section A

Understanding Energy Use, CO_2 Emissions and Their Drivers in

Selected Mega-Cities

2 Energy, Cities, and Sustainable Development

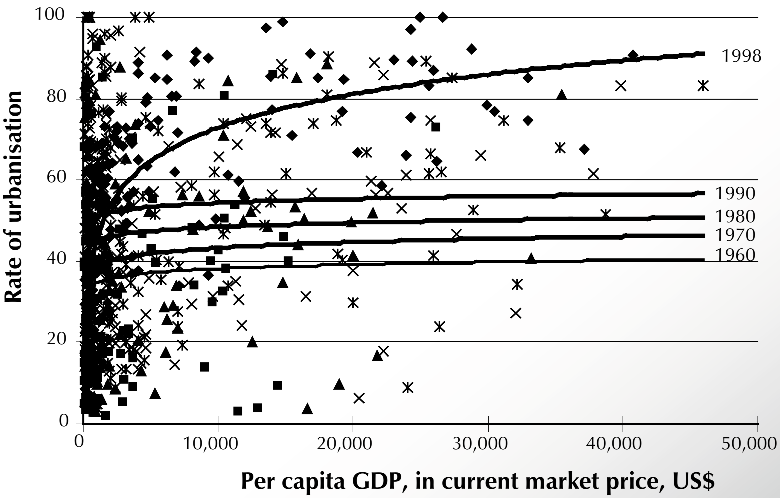
Sustainability and sustainable development have different definitions, yet all link them closely to energy use, emissions and urbanisation. This section traces and highlights those relationships and proposes a policy framework. In particular, this section aims to answer questions such as the following: How are cities and sustainability linked? What determines urban energy use? What is the relationship between energy and emissions and economic growth in cities? What is the role of urban policies?

2.1 Urbanisation and the Role of Cities in Sustainable Development

Human-imposed threats to global sustainability have two fundamental dimensions: population growth and the ever-increasing per capita demand for good and services, particularly material needs and energy. Both impose direct and indirect pressures on the human carrying capacity of the earth. Today, 75% of the population in industrialised countries lives in urbanised areas (UN, 2002). Although a smaller proportion of the populations of developing countries lives in cities, cities are still driving forces for development and centres for power and cultural and societal transformation.

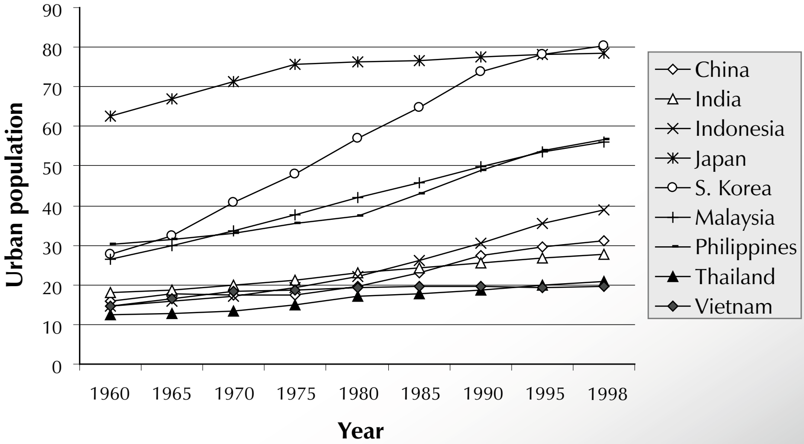
The number of people living in urban areas is increasing rapidly around the world. In recent decades, such rates have accelerated. In 1950, 30% of the world population lived in urban areas; that figure had increased to 47% in 2000 and is expected to increase to 60% by the year 2030. From 2000 to 2030, virtually all population growth is expected to occur in urban areas and mostly in less developed regions of the world (UN, 2002). Figure 2.1 depicts this phenomenon. In Asia, rapid urbanisation is a distinctive feature. From 1990 to 1998, the average urban population growth per year was estimated at 3% for East Asia and 3.2% for South Asia; in contrast, the world average was just 2.1% (WDI, 2001). The potential for urban growth in Asia is tremendous; it is estimated that the population in cities in developing countries will increase from today 's 37% to over 54% by 2030 (UN, 2002). This means that 2.6 billion people will live in Asian cities; the number will exceed twice the current population of the People Republic of China and represent 53% of the world urban population by 2030 (ECOASIA, 2001). Predictions show that in 2015 there will be 358 cities worldwide with a population of over a million people; of them 153 are expected to be in Asia (HABITAT, 2001). Of an estimated 27 mega-cities (exceeding a population of ten million), 15 will be in Asia. The sustainability of these cities will have enormous implications.

Cities contribute towards promoting global sustainability as we as impede progress towards sustainability. Since cities are centres of high living standards, they consume large amounts of material goods, which leads to the over-utilisation of limited natural resources, including energy



Source: *World Bank Indicators CD-ROM 2001*

Figure 2.1 **World urbanisation trend**



Source: *World Bank Indicators CD-ROM 2001*

Figure 2.2 **Urban populations in selected Asian countries**

resources, and to the emission of large volumes of GHG. At the same time, people living in cities set the direction of future development and can promote the movement towards sustainable development. Cities are engines of economic growth that provide space for innovation, knowledge, technology and employment. High population density and massive consumption opens several options for using compactness as a means to effectively utilise natural resources and practice efficient (and effective) urban infrastructural development. For example, compact settlement and high population density in cities may reduce per capita infrastructure and distribution costs and open up opportunities for economies of scale. Thus, cities can greatly facilitate the implementation of measures to reduce stress on sustainability. Cities and sustainability bring two major environmental issues to the forefront for policy makers. The first is the intensive consumption of energy and materials which affects natural systems and ultimately areas and people outside the boundaries of cities and even future generations. The second is the exposure of a large and concentrated urban population to worsening air, water and solid waste pollution and to considerable vulnerability related to global climatic changes.

2.2 Determinants of Energy Use in Cities

Energy plays a vital role in sustaining the metabolism of cities. Energy has no conflict with urbanisation; in fact, due to their compact population and infrastructure, cities open up avenues for the efficient utilisation of energy. Compact cities need complex energy management systems, whose provision challenges policy makers. Asian cities, in contrast to European and North American cities, tend to get denser and denser and expand. Because North American cities are low density and sprawled over large areas they require large amounts of energy to run their transportation and distribution systems and their public transportation is cost ineffective. Energy use concerns are not related only to availability or use, but also to implications after their use. Energy produces local air pollutants and GHG as waste; if their concentrations reach unacceptable levels, there are serious local and global implications for human health and natural ecosystems. Efficient utilisation of energy is the key to conserving depleting energy resources, as well as to reducing the levels of air pollutants such as NO_x, SO_x, hydrocarbons, CO, particulate matters, CO_2, and so on. Several key factors determine the extent and nature of energy use in cities:

Compactness of urban settlements

The compactness of urban settlements influences the demand for energy for transportation and for other areas such as district heating and cooling using co-generation systems. Urban sprawl, in which low-density suburbs depend on lengthy distribution systems, undermines efficient energy use.

Urban spatial structure and urban functions

Urban spatial structure and urban functions affect energy use as they influence the demand for mobility of urban dwellers. Mixed land use (residential and industrial, or residential and commercial, etc.) results in different energy use than does segregated land use. Urban zoning policies and industrial relocation from city centres to peri-urban areas in Asian cities significantly influence travel demand and energy use. Similarly, the energy use patterns in commercial cities are different from those in industrial cities.

Nature of transportation system

Transportation systems are very important as mobility is a key aspect of urban life. Historically, cities have moved from non-motorised to rail-based and then gradually to automobile-dominated transportation. The energy implications of transport depend on a number of factors: the availability of a built-in infrastructure for rail and road networks, mass transportation systems, the share of public and private travel demand, the role of alternative fuel vehicles, and the share of small-occupancy vehicles such as two-wheelers (used in India, China, Thailand, Indonesia, etc.) among others. Increasingly, cars dominate transportation due to rising incomes, increased social status through car ownership, and inefficient public transportation systems. This trend threatens energy security and results in increased local air pollution and GHG emission.

