3.5

Urban Energy Consumption at the Household Level

Electricity meters in a city apartment building
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Trends in developed countries

Studies suggest that residential and commercial buildings are responsible for about 30 per cent of the greenhouse gas emissions of countries belonging to the Organization of Economic Cooperation and Development (OECD) countries.[1] Actions aimed at reducing emissions from buildings depend not only on climate, building type and level of economic development, but also on lifestyle, energy sources availability and structure of the local energy system.

Heating of residential and commercial buildings ranks first in the household energy end uses in developed countries, and is one of the main causes of energy-related greenhouse gas emissions. The main obstacle to the reduction of emissions derives from the fact that much of the current urban building stock in Europe was designed and constructed when energy was cheap and global warming was unheard of. Inefficient design and construction, combined with the prevalent use of cement, steel and glass in modern architecture, have led to energy waste in buildings, which rely heavily on energy-intensive heating and cooling systems.

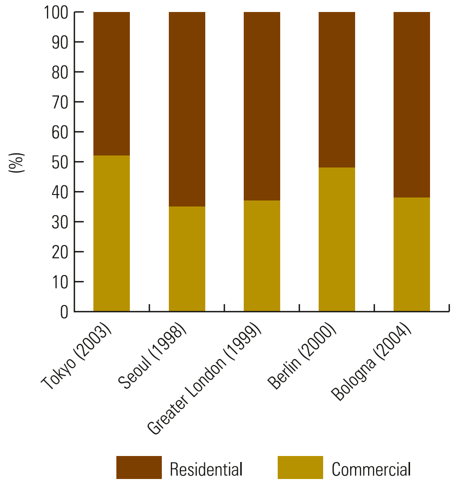
Paradoxically, old buildings – built in the 19th century or before – are less energy-dependent than those built in the 1960s and 1970s. This is because, in the past, buildings were designed to obtain the highest comfort levels with the minimum use of energy technologies, using appropriate building materials suited to the local climate. The result of the modern trend towards using energy-intensive building materials not appropriate for local climates has led to the very high energy consumption figures in developed countries.

In cities of developed countries, the energy consumed by residential buildings is significant, as shown in fig 3.4.1. In London, Seoul, Berlin, and Bologna, for instance, residential buildings consume more than 50 per cent of the total energy used. However, in cities experiencing rapid economic growth, such as those in China, the commercial sector consumes the bulk of energy.

Since energy consumption for both heating and cooling is strongly affected by the quality of building envelopes, building design has a tremendous impact on energy demand. Adopting energy-efficient building regulations – including requirements for insulation, low-impact building materials and flexibility to improve as technologies change – is important for countries to reduce their dependence on scarce resources, however, regulations are seldom fully enforced.

Builders often complain that well-insulated buildings are more costly to build than poorly insulated buildings, but evidence shows that the savings on household energy bills quickly offsets the higher initial cost of construction. Poor insulation also increases the costs of heating, which impacts low-income households most acutely. The European Community Household Panel (ECHP), for instance, recently revealed that 17 per cent of households in the EU-15 declare an inability to adequately heat or insulate their homes.[2] The latest available estimates suggest that in 2004, some 2 million households in the United Kingdom experienced difficulty in keeping their homes warm at an acceptable level of cost.[3] The same applies to Southern Europe, where an alarming 45 per cent of households in Greece, 55 per cent in Spain and 74 per cent in Portugal[4] are not able to meet reasonable comfort conditions because of their inability to pay for the fuel needed to heat their un-insulated buildings. A study carried out in 2004 in the major Athens, Greece, area found that poor insulation of residential buildings was directly related to heating expenditures: the lower the income of the household, the higher the cost of heating per person and unit of surface.[5]

FIGURE 3.5.1: **SHARE OF ENERGY CONSUMPTION IN RESIDENTIAL AND COMMERCIAL SECTORS IN SELECTED CITIES IN HIGH-INCOME COUNTRIES**



Source: UN-HABITAT, 2008
Note: Data derived from various sources, 1998-2004

Adequate building envelope insulation and good-quality buildings do not just lead to lower energy consumption and higher comfort levels, but also to better health of the occupants. In many recent surveys in Eastern Europe, households have complained about insufficient heat from dilapidated district heating systems, which have resulted in increased rates of illness. For example, in Sevastopol, Ukraine, 56 per cent of inhabitants of poor quality housing got sick because indoor temperatures were too low.[6]

Since the early 1980s, however, a growing concern about energy conservation has led central governments and cities to implement new regulations for buildings. In spite of the regulations, the overall impact on energy use has been rather limited, for several reasons, namely:

- The regulations apply only to new buildings or to old buildings that have been completely renovated, and not to old buildings that form a large proportion of the building stock in Europe.

