Mauritius, Mexico, Morocco, Namibia, Panama, Paraguay, Peru, Philippines, Poland, Romania, Russia (and USSR in 1975), Serbia and Montenegro, Slovakia, South Africa, Sri Lanka, Swaziland, Syria, Thailand, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, Uruguay, Venezuela.

Low-Income Countries: Afghanistan, Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Rep, Chad, Congo, Congo Dem Rep, Côte d'Ivoire, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Haiti, India, Kenya, Korea DPRP, Kyrgyzstan, Laos, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Moldova Republic, Mongolia, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tajikistan, Tanzania, Togo, Uganda, Uzbekistan, Viet Nam, Yemen, Zambia, Zimbabwe

Source: World Wildlife Fund, ZSL, GFN, Living planet report 2006, http://assets.panda.org/downloads/living_planet_report.pdf

FIGURE 3.4.7: **ECOLOGICAL FOOTPRINT BY COMPONENTS IN SELECTED CITIES**



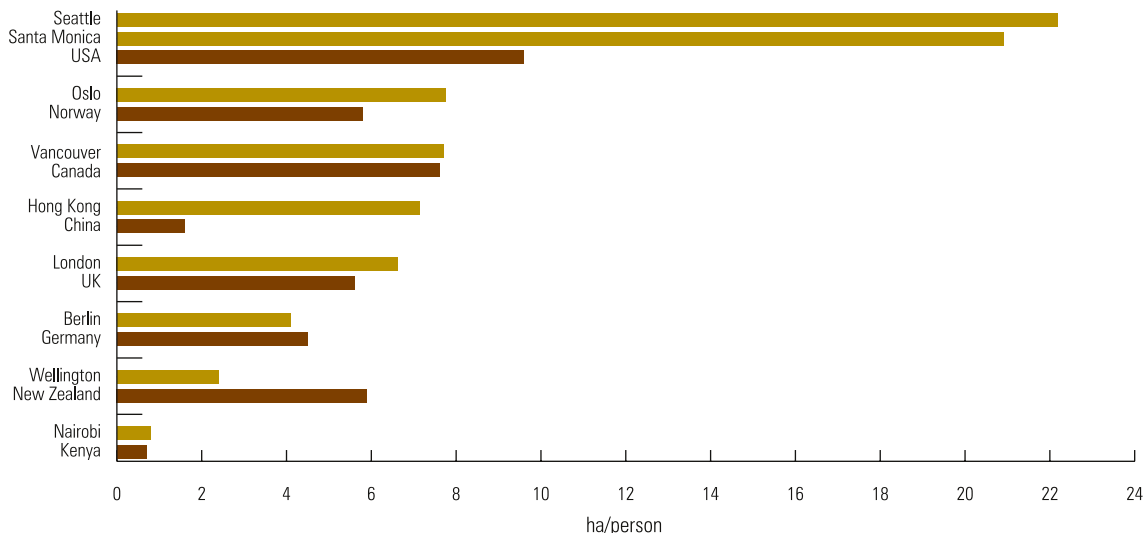
Source: UN-HABITAT Global Urban Observatory 2008
 Note: Data from various sources

MAP 3.4.8: **ECOLOGICAL FOOTPRINT OF BERLIN FOR THE YEAR 2000**



Source: Jens Pacholsky

FIGURE 3.4.9: **ECOLOGICAL FOOTPRINT OF SELECTED CITIES AND OF THE COUNTRIES WHERE THEY ARE LOCATED**



Source: UN-HABITAT Global Urban Observatory 2008
 Note: Data from various sources

NOTES

- ¹ Bettencourt et al., 2007
- ² Wackernagel & Rees, 1996.
- ³ Global Footprint Network, 2007