Income level and lifestyle

Since cities are engines of economic growth, it is often difficult for policy makers, especially those in rapidly industrialising cities, to constrain increasing energy use. Past research on the relationship between income and energy use at the national scale has clearly demonstrated that there is a strong correlation between per capita commercial energy consumption and gross domestic product. It is generally accepted that per capita energy use increases with income (though from some point it may actually decrease). High income is associated with better lifestyles and more consumption, which affect energy use in and beyond the borders of cities. Consumption-oriented lifestyles are associated with the greater utilisation of natural resources as well as with the greater energy use needed to produce these materials (and hence, with more GHG emissions). This relationship is important in the sustainability debate as global sustainability seeks to provide welfare and equity along all scales (spatial and temporal).

Energy efficiencies of key technologies

Energy efficiency is defined as the energy needed to produce a unit of service. Since demand is for services, not for energy, energy efficiency can directly improve or worsen energy use. Technologies whose efficiency dominates cities include automobile fuel and household and commercial appliances used for lighting, heating, cooling, and cooking. Improving of energy efficiency is a function both of the technology itself and of patterns of utilisation.

Industrial processes

The energy efficiency of production processes and boilers (industrial energy use) affects energy use, too, but it is not discussed in detail in this paper. Cities in Asia are rapidly relocating their primary industries either to peri-urban areas or to areas outside city borders, leaving cities increasingly dominated by the tertiary sector. Small and medium-sized enterprises (SMEs), however, remain prevalent in many Asian cities and pose a big challenge for policy makers. The role of local policy makers in this area is limited in South and Southeast Asia.

Building technologies and floor space use

Building-related technologies such as air conditioners, district heating and cooling systems, insulation systems and other building energy management systems have significant effect on energy use. Services such as lighting and space heating/cooling depend directly on floor space, whose use depends on a number of factors such as real estate market prices, business culture and socio-cultural factors.

Waste management

Big cities, especially mega-cities, are producing an increasing volume of solid waste, a fact making its management increasingly complex. Policy makers resort to either incinerators or landfills although both options emit GHG. Incineration uses energy and emits CO_2, while landfills emit methane, whose effect on GHG is 22 times higher than that of CO_2.

Climate factors

Climate factors, especially excessive heat and cold climate conditions, directly affect energy use due to the greater demand of heating or cooling services. Cities in North Asia such as Beijing require more energy for energy than do cities with temperate climates. Some cities in Asia, such as Tokyo and Seoul, also suffer from urban heat island (this is a phenomenon in which the core urban temperature is a few degrees higher than that in the suburbs; this creates hot-spots in cities), where concentrated urban energy use is a major factors, responsible for exacerbating urban warming. This sometimes triggers a vicious cycle in summer, where increasing the use of cooling devices contributes towards increasing the heat island effect. Heat islands may be beneficial to relatively cooler cities by reducing their heating energy demand in winter, but research has shown that the penalties in summer far exceeds the winter gains in cities such as Tokyo, which experiences hot and humid summers.

2.3 The Income-Energy-Environment Conundrum

As cities are dynamic systems, it is important to understand trends in energy use and emissions over time. Like the human body, cities can be characterized by "metabolism," where energy and materials are used as input and waste as output. In this process, waste production is a function of various driving forces and their interactions. The risk to citizens from exposure to waste is a prime concern for policy makers. Research has demonstrated that risk perception varies with income level and urbanisation, among other factors.

The World Bank (see WDR, 1992) has outlined, in correspondence with increasing levels of economic development, the following three levels of urban environmental problems: (1) poverty-related issues (such as safe water and sanitation) (2) industrial pollution-related issues (such as PM and SO_2) and, (3) consumption-related issues (such as solid waste and CO_2 emissions). It does not say anything about the evolution of these issues over time or with income growth. Bai and Imura (2001) hypothesise and demonstrate that selected cities have proceeded through stages: (1) poverty, (2) industrial pollution (3) consumption and (4) sustainable eco-city. Their model provides a picture of how selected highly industrialised cities evolved in the past, but a careful examination of factors other than income which might have contributed to this environmental transition is needed, particularly in the case of less highly industrialised cities. Without this background, we have no sound theoretical basis for predicting the environmental transition of cities that are currently undergoing rapid economic growth. In particular, we need to consider the following factors, especially in the case of energy- related environmental problems:

- The three levels of environmental problems discussed by the World Bank (1992) are associated with a number of environmental problems from energy use and are occurring simultaneously in Asian cities, rather than in stages. This is partly due to the existence of different income classes created by large income disparity among urban dwellers.
- Income is only one factor among a large set of factors (political, cultural, societal, economical, geographical and urban management) that determine the dynamics of urban environmental transition and the associated environmental burdens from energy consumption.
- Evolution theories, such as that discussed above, implicitly support the hypothesis that the transition of cities follows some fixed or pre-defined path, which in itself is not convincing. Policy implications from such analysis are difficult to use in a practical sense. In reality, each city evolves differently due to a unique set of internal and external factors. IIED (2001) has shown that historical transition cannot provide a model for future urban development when global resources are being depleted and other conditions are evolving.

Peter Marcotullio (see Marcotullio *et al.*, 2003; Marcotullio, 2003; and Marcotullio and Lee, 2003) and Gordon McGranahan (see McGranahan *et al.*, 2001) provide alternatives to the evolutionary stage model. McGranahan *et al.* (2001) presents a simple picture of shifting environmental burdens from the local to the global, from the immediate to the delayed, and from issues that threaten health to issues that threaten life support systems. Marcotullio presents a model of urban environmental transition in which urban environmental issues are compressed over time and space with a shift in scale (local to global), timing (immediate to delayed), impact, and character (health-threatening to ecosystem-threatening) rather than with the simple formation of stages.

Table 2.1 Gross national product per capita (in US$, 1990)

Country	1965	1990	Average annual growth, %
Indonesia	190	570	4.5
Philippines	529	730	1.3
Thailand	484	1,420	4.4
Malaysia	870	2,320	4.0
South Korea	972	5,400	7.1
Singapore	2,312	11,160	6.5
Hong Kong	2,554	11,490	6.2
Japan	9,313	25,430	4.1

Source: *World Bank. (1992) World Development Report 1992: Development and the Environment. New York: Oxford University Press for the World Bank.*

Table 2.2 Gross regional product per capita of selected Asian cities, 1990

(in US$, 1990)

City	GRP per capita
Surabaya	726
Jakarta	1,508
Manila	1,099
Bangkok	3,826
Kuala Lumpur	4,066
Seoul	5,942
Singapore	12,939
Hong Kong	14,101
Tokyo	36,953

Source: *Kenworthy, J. R. and Laube, F.B. with Peter Newman, Paul Barter, Tamim Raad, Chamlong Poboon and Benedicto Guia, Jr. (1999). An International Sourcebook of Automobile Dependence in Cities, 1960-1990. Boulder: University Press of Colorado.*

The income growth of Asian cities has been tremendous and had usually exceeded their national averages (Table 2.1 and 2.2). The Environmental Kuznet Curve (EKC) theory suggests that a rise in income leads to an increase of environmental adversity but, that after some point, it results in a decrease in environmental adversity; the result is an inverted U-shaped curve. Many studies conducted in the past have tested the validity of the EKC under different sets of environmental adversities and concluded it is reasonably valid for industrial air pollution, particularly SO_2 emissions. The EKC may be valid at the national level, but its applicability to cities is questionable. First, cities do not have well-defined boundaries and their interactions with other places are both very intense and poorly documented. Obtaining reliable data to check the validity of the EKC and setting boundaries for the city are significant problems. Second, there is a growing trend to relocate major industries away from densely populated areas; what remains in a city are commercial activities, service industries and other activities that put a greater emphasis on mobility, infrastructure development and households than industrial activities do. Major sources of air pollution in many cities include urban transportation and industries, which are in turn associated with low-income groups and urban poverty. In sum, establishing an EKC relationship between income and environmental adversity at the urban level—if it is indeed valid—is difficult.

The major reason for this anomaly is that when income grows, not only the scale but also the nature of growth is important. The question of how income growth is responsible for transition can be seen in terms of the relation between income and environmental adversity. This question places emphasis on two important aspects of development: (1) the dynamics of the urban transformation process, its evolution, and its distinctive internal and external features; and (2) the responses of policy makers. These two issues simultaneously affect the urban environmental transition in terms of energy- related issues.

The urban environmental problems that result from energy use are strongly tied to urban management. When environmental problems occur, most policy makers try to solve immediate issues without paying enough attention to the underlying causes. This is true all over the world, but perhaps more so in South Asia, where policy implementation is either weak or does not exist or where policies are not well formulated to address problems. Thus, cities with similar income levels vary widely in terms of the environmental problems they experience: a well-managed city with a medium or low income may be better off than a richer city with poor urban environmental management. The lesson is that good policies and good urban environmental governance can perform miracles irrespective of economic levels.