- Living space increases as household incomes rise. The average size per dwelling in the EU-15 countries has increased from 84 square metres in 1985 to 89.5 square metres in 2001, at an average annual rate of 0.4 per cent or 0.3 square metres per annum.[7] The size of U.S. dwellings has grown even more. In California, the floor area of a new single-family home has doubled from approximately 100 square metres in 1972 to 200 square metres today[8]. As the average size of dwellings increases, more energy is used for heating and air conditioning. Moreover, larger houses are being shared by smaller families. The size of families in the developed world is decreasing, with a concomitant increase in the number of dwellings necessary to accommodate one or two occupants. This phenomenon is especially attributable to the increasing number of elderly people. An urban audit of 258 cities in the European Union found that an increasing number of people are living alone and that the average living space per inhabitant varies significantly among cities. City dwellers in Denmark, the Netherlands, Sweden, and Germany, for instance, have more than twice the living space of urban inhabitants in Romania, Latvia and Poland.[9]

For these and other reasons, tighter measures are needed to limit energy consumption both in existing and new buildings. In some places, new buildings are designed to be carbon neutral, as is the case in the U.K., where carbon-neutral building regulations will be enforced by 2016.

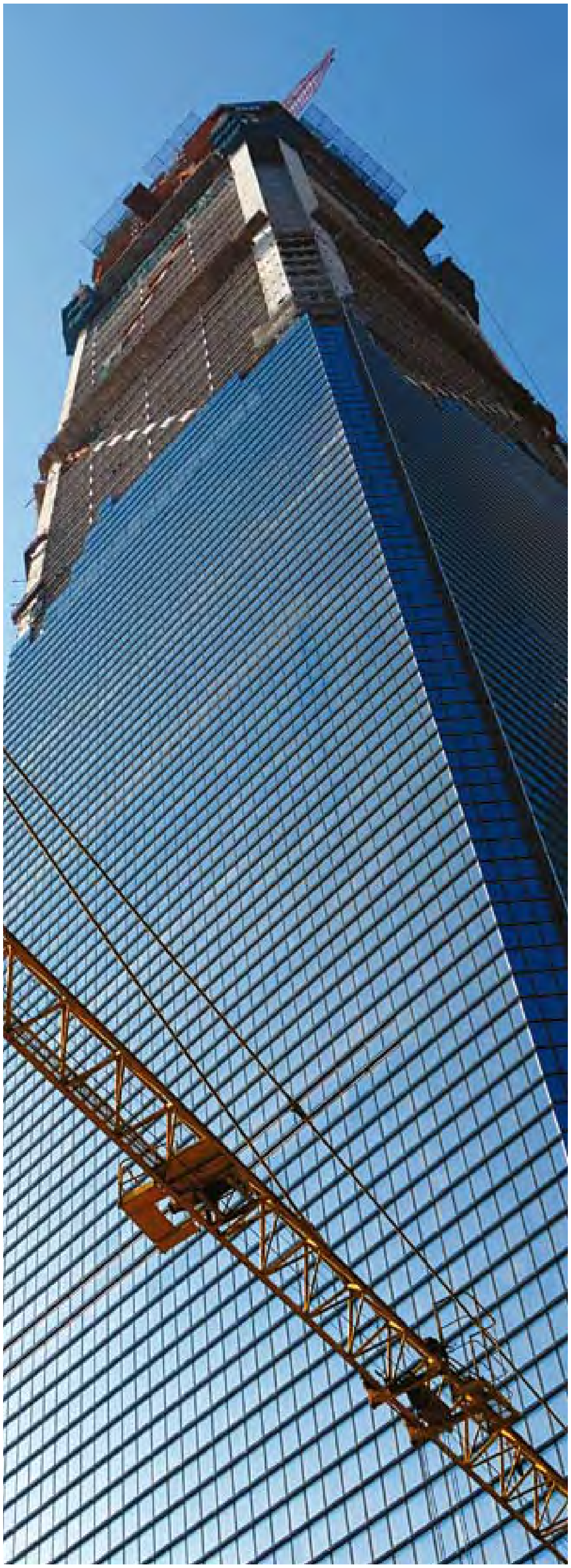
Trends in developing countries

In developing countries, population growth, urbanization and economic development are having a huge impact on the construction industry. The most striking example comes from the rapidly growing economy of China, where new buildings are being constructed at the rate of an estimated 1.8 billion square metres per year.[10] China is taking energy conservation seriously by enforcing new building regulations; India, too, has made compliance with its Energy Conservation Building Code, launched in 2007, mandatory.