In performing the dual tasks of economic development and environmental protection, cities tend to give policy priority to immediate, local issues and to regard issues such as global warming as long-term, distant threats when, in fact, municipal policies that reduce energy consumption bring multiple benefits to a community. They help solve the problems of air pollution and traffic congestion and tackle global problems such as the emission of GHG, in particular CO_2. There are many technological and non-technological management options through which the environmental implications of energy use can be minimised without seriously compromising economic growth. For example, the disassociation of environmental problems and economic growth in Japan in the 1970s and 1980s was largely the result of implementing environmental regulations with end-of-pipe and process enhancements (Sawa, 1997). Each city has to address its own distinctive features; the role of policy makers is to explore alternative policies and implement them successfully.

2.4 Comprehensive Policy Framework for Energy-Environment Management in Asian Cities

Energy management has traditionally not been a priority for municipal policy makers as major energy-related decisions are usually made by national governments. Accordingly, no comprehensive policy framework exists for energy issues at the city level. Interventions in energy- related policies at the local level emerge primarily either from energy availability or from the impact of energy use on the environment, namely air pollution. In the case of energy management, there is often no policy framework. A comprehensive policy framework for urban environmental management is also lacking in general, and environmental policy response is often fragmented into different sectors and actors without proper coordination.

The need to empower local governments to manage their cities is well understood by national governments and processes for empowering local governments have been underway for several decades. Still, the major role of municipal governments in Asia is often limited to solid waste[1]. In many countries, especially those in South Asia and Southeast Asia, water/wastewater and air pollution management is the responsibility of the national government. Economically more developed Northeast Asia is one step ahead: local governments assume authority for more aspects of governance. In China, for example, the decentralisation of environmental affairs is well institutionalised, and environmental protection bureau in each city are responsible for environmental affairs. According to the framework established by the State Environmental Protection Administration (SEPA), these bureaus work under municipal governments in coordination with the Provincial Environmental Protection Bureau. Four cities, Beijing, Shanghai, Chongqing and Tianjin, have provincial authority and work directly with SEPA. In India, city-level environmental bureau do not exist. The role of large municipal governments such as Mumbai is limited to solid waste and, to some extent, wastewater management. Mumbai exercises some authority over air pollution but only through traffic management. The Central Pollution Control Board[2] of India exercises much pollution control through state pollution control boards, while most industrial pollution control falls under the responsibility of state industrial development corporations. Like the four aforementioned cities in China, the capital of India, New Delhi, is categorised as a state and the Delhi Pollution Control Board exercises the same authority as do the other states of India. In Thailand, the Bangkok Metropolitan Administration exercises limited control over air pollution management such as management of traffic, managing one air quality monitoring station, and checking of in-use vehicle emission with traffic police. The Pollution Control Department under the Ministry of Natural Resources and Environment is responsible for implementing air pollution control measures in Bangkok.

Close cooperation among municipal governments and national agencies is mandatory if a sound policy framework and policy implementation mechanisms are to be developed. In addition to the government, other stakeholders in policy making and policy implementation process must be

1. In some cities, waste water management falls under the municipal government (for example in India). A city's role depends on its size and on its economic and/or political status.

2. These are semi-autonomous bodies with representation by different stakeholders. The Ministry of Forests and Environment is the line ministry.

involved. A top-down process alone may not work. Typically, the private sector and civic society (NGOs, the media, community groups, consumer associations, etc.) play significant roles in such processes, and without their consensus, policies may not produce desirable effects or may result in failure. The involvement of stakeholder in centrally planned countries such as China and Vietnam is low and the government is very strong. In Northeast Asia, in general, despite strong governments, some consideration to stakeholders, especially corporate stakeholders, is given. Increasingly, policy makers are realising the need to involve different stakeholders in policy making and implementation processes.

Most policy responses to energy-environment issues (namely local air pollution and CO_2 emissions) emphasise end-of-pipe solutions and, in general, ignore the major factors which cause them. In the case of the transportation sector, for example, major policy efforts are directed at emission compliance and fuel quality interventions rather than at controlling vehicle ownership and vehicle utilisation rate and reducing the need to travel through interventions in urban planning. Such end-of-pipe measures are often favoured by policy makers and political establishments but are essentially short-term measures.

Choices of policy instruments, which include regulatory, economic and institutional arrangements, are important in implementing energy-environment management policies. Regulatory instruments (command-and-control) prevailed in the past and are still dominant today. Several cities have tried using economic instruments including pricing regulations, incentives, and taxes and subsidies applicable to various sectors to manage specific problems. Singapore's use of economic instruments to control vehicle ownership and use has caught the attention of the world. Some city-level efforts to promote voluntary mechanisms such as appliance labelling and information disclosure on the energy performance of buildings are being made in Tokyo.

A comprehensive urban energy policy framework seeks a balanced consideration of short- and long-term measures and addresses a variety of methods and stakeholders. Figure 2.3 proposes such a framework.

The policy framework in Figure 2.3 accounts for direct energy use and CO_2 emissions as well as for indirect energy use and CO_2 emissions embedded in electricity use in respective sectors. Cities, especially mega-cities, are centres for consumerism, but the production of the goods and services demanded usually takes place outside a city's boundaries. It is there that CO_2 is emitted. Since a city's emission footprint extends beyond its boundaries, it should be responsible for these emissions. In order to obtain a clear picture of the responsibilities of cities, accounting for indirect energy use is necessary. Policies aiming at indirect emissions are at present unimaginable for most municipal policy makers in Asia. In Japanese cities, however, such policies are being implemented through the government 's general policy to create a "sound material cycle society." Although explicit policies at the local level are not expected at this time, it is important to raise the awareness of policy makers about this issue.

The causal framework for energy-environment management is (1) identifying the options available in the short-term; (2) intervening in the appropriate determinants; (3) finding the right ways to intervene (4) finding appropriate tools for intervention and creating consensus; and (5) carrying out monitoring and providing feedback.

Section in which to intervene (excluding industry	Physical indicators	Ways to intervene	Tools with which to intervene	Future scenario	Consensus of stakeholders
Urban planning	Population density Urban functions Urban land use Building	1. Technology options 2. Management options *(Based on the nature of each determinant)*	1. Economic tools 2. Regulatory tools 3. Institutional arrangements 4. Voluntary mechanisms *(Based on an evaluation of the number of tools applicable to each sector, determinant or way)*	1. How might such determinants change in the future? 2. What kind of technologies and management principles might evolve in the future?	1. Who are the stakeholders? *(National government, local government, private sector, civil society)* 2. What kind of combinations of *determinants, ways* and *tools* would be most suitable given the roles of various stakeholders?
Urban transport	Travel activity Travel modes Energy intensity Fuel quality and choice				
Households	Number of households Floor space use Appliance utilisation Energy efficiencies Fuel choice Building				
Business	Office floor space Appliance utilisation Energy efficiencies Fuel choices Buildings				
Waste	Waste volume Incineration Landfill Energy recovery				

Figure 2.3 Policy framework for energy emission-related issues in cities

3 Factors Driving Energy Consumption and Emission

3.1 Introduction

Earlier sections in this report outlined some of the physical determinants of energy use and emissions in a comprehensive policy framework. These were mostly sectoral in nature. At the macro-level, the major driving forces behind energy consumption and CO_2 emissions in rapidly industrialising cities are related to lifestyles and to behavioural and socio-economic aspects of urban life. A sound understanding of these factors is essential for proactive/anticipatory as well as end-of-pipe/curative policies. In rapidly industrialising cities such as Tokyo in the 1970s and 1980s, Seoul in the 1990s, and Beijing and Shanghai in last two decades, the behaviour of driving factors has changed drastically. Some of the driving factors are as follows:

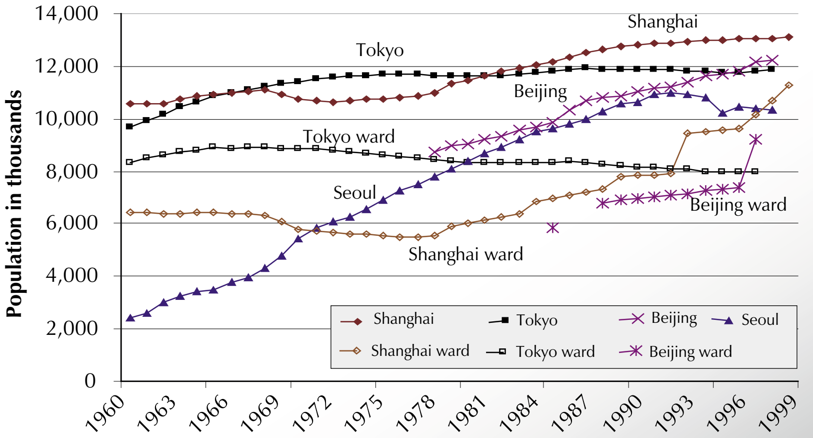
- urban demographic changes;
- patterns of urbanisation and land use;
- income growth;
- structure of economic activities;
- lifestyle and social transformations;
- material dynamics and consumption patterns;
- climate and urban geography.

This section describes the salient features of the changes in these physical determinants that Tokyo, Seoul, Beijing and Shanghai have experienced in the last few decades. It also examines the driving factors in several sectors, namely residential, business, urban transport and waste.

3.2 Demographic Changes

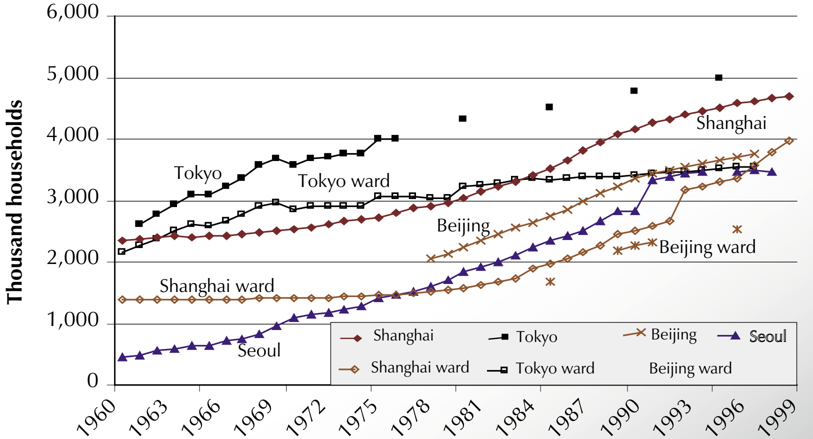
Urban demographic trends, especially day and night-time populations and the size and number of households, affect the scale of energy use. Tokyo's population has stabilised since the early 1970s; in fact, the population of the 23 wards constituting downtown Tokyo is decreasing. Seoul experienced unprecedented population growth before 1990, but soon afterwards the population started decreasing. Beijing's and Shanghai's populations have been growing, especially since 1980, but less rapidly than other similar cities in Southeast Asia. Much of this growth is attributable to migrant populations, as the one-child policy is strictly enforced in Chinese cities. Changes in the political boundaries of Beijing have often resulted in drastic population changes. The number of households is increasing in all four cities, primarily due to the rapidly decreasing size of the average household. The population of Shanghai is greater than that of Tokyo, but has fewer households. The number of households could be a more important determinant of energy use than population.

Another important aspect of demographic change is the difference in the day and nighttiime populations. Tokyo attracts a significant number of commuters, who are not counted in the resident population. One-third of the total workforce commutes from surrounding cities and prefectures utilising its well-developed surface rail and subways. The ratio of the daytime to nighttime population increased from 1.15 in 1975 to 1.25 in 1999 in Tokyo and stabilised only after 1990. In the 23 wards the ratio reaches as high as 1.41 (TMG, 2000). In contrast, the ratio in Seoul is 1.04 and is insignificant in Beijing and Shanghai (Yoon and Araki, 2002).



Source: *Internal database compiled from statistical yearbooks of cities*

Figure 3.1 Population trends, in thousands



Source: *Internal database compiled from statistical yearbooks of cities*

Figure 3.2 Household populations, in thousands

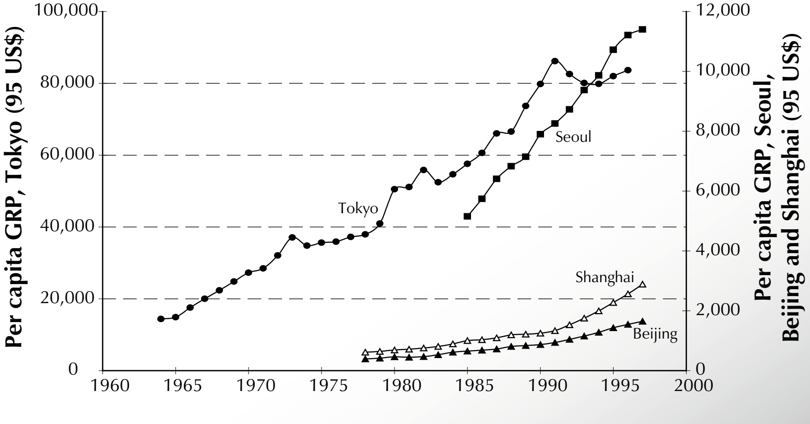
3.3 Patterns of Urbanisation and Land Use

Urban population density, the structure of urban functions (the concentration of certain type of activities), urban geography and land-use patterns (mixed land use vs. zoning) are important determinants of energy use and emission. For example, a compact city may have a lower per capita energy consumption due to its compact infrastructure and lower per capita building floor space, both traits which reduce energy use. This relationship may not always hold true, however, as a number of other factors affect energy use. In Japan, the per capita energy consumption in dense urban areas is lower than that in non-urban areas (Ichinose *et al.*, 1993). Developed countries exhibit a similar relationship. In contrast, developing countries such as China and Thailand report the opposite trend: city residents use more energy (Ichinose *et al.*, 1993). Since the income gap between urban and rural areas is small in developed countries, density has a clear influence on per capita energy use. In developing countries, in contrast, the effect of the huge income gap surpasses that of density for commercial energy uses (non-commercial uses are not considered in many studies) and the effect of density is often not seen. In later sections, we will show that the energy and CO_2 performances (in terms of a cumulative index of economy and per capita energy/emission) of Tokyo and Seoul is better than those of Beijing and Shanghai partly because of the density effect. This density effect is especially significant in the central business districts of cities. Because large cities in China such as Beijing have a combination of urban and rural settlements (the definition of a city is based on political boundaries), it is difficult to generalise the implication of urban density for the political definition of a city.

The traditional urban structure of Tokyo is core central. In the long run, it plans to adopt a multi-core urban form that might have significant implications for energy use. It is also characterised by mixed land use, a system which is usually better for energy. In Beijing and Shanghai, urban zoning for industrial and other activities has become common practice in the last few decades. The exact implications of relocating industries from residential areas to designated industrial zones on energy use are difficult to quantify, but such measures have resulted in reductions in the concentration of air pollutants in residential areas in Shanghai and Beijing (Stubbs and Clarke, 1996). In Beijing, five ring roads contain urban areas: the first surrounds the Forbidden City; the second contains the downtown areas; the third, fourth and fifth ring roads embrace the urban core, urban area and built-up areas respectively; and beyond the fifth ring road are suburban and rural areas. These suburban areas are expected to grow substantially as many new housing complexes are being constructed in and around the fifth ring road. Beijing is already developing fourteen satellite towns in suburban areas outside the fifth ring road. Such plans are expected to increase sprawl and travel demand in the future and may affect energy demand and CO_2 emissions if the provision of infrastructure remains energy inefficient. In the Seoul metropolitan area, the most recent urban expansions have taken place around Koyang, Paju, Kimpo, Inchon, Ansan, Sihwa, Sungnam, Anyang and Suwon (Yoon and Lee, 2002).