In the 21st century, the energy requirements for heating buildings in developing countries that experience cold winters will grow sharply – not only because of increases in dwelling size, but also because of the rising comfort threshold of households. This phenomenon has already occurred in developed countries where, at the beginning of the 20th century, even the wealthiest households heated only one room in their dwelling,[11] and the temperature usually did not exceed 18 °C. At the end of 20th century, the same households were heating their whole dwelling, even the unoccupied rooms, and the required comfort threshold rose to more than 20 °C.

Energy policies addressing the residential sector should set as a priority the improvement of the building envelope, especially in dwellings occupied by low-income people. Increases in fuel prices create the most economic problems for low-income residents, and if fuel prices rise precipitously for whole communities, social problems are likely to follow.[12] The fuel or energy ladder implies that change in household income is reflected in the type and cost of fuel used. In general, low-income households tend to use fuels that are more costly and more energy inefficient, such as charcoal and biofuels. Thus, climbing the energy ladder not only improves the quality of life of poor households, but it also makes them less likely to use fuels that are costly and harmful to the environment. Low energy, appropriately designed buildings, therefore, not only contribute to climate change mitigation but also reduce the vulnerability of the poor.

Cities play a crucial role in the implementation of national standards, as they have the capacity to issue building permits and ensure projects meet energy-efficiency code regulations, and they can introduce new energy conservation rules in master plans. City administrations usually overlook, however, such details as the embedded energy in construction materials. Especially in emerging economies, where the construction sector is growing fast, a large amount of energy consumed by the industrial sector goes into the production of cement, steel, aluminum, and glass – materials needed for building construction. Among the global warming mitigation actions cities should consider the use of low embedded-energy construction materials that can be derived by introducing innovations in traditional materials and construction techniques to improve performance and durability.



Construction of a very tall skyscraper in Pudong, China: New buildings in China are being constructed at the rate of an estimated 1.8 billion square meters a year.
©Robert Churchill/iStockphoto

Energy-efficient buildings in Beijing

Since 1991, Beijing has implemented mandatory energy-saving design standards for new housing. Residential buildings that have not been designed according to the energy-efficiency standards are not allowed to start construction. By the end of 2003, a total of 120 million square meters of energy-efficient residential buildings had been built, of which 60 million square meters of residential buildings had met the energy-efficiency design standard, which requires a 50 per cent reduction in energy use over buildings designed before 1991.

Energy-efficient buildings have brought about substantial social benefits. The average room temperature in an energy-efficient residence during the winter has gone up to more than 18 °C. In June 2004, Beijing issued an energy efficiency building standard requiring a 65 per cent reduction in energy use for residential buildings. The city took the new measure because it still lags behind advanced international levels, even with its 50 per cent energy efficiency standard. The difference is not in material, equipment or construction techniques, but in the design standard. In recent years, the area of newly started and resumed construction in Beijing has stayed above 100 million square meters annually. With such large-scale construction, if weaker energy efficiency standards continued to prevail, the result would be heavy energy consumption too difficult and costly to remedy in the future.

To raise the quality of construction and ensure compliance with the energy-efficient design standard, Beijing has compiled a local standard for the "Inspection and Acceptance Criteria for Insulation Projects in Energy Efficient Residential Buildings", the first of its kind in China. The standard lists requirements for material quality, construction technology, quality inspection and management, supervision and inspection and acceptance involved in building energy efficiency and insulation projects. It calls for random on-site inspections to supplement project monitoring.

Source: Xingyue, 2004.

▲
Apartment block in Beijing, China
© Jimmy Wang/iStockphoto

Embedded energy

Energy consumption in buildings occurs in five phases. The first phase corresponds to the manufacturing of building materials and components, termed "embedded energy". The second and third phases correspond to the energy used to transport materials from production plants to building sites and the energy used in the actual construction of the building, which are referred to as "grey energy" and "induced energy", respectively. In the fourth phase, energy is consumed in the running of the building when it is occupied – "operational energy". Finally, energy is consumed in the demolition process of buildings as well as in the recycling of their parts. Concrete, aluminum and steel, for instance, are among the materials with the highest embedded energy content and their production is also responsible for large quantities of CO_2 emissions. Plastic is another energy-intensive material.

In aggregate terms, embedded energy consumption accounts for a significant share of the total energy use of a country; in the case of the United Kingdom, estimates suggest that 10 per cent of the total energy consumption is embedded in building materials. Embedded energy can be reduced by choosing different building materials. Studies show that the total energy consumption in manufacturing of steel beams is two to three times higher and the use of fossil fuels is 6 to 12 times higher than in the manufacturing of glued laminated timber beams. Dutch studies reveal that an increase in wood use could reduce CO_2 emissions by almost 50 per cent.

Source: UNEP, 2007.