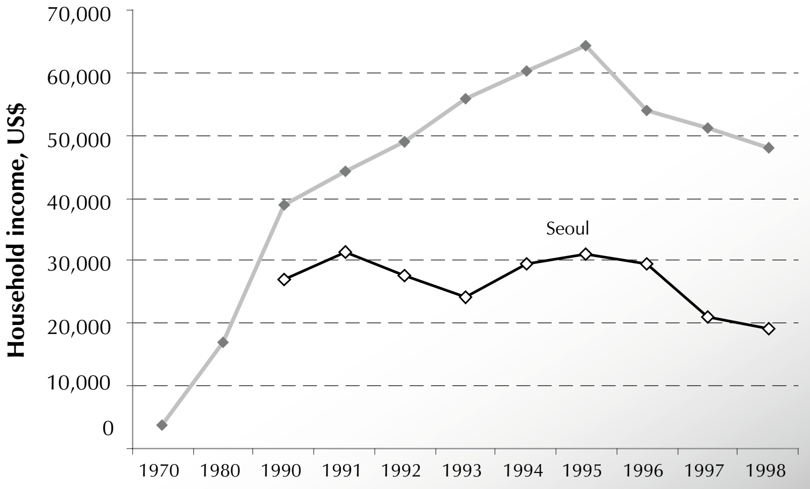
3.4 Income Growth, and Lifestyle Changes

Rapid industrialisation in Northeast Asian cities has resulted in high economic growth. Tokyo experienced sustained economic growth from the early 1960s until it went into recession in the early 1990s. The financial collapse of South Korea in 1997 had obvious implications for Seoul, but Seoul has since regained growth rates. Double-digit growth in Beijing and Shanghai has continued since 1990. Economic growth in cities has led to an increase in disposable income, which in term affects the lifestyles of residents: they can afford to consume more material goods, follow fashions and pursue leisure activities and thus they use more energy. Upsurges in the use of electric appliances in households and businesses are described in the next section. Figure 3.3 shows trends in per capita gross regional/city product (GRP) in the four cities over the last few decades. Figure 3.4 shows the household income for Tokyo and Seoul.



Source: Internal database compiled from statistical yearbooks

Figure 3.3 Trends in per capita gross regional product for four cities

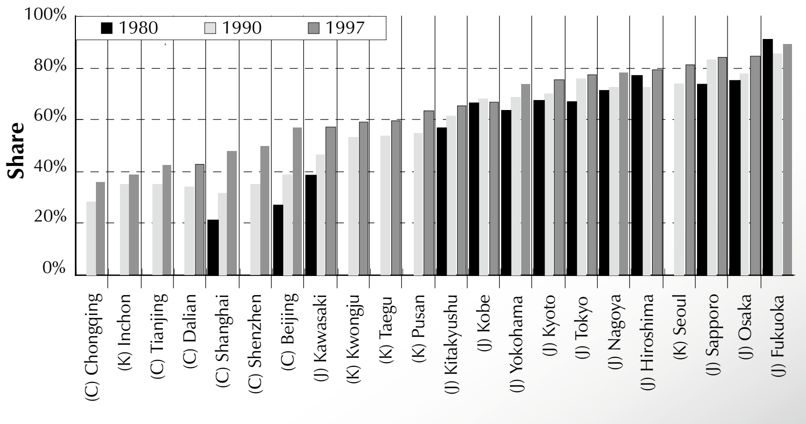


Source: Internal database compiled from statistical yearbooks

Figure 3.4 Net disposable income in Tokyo and Seoul

3.5 Structure of Economic Activities

A gradual shift from primary industries to tertiary and commercial activities has been observed in cities. Growing populations, high population density, noise and environmental problems related to primary industries are forcing industries to relocate from city centres to city outskirts and peri-urban areas. At the same time tertiary sector activities are becoming more prevalent in cities and the value added from the tertiary sector has increased consistently. The share of the tertiary sector in the total value added has risen in Tokyo from 67% in 1980 to 78% in 1997. Similar trends in other cities are shown in Figure 3.5. While Tokyo and Seoul are commercial cities, Beijing and Shanghai are industrial. As a result, the industrial sector is expected to play a major role in any measures implemented to reduce energy use and emissions in Beijing and Shanghai but not in Tokyo or Seoul.



Source: Dhakal, S. and S. Kaneko (2002). Urban Energy Use in Asian Mega-Cities: Is Tokyo a desirable model? Proceedings of IGES/APN Mega-City Workshop on Policy Integration of Energy Related Issues in Asian Cities, 23-23 January, 2002, Riga Royal Hotel, Kitakyushu, Japan, pp 173-181.

Figure 3.5 Share of value added by the tertiary sector in selected cities

3.6 Household and Business Sectors

A number of factors, particularly the scale and intensity of cooking, lighting, use of electrical appliances and heating/cooling devices, influence energy use in a household. Lifestyles and technology are key issues that any measures to reduce energy use by households need to address. Building floor space per household, which is one a major determinant, has not increased significantly in Tokyo in the last two decades: the average ranged from 50 to 60 km^2 per household from 1980 to 2000. Increases in floor space per household in the other three cites have also been nominal. However, this rate has been drastically increasing in rural areas of Beijing and Shanghai (Matsumoto *et al.*, 2003). The use and diffusion rate of household appliance differs from city to city. Tokyo is saturated in terms of key household appliances[3], which Beijing and Shanghai are rapidly catching up with Seoul and Tokyo in the use and diffusion of appliances[4]. The automation of offices and the increasing use of electrical and electronic equipment, especially computers, is one of the major determinants of energy use in Tokyo. In some of the four cities, central heating systems based on boilers are common. The fuel type and efficiency and nature of the boilers used in central heating and cooling systems are important factors in the energy use of household and business sectors in Seoul, Beijing and Shanghai. In Tokyo central heating systems are not commonly used. The type of fuel used varies from city to city. Seoul relies on oil-based central heating and cooling systems, while coal is still a major source for residential boilers in Beijing and Shanghai. In recent years, there have been rapid changes in the fuel structure in households. Many have switched from coal to oil or oil to natural gas. In Tokyo, the energy efficiency of key appliances has reached from saturation; further improvement will be difficult. Another factor which influences energy use in households and in the commercial sector is building insulation. In Seoul, Beijing, and Shanghai, building insulation, especially that in residential houses, is much poorer than it is in Europe and North America and is responsible for major energy losses. Table 3.1 compares some of the technological efficiencies of Shanghai with those of OECD countries.

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3 Tokyo: Refrigerator (1.2 per hh), microwave oven (almost 1 per hh), washing machine (1.1 per hh), electric vacuum cleaner (1.3 per hh), TV (about 2 per hh), and video player (1 per hh). Air -conditioner use has gradually increased to about 1.6 per hh, while kerosene heater use has drastically decreased from the early 1980s.

4 The diffusion rate of refrigerators in urban Beijing and Shanghai was 100% in 2000. Air conditioner diffusion in urban Beijing and Shanghai in 2000 was 60% and 80%, respectively. The diffusion rates for TVs and microwavres is over 100% in all four cities.

Table 3.1 Comparison of energy efficiency in Shanghai and in OECD countries, 1998 (indicative)

	Unit	Shanghai	OECD countries
Coal-based electricity production	(GJ el/GJ fuel)	0.38	0.40–0.44
Primary steel production	GJ/tonne	20–25	18–20
Oil refining	GJ/GJ	0.03	0.03–0.07
Coal-fired industrial boilers 410 t steam/ hr	(GJ steam/GJ fuel)	0.65	0.7–0.75
Passenger cars	L/100 km	10	8–14
Colour TV	Watts	100–150	70–120
Air conditioners	Kw cold/kw el	3.6–4.4	3.8–5.5

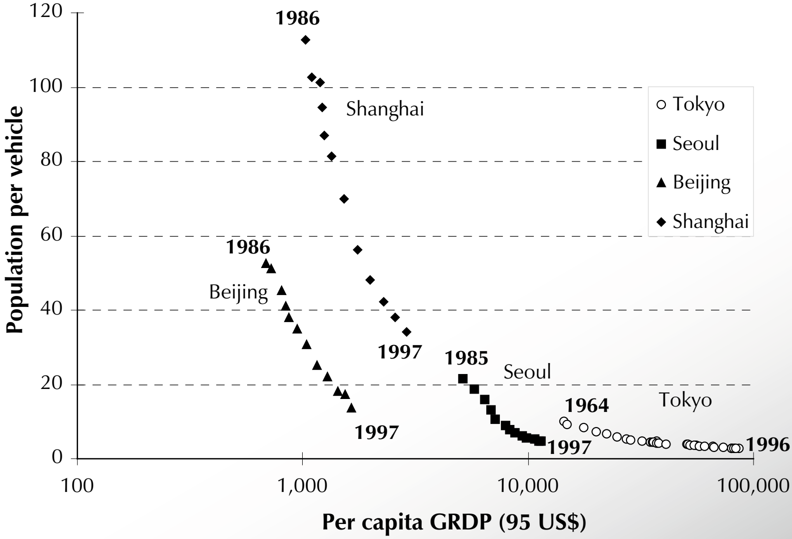
Source: Dolf Gielen and Chen Changhong (2001). The CO_2 emission reduction benefits of Chinese energy policies and environmental policies: A case study for Shanghai, period 1995-2020, Ecological Economics vol. 39 (2001) pp. 257-270.

3.7 Urban Transportation

3.7.1 Speed and Scale of Motorisation

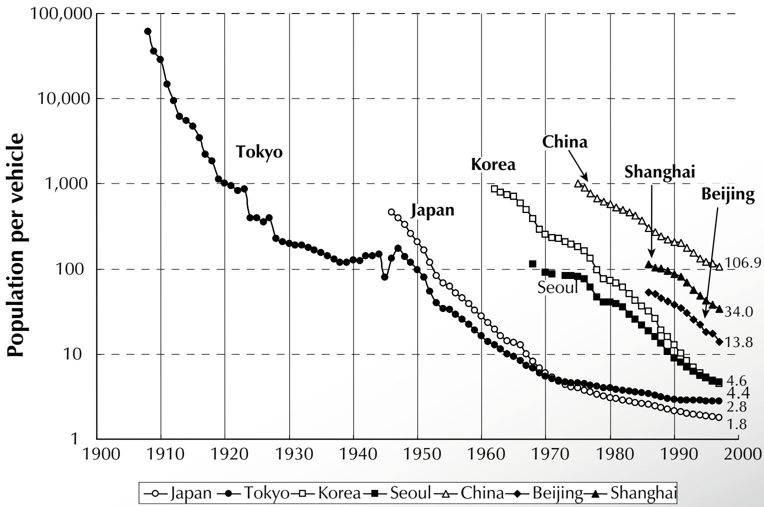
In the transport sector, the growing number of private cars is a key determinant of energy use and CO_2 emissions. Motorisation in Tokyo started in the early 1950s, and vehicle ownership rose rapidly in the 1970s. Since then, ownership rates have not increased rapidly. In fact, growth in ownership has stagnated in Tokyo ward areas due to saturation and in wider Tokyo has been nominal since the recession of the Japanese economy in the late 1980s. In Seoul, rapid motorisation began in the mid-1970s and early 1980s, but growth rates have been tremendous, becoming saturated by the mid 1990s, following a typical S-shaped market penetration curve (Figure 3.8). Beijing and Shanghai have rapid rates of motorization as shown in Figure 3.6. Beijing, compared to Shanghai, has a higher scale of motorization. Shanghai started with a low level of motorisation but is rapidly caching up, and the gap that existed between Beijing and Shanghai has narrowed in recent years. Seoul reached a higher level of motorisation at a lower income stage (per capita economic output) than Tokyo did. The case of Beijing is serious: while its income is constantly rising, its inability to shift to rail-based mass transportation might put it into a situation like that Bangkok faced in the mid-1990s. Shanghai seems to be following Seoul in its per capita vehicle trend. Tokyo, Seoul and Beijing seem to have a 20-year time difference for the same level of motorisation; Tokyo in the 1950s, Seoul in the 1970s, and Beijing in the 1990s have the same level of motorisation (people per passenger vehicle), as shown in Figure 3.6. It also highlights the differences in patterns of vehicle ownership in cities of different countries in contrast with those at the national level. For example, the vehicle ownership rate (per person) in Beijing and Shanghai is much higher than China national average, while Seoul rate is almost the same as Korea. Japan national average trailed behind Tokyo until 1970, after which Tokyo rate of vehicle ownership dropped below the national average (see Figure 3.7). Interestingly, the point (around 4.5 people per vehicle) at which the gap between city and national vehicle ownership is zero seems to coincide in both Japan and Korea. It will be interesting to see whether this is true in other cities and if there are any patterns.

Trends in the use of private vehicles (cars) and public vehicles (buses and trucks) are major determinants of energy use and emissions from



Source: Internal database compiled from statistical yearbooks

Figure 3.6 Speed of motorisation in Tokyo, Seoul, Beijing and Shanghai



Source: Internal database compiled from statistical yearbooks

Figure 3.7 Scale of motorisation: population per vehicle in Tokyo, Seoul, Beijing and Shanghai

urban transportation. Figure 3.8 shows these trends. Cars, in particular, are significant because of their large number and their strong correlation with income growth. Growth in the number of cars in the dense ward areas of Tokyo has stagnated, while the number of cars in the Tokyo metropolitan area is moderately increasing. The absolute number and the growth in the number of cars in Beijing and Shanghai was, in the past, much less than it was in Tokyo. Beijing has always had more cars than Shanghai and since 1990 the number of vehicles in Beijing has increased rapidly. The numbers of buses and trucks are falling in Tokyo and more rapidly in its ward areas, probably due to the stagnation of urban populations in ward areas and the greater reliance on surface railways for long-distance commuting and subways for passenger transportation. In Seoul, however, the numbers of buses and trucks continue to increase (partly due to its having relatively small populations of long-distance commuters and few subway stops). The numbers of buses and trucks continue to increase in Beijing and Shanghai; in particular, the number of light-duty trucks in Beijing is increasing so rapidly that policy makers concerned about the environment are expected

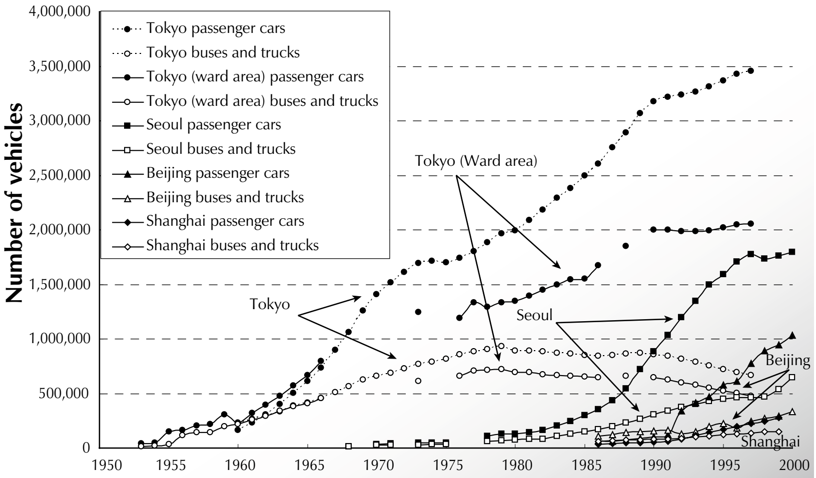


Figure 3.8 **Trends in the number of cars, buses and trucks in Tokyo, Seoul, Beijing and Shanghai**

to apply stringent controls soon. The growth in the number of taxis in Beijing and Shanghai is tremendous: numbers increased from 9,000 to 653,000 in Beijing and from 500 to 224,000 in Shanghai from 1980 to 1997[5].

3.7.2 Road and Railroad Infrastructure

Roads play an important role in any urban transportation system: an adequate network is essential to guarantee the smooth flow of traffic. Comparisons of road systems show that Tokyo has the largest per capita road area, 12 m^2. Figure 3.9 compares the per capita road area and the vehicles population per km of road length in the four cities. Beijing and Shanghai have significantly lower per capita road areas as well as the highest numbers of vehicle per km of road. The infrastructure needed to accommodate even such a moderate level of vehicle ownership is inadequate in Beijing. From 1979 to 1999, the road length in Beijing nearly doubled, while the number of vehicles increased seventeen-fold (He, 2004). Road area in Shanghai rapidly increased after 1990. The Tokyo metropolitan region has a well-developed and well-connected subway

5 Source: Internal database compiled from various statistical year books and government documents of Beijing and Shanghai

and surface rail system of 2,143 km. These rail networks were constructed well before motorisation had begun and thus did not face fierce competition from motorisation. The current state of the subway network is shown in Table 3.2. A closer look at the subway traffic and infrastructure reveals the following points:

- Before 1990, the rate of subway expansion (the length of subway lines) and rate of increase in subway passengers (the rate of utilisation) were almost identical in Tokyo ward areas. This insured a high rate of subway utilisation by passengers. However, passenger traffic has stalled or decreased in Tokyo ward areas since the early 1990s. In contrast, the rate of subway expansion (in terms of length) has increased.