Energy used for cooking

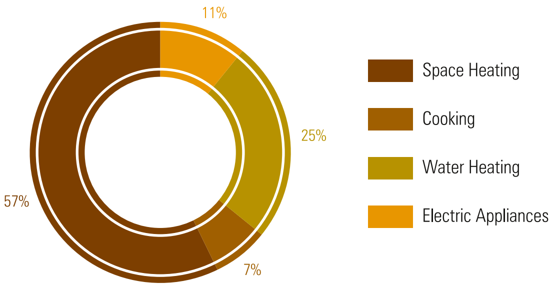
While most energy in residential buildings in EU-15 countries is used for heating, an entirely different picture emerges in the dwellings of the lowest-income inhabitants of cities in developing countries, where energy (produced mainly by burning kerosene or charcoal) is primarily used for cooking. In developed countries, energy for cooking ranges from between 4 and 7 per cent of the total household energy consumption, while in a large number of developing countries, cooking comprises the majority of households' energy consumption.

Use of traditional biomass fuels (such as animal dung, crop residues, wood, and charcoal) for cooking and heating is generally declining in non-slum urban areas of developing countries; many slum dwellers, too, are switching to non-biomass forms of energy as soon as they are in a position to afford it. In urban India, for example, the share of biomass fuels in urban areas has declined from 49 per cent in 1983 to 24.4 per cent in 1999, owing to increased availability of other sources of energy (liquid petroleum gas, kerosene and coal).[13]

Many households in African and Asian cities, however, still rely mainly on biomass fuels for cooking. Estimates suggest that in the Kenyan capital of Nairobi, a large proportion of urban households' requirements are met by charcoal; that corresponds to a consumption of approximately 91,250 tonnes annually, which equals the destruction of more than 900,000 tonnes of green wood each year.[14] In Dhaka's slums and squatter settlements, biomass is burned at a rate of 0.25 kg per day per person, resulting in 500 tonnes of fuelwood burned per day.[15]

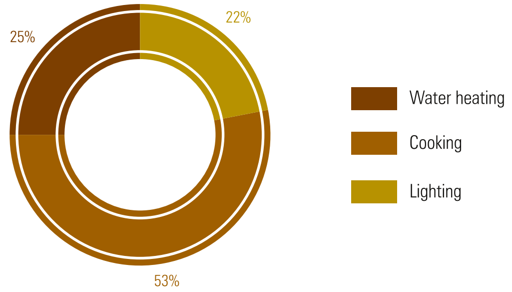
Demographic and health surveys conducted in several developing countries between 1995 and 2003 show that a large majority of households in sub-Saharan African cities are still primarily dependent on biomass fuels for cooking.[16] In these cities, urban living has not led to change in use of cooking fuels in slum areas, or in non-slum areas. For example, in Benin, 86 per cent of urban households use wood or charcoal for cooking. The use of wood and charcoal is not confined to Benin's slum areas: 74 per cent of non-slum households also use these fuels for cooking, compared with 92 per cent of slum households. In Benin, the energy transition in non-slum areas is mainly

FIGURE 3.5.2: **HOUSEHOLD ENERGY USE PATTERNS IN EU-15, 1997**



Source: Commission of the European Communities, 2001.

FIGURE 3.5.3: **LOW-INCOME HOUSEHOLD ENERGY USE PATTERNS IN CAPE TOWN, 1996**



Source: Winkler, et al., 2005.

Nearly a quarter of urban Indian households use traditional biomass fuels for cooking.
©Gilles Delmotte/iStockphoto

from wood to charcoal; use of gas, kerosene and electricity for cooking is not yet an option for many households. Since many households in African cities cannot afford kerosene and liquefied petroleum gas (LPG), the large majority continue to rely on fuel wood and charcoal. However, the use of solid fuels in non-slum areas of African cities cannot be linked to lack of financial resources – a disturbing trend noted in African cities is the continued use of solid fuels even in non-slum areas where households can afford electricity, kerosene and LPG for cooking. This suggests that when people move up the economic ladder, they change fuels for heating and lighting, but not necessarily for cooking.

However, the transition from biomass to other sources of energy for cooking has been observed in other cities of African countries, including Gabon, Kenya and Nigeria. In cities of these three countries, use of gas and kerosene for cooking is more common than use of solid fuel. In Gabon, 68 per cent of urban households use gas, while in Kenya and Nigeria, use of kerosene for cooking is quite common among urban households (47 per cent and 46 per cent, respectively). It is interesting to note, however, that in Nigeria, which is among the larger producers of petroleum, a large proportion of urban households still rely on wood and charcoal for cooking (49 per cent). Zimbabwe offers a somewhat different picture: use of kerosene is prevalent not just in urban areas but in some rural areas as well.