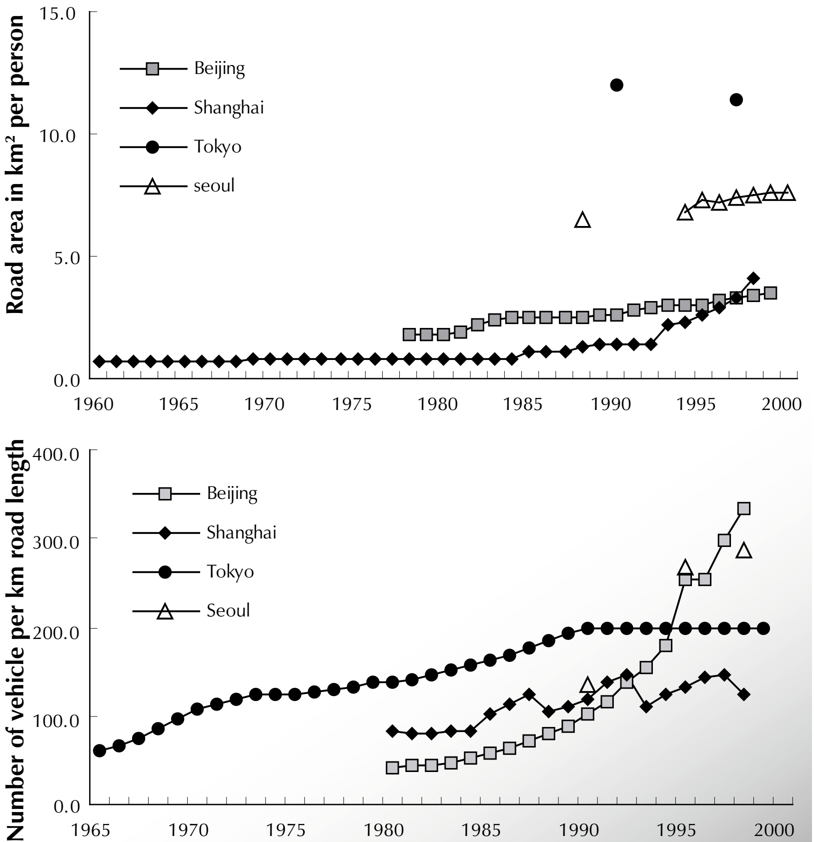


Figure 3.9 Comparison of road infrastructure

- The length of subway lines in Seoul is almost equal to that in Tokyo, but the rate of subway utilisation is lower. After the completion of four more lines which are currently under construction, the total subway length will be about 280 km.
- Subway construction in Beijing stalled from the mid 1980s to the early 1990s although the utilisation rate of the existing subway increased during this period. The stalling of both the construction of additional lines and the expansion of existing lines gave rise to rapid motorisation. Since the late 1990s, urban railway construction has been progressing; Beijing hopes to fulfil its goal of 254 km by the 2008 Olympic Games. From the current three lines, Beijing plans to construct ten more lines by 2008.

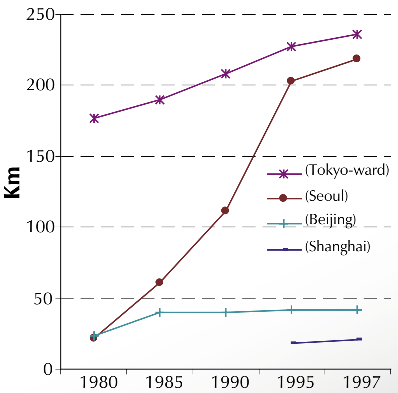
Table 3.2 Urban railway information in selected cities (2000)

	Beijing	Shanghai	Tokyo	Seoul (1998)
Total length (km)	55.1	65.0	248.7	218
Number of stations	45	48	235	115
Number of lines	3	3	12	4

Source: He (2004).

3.7.3 Transport Mode

Figure 3.11 shows the share of various modes of travel used in cities (in passenger times). The figure shows that the structure of travel modes in Tokyo and Seoul (except buses and subways in Seoul) has not changed in recent decades, whereas in Beijing and Shanghai it has. In contrast to the other three cities, travel by subway and taxi is very high in Tokyo and by private cars very low. In Seoul, the expansion of



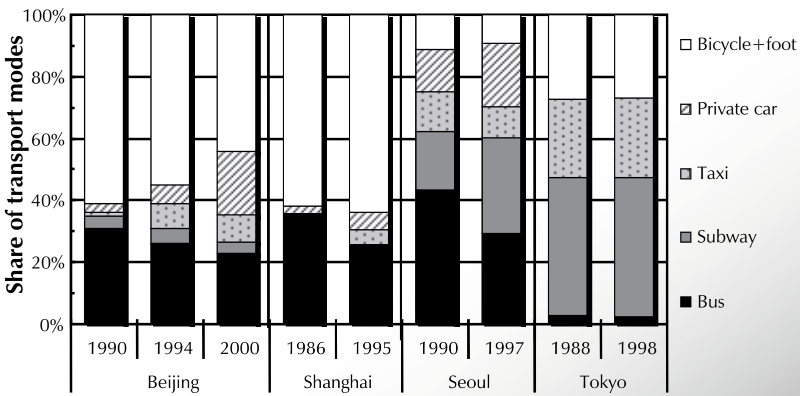
Source: Internal database compiled from statistical yearbooks and other sources

Figure 3.10
Subway lengths in selected cities

the subway has considerably reduced travel by bus. Travel by non-motorised modes (walking and bicycles) and by buses is rapidly decreasing in Beijing, while travel by private modes is increasing. Travel by car in Beijing increased from less than 5% of total travel in 1990 to almost 20% in 1990; travel by taxis has also increased significantly (He, 2004). Shanghai has also witnessed a rapid increase in private car travel despite stringent control; the increase, however, is less than it is in Beijing.

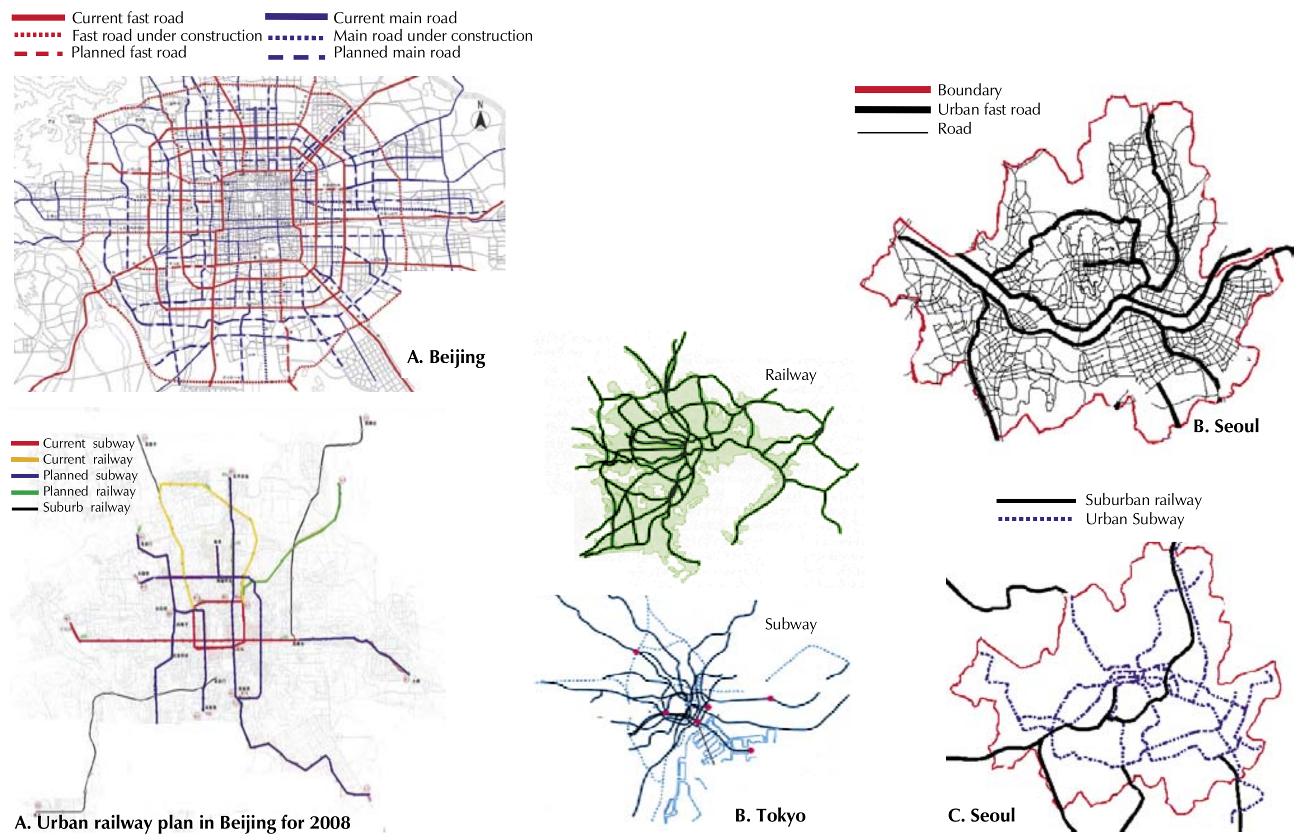
- In Tokyo, rail accounts for about 45% of total passenger transportation (1998).
- In Seoul, roads account for about 70% of passenger transportation (1997).
- In Beijing and Shanghai, roads account for over 95% of passenger transportation, including non-motorised modes (2000).
- In Beijing and Shanghai, increases in private and low-occupancy modes, such as cars and taxis, are placing pressure on the available road infrastructure.