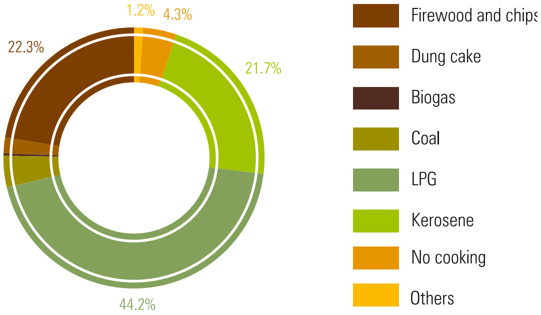
It is clear that the urban transition in many sub-Saharan African countries has not yet translated into an energy transition, as it has in developed countries and most countries of Latin America, North Africa and Asia. In Egypt and Morocco, for instance, the use of gas for cooking is almost universal. However, some Asian and Latin American cities still have large proportions of urban residents who are dependent on biomass fuels. In Bangladesh, Nepal, Guatemala, and Nicaragua, more than 40 per cent of urban households are still dependent on biomass fuels.

In general, the lower the income of the household, the higher its share of traditional biomass used for cooking.[17,18] The size of the settlement also plays a role. In intermediate and small cities, the share of traditional biomass fuels used for cooking is higher because they are easily available, and it might not be economically viable for households to set up alternative energy sources, such as electricity.

Incomplete combustion processes of biomass fuels contribute to greenhouse gas emissions. As illustrated in Figure 3.5.5, biomass cookstoves release significant levels of carbon dioxide, carbon monoxide, methane, and nitrous oxide, not only polluting the environment, but also putting the people who use them at risk of exposure to dangerous toxins. Biomass stoves are also notoriously inefficient. The energy efficiency of traditional cooking devices is poor: more than 80 per cent of the heat generated while cooking with wood on a traditional fire does not end up "in the pot".

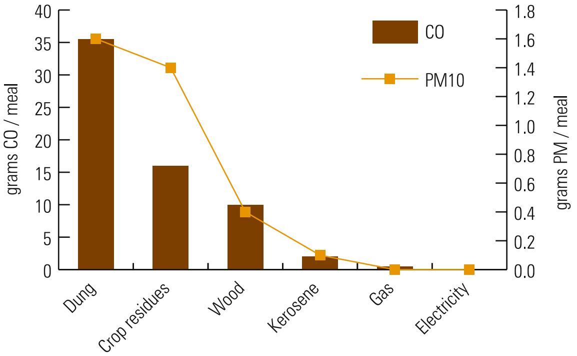
Improving the efficiency of traditional cooking devices, reducing the amount of wood fuel needed, and reducing indoor air pollution have become priorities in the development of improved stoves. Several types of improved stoves have

FIGURE 3.5.4: **SHARE OF ENERGY USED FOR COOKING IN URBAN HOUSEHOLDS IN INDIA, 1999/2000**



Source: Pandey, 2002

FIGURE 3.5.5: **EMISSIONS BY COMMON COOKING FUELS PER MEAL**



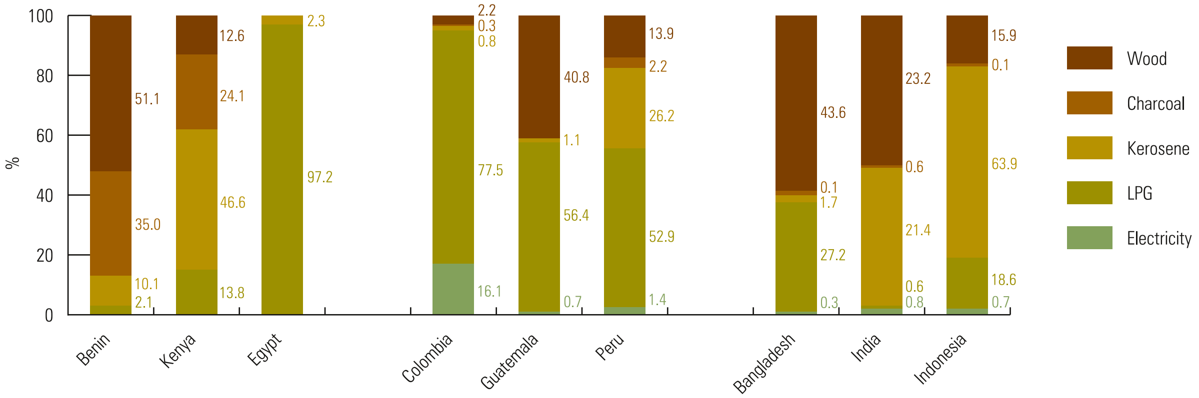
Source: Smith, et al., 2000.

been developed all over the world, in different models to suit varying available materials and skills, types of fuel, food and cooking habits, and other requirements, all aiming to lower costs, improve energy efficiency and reduce or eliminate indoor air pollution.

From the perspective of climate change mitigation, however, improved stoves are not sustainable in the long run. They may continue to play an important interim role in improving the quality of life of the urban poor, but the long-term goal should be to eliminate household use of unprocessed solid fuels. The charcoal fuel cycle is probably the most greenhouse gas-intensive major fuel cycle in the world, even when the wood is harvested renewably, which it often is not.[19] Each meal cooked with charcoal in sub-Saharan Africa has 2 to10 times the global warming effect of cooking the same meal with firewood and 5 to 16 times the effect of cooking the same meal with kerosene or LPG, depending on the gases that are included in the analysis and the degree to which wood is allowed to regenerate.[20] A study carried out for India[21] confirms that LPG and kerosene show the lowest greenhouse gas emission, compared with all the other commonly used fuels, with exception of biogas, the emissions of which are negligible.

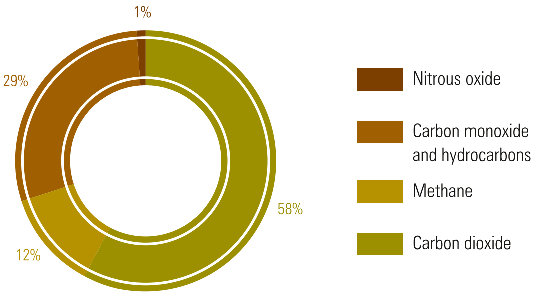
Poverty and lack of basic services in urban areas contribute to the growth of carbon emissions because the urban poor are forced to rely on polluting and unsustainable sources of energy for cooking and lighting. Moving up the economic ladder, therefore, often means moving up the energy ladder, as higher incomes mean people can afford energy-efficient fuels that are less polluting and that produce fewer greenhouse gases. Lack of access to electricity and other energy sources in many countries has forced people to rely on traditional biomass fuels, as in Liberia, where the electricity supply is unreliable in urban areas. Given the abundance of Liberia's forests, fuel wood and charcoal are becoming the principal sources of energy in urban areas; consumption skyrocketed both during and after recent civil conflicts there. The UN Food and Agricultural Organization (FAO) suggests that because of the continuous absence of electricity supply in Liberia's urban sectors and the lack of other alternative sources of household energy supply in most parts of the country, the demand for fuel wood is expected to increase.

FIGURE 3.5.6: **DISTRIBUTION OF URBAN HOUSEHOLDS BY TYPE OF FUEL FOR COOKING IN SELECTED COUNTRIES**



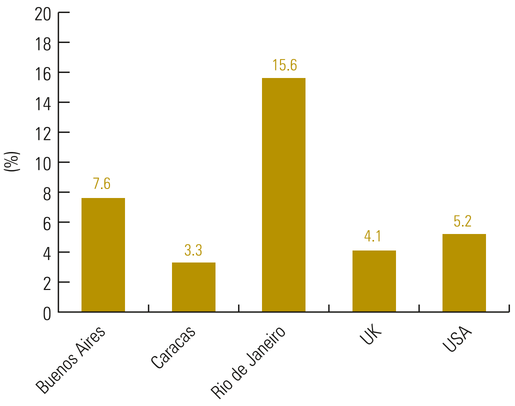
Source: UN-HABITAT, Global Urban Observatory, 2008

FIGURE 3.5.7: **GREENHOUSE GAS EMISSIONS FROM A TYPICAL BIOMASS COOKSTOVE**



Adapted from Holdren & Smith, 2000

FIGURE 3.5.8: **PROPORTION OF FAMILY INCOME USED FOR ENERGY IN LOW-INCOME HOUSEHOLDS IN SELECTED CITIES AND COUNTRIES**



Source: World Energy Council, 2006

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Rising incomes have led to increased electricity consumption in Chinese cities.
©Andrew Wood/iStockphoto

Electricity consumption

Average electricity consumption in the world's households ranges widely from zero in the lowest-income households of cities in developing countries to more than 16,600 kilowatt hours per year in urban Norwegian dwellings,[22] where electricity is traditionally used for almost everything – from space heating to cooking.

The range of electricity consumption around the world cannot be justified only by income or climate. For instance, while the diffusion and types of appliances in Europe and the United States are quite similar, electricity consumption and consequent CO_2 emissions vary greatly both between the two regions and within them. In San Francisco, the average household electricity consumption is 2.4 times lower than the U.S. average and 2.6 times higher than that of Milan, Italy, or 1.5 times higher than that of London, U.K. In the city of Oxford in England, household electricity consumption is 2.3 times higher than that of the Italian city of Bologna.

In the United States, the difference between national average electricity consumption and consumption in individual cities is mainly explained by the fact that in some cities, other sources of energy are available, such as natural gas. The differences in energy consumption between U.S. and European cities can also be attributed to differences in size and efficiency of appliances and lifestyles. Refrigerators in the U.S., for example, are generally larger than European refrigerators, and not all states impose minimum efficiency requirements on domestic appliances, as does the European Union. Within Europe, the differences in energy consumption are also determined by differences in the cost of electricity among countries. In general, high household electricity consumption is the consequence of low-efficiency appliances. The size of the dwelling, user energy consciousness and the cost of electricity also play important roles.

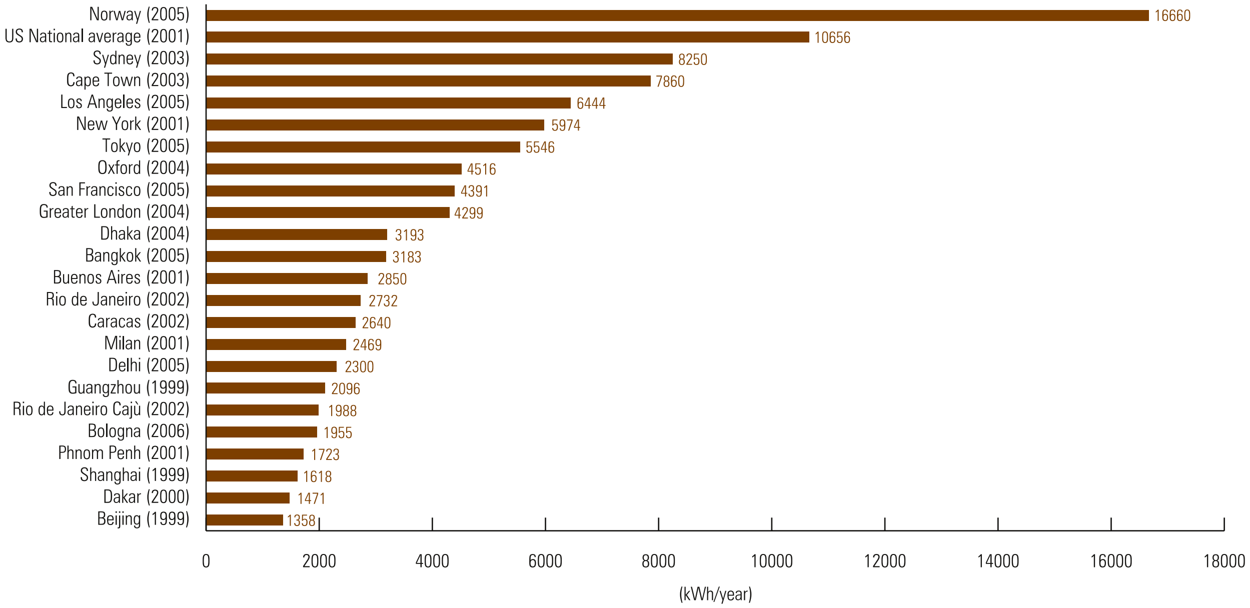
Air conditioning is increasingly contributing to household electricity consumption, in urban areas of both developed and developing countries. In Shanghai, the rise has been particularly sharp, increasing from 0.2 air conditioners per dwelling in 1994 to 1.6 air conditioners per dwelling in 2004.[23] It is not surprising then, that Shanghai's residential and commercial air conditioning load accounts for 40 per cent of the peak electricity load in the summer.[24] In other Chinese cities, such as Guangdong, Beijing and Chongqing, the average number of air conditioners per dwelling now exceeds 1; in Chongqing,[25] air conditioning accounts for 40 per cent of summer electricity peak load,[26] similar to that of Shanghai.

Electricity consumption in China is also growing with the increasing prevalence of electrical heating systems, especially in cities where electrical heating was not previously available. In Shanghai, a survey of more than 1,000 households showed that the air conditioner is used as a heat pump for an average of 3 hours per day in the winter.[27] Electricity consumption is expected to grow in China as incomes rise and as lifestyles change, especially in urban areas.

Improving efficiency of household appliances is crucial for reducing electricity consumption. In Europe, energy labeling that informs consumers about the energy consumption of appliances is standard practice and compulsory. Similar approaches have been developed in Japan. The United States has been promoting Energy Star, a voluntary labeling programme designed to identify and promote energy-efficient products. In China, minimum energy standards were introduced in 2003 and are being updated.

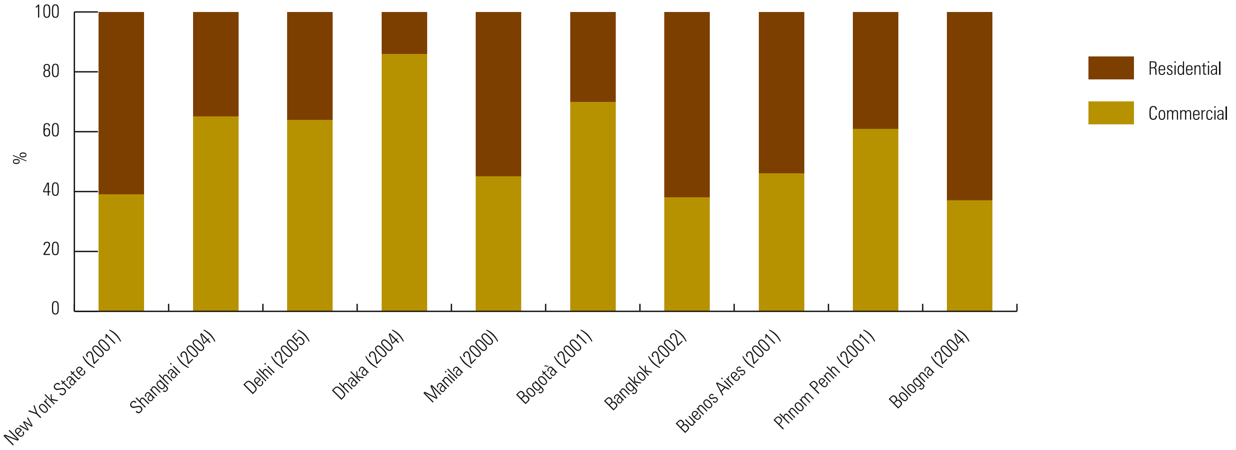
But while increased energy efficiency can have wide-ranging benefits, the full extent of these benefits is difficult to capture in developing countries, where appliances and technologies with low initial costs might be preferred, where capital for replacing inefficient equipment might not be available, and where regulatory or technical standards might be inadequate.

FIGURE 3.5.9: **ELECTRICITY CONSUMPTION PER HOUSEHOLD (KWH/YEAR) IN SELECTED CITIES AND COUNTRIES**



Source: UN-HABITAT Global Urban Observatory 2008
Note: Data from various sources, 1999-2006

FIGURE 3.5.10: **SHARE OF COMMERCIAL AND RESIDENTIAL ELECTRICITY CONSUMPTION IN SELECTED CITIES**

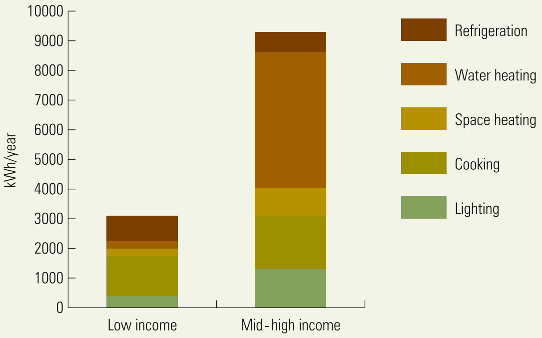


Source: UN-HABITAT Global Urban Observatory 2008
Note: Data from various sources, 2001-2004

Cape Town: Scaling the energy ladder

Cape Town, unlike most African cities, is unique in that its electricity consumption is extremely high, even though 60 per cent of its population comprises low-income households. This is largely explained by the fact that electricity is used in almost all household appliances, including those for cooking and hot water production, even among the low-income share of the population. This derives from a national policy that has been promoting extensive electrification and low-cost electricity for the poor, with the aim – almost fully reached – of eliminating the health hazards associated with the use of biomass and improving residents' quality of life. In Cape Town, the first 50,000 kilowatt hours per month are provided for free to low-income households, but this amount meets only a small part of the households' electricity needs. High- and middle-income households consume nearly three times as much electricity as low-income households, as illustrated in the graph below, with the largest proportion of consumption going towards heating water. In low-income households, on the other hand, a large proportion of electricity is used for cooking.

FIGURE 3.5.11: **HOUSEHOLD ELECTRICITY CONSUMPTION DIFFERENCES IN CAPE TOWN**



Source: Winkler, et al., 2006.

NOTES

[1] UNEP, 2007a.
[2] Healy, 2003.
[3] U.K. Department for Business, n.d.
[4] Balarasa, et al., 2007.
[5] Santamouris, et al., 2007.
[6] World Bank, n.d.
[7] ENERDATA, 2003.
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[10] Siwei, 2004.
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[13] Padey, 2002.
[14] City of Nairobi Environment Outlook, 2007.
[15] UNEP, 2005.
[16] UN-HABITAT, 2006b.
[17] Modi, et al., 2006.
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[20] Bailis, et al., 2004.
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[24] Shanghai Research Institute of Building Sciences (SRIBS) & Politecnico di Milano (BEST), 2006.
[25] Long, et al., 2004.
[26] Mingjia, 2004.
[27] Long, et al., 2004.