While there is an increase in the volume of total travel, the share of travel by buses has decreased in Beijing, as demonstrated in Figure 3.11. The actual number of buses, however, is increasing. From 1990 to 1998, the number of buses increased by 87%, but passenger traffic increased by only 22% (He, 2004). This shows that the comfort of bus travel is much greater



Source: He (2004)

Figure 3.11 Variations in transport modes in four cities



Source: Compiled from various sources, mainly He (2004), Tokyo Urban Transport: Akio Okamoto

Figure 3.12 Graphical sketch of road and rail networks in Tokyo, Seoul, and Beijing

than it was in the past, but at the same time, it highlights the inability of the public transport to attract passengers due to low service quality (lack of punctuality, distance of bus stations, etc.). The drastic increase in taxi travel suggests that a considerable number of passengers are looking for better service from and greater efficiency in public transportation.

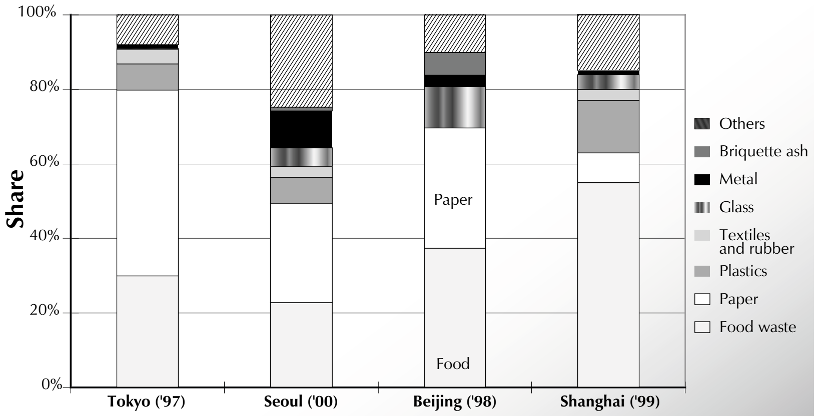
3.8 Waste Management[6]

Due to the increasing volume of waste, municipal waste management is becoming an ever more serious challenge for urban policy makers. Whether waste is recycled or incinerated, it requires energy, and the resulting emissions are not insignificant. That incineration and landfill usage have various advantages and disadvantages from a waste management perspective is a given; less obvious is the fact that each method has a different effect on the type and amount of GHG emissions. The disposal of waste in landfills results in the production of methane, a gas 22 times more harmful than CO_2 in terms of its contribution to greenhouse effect. Incinerators, in contrast, use energy to burn waste and produce CO_2 from that energy use as well as from the waste that is burnt. Choosing a method is not motivated solely by a consideration of GHG emissions: incinerators, unlike landfills, allow for energy or heat recovery. If this heat or energy is used to produce power, CO_2, which otherwise would have been released into the atmosphere and thereby gone to waste, can be recycled.

The composition and volume of municipal solid waste (MSW) have a significant effect on the method of treatment and therefore on GHG emission. The per capita waste generated in Tokyo, Seoul, Beijing and Shanghai in 1999 was 1.13, 1.06, 1.107 and 1.04 kg/person/day respectively. The volume has been decreasing in Tokyo since 1989 and in Seoul from 1992[7], while it is rapidly increasing in Beijing and Shanghai. Figure 3.13 shows the share of various types of waste treatment in the four cities.

6 Based on a report written by Dr. Eui Young Yoon for the project. See Yoon and Jo (2003a) and Yoon and Jo (2003b).

7 Data on Seoul shows that there was a drastic reduction in the volume of waste in 1992. The huge data discrepancy was due to the fact that until 1991 data was based on the volume collected by garbage trucks, whereas after 1992, it was based on weight. Since 1992, MSW has continued to decrease.

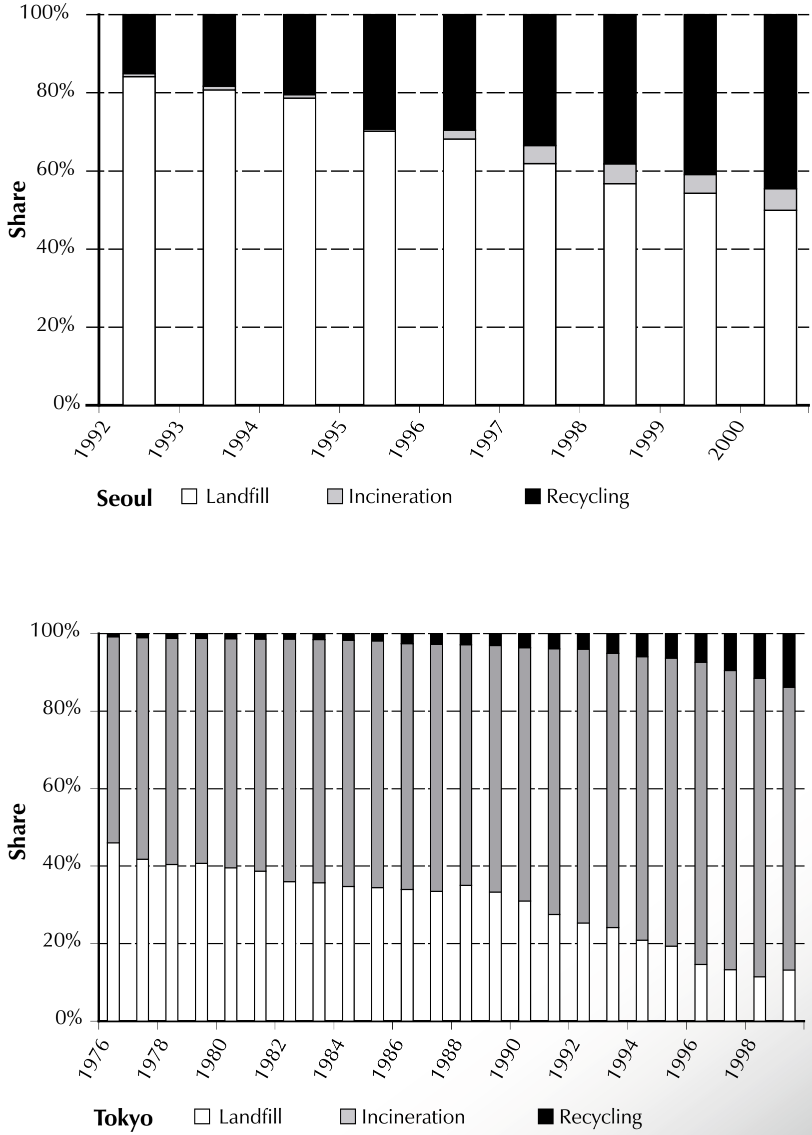


Source: Internal database compiled from city statistics

Figure 3.13 Waste composition in cities

The proportions of waste recycled (after separation), buried in landfills and incinerated are important from the standpoint of energy and emission. Incineration has increased in Tokyo over time; today over 85% of waste is incinerated in 18 incinerators. In Seoul, most waste is placed in landfills. As of 1999, Beijing had six landfill sites, two composting facilities and one incineration facility. Most of its waste goes to landfills. In Shanghai, there are only two landfill sites. Little attention is given to waste in Beijing or Shanghai although the current rates of economic growth and waste generation suggest that these cities will face serious waste problems soon.

Source reduction is the most effective method for reducing GHG emissions (ICLEI, 1999). Table 3.3 shows that recycling is the next best option, while using landfills and incineration (without heat recovery) produces more GHG.



Source: Internal database compiled from city statistics

Figure 3.14 Method of treatment of municipal solid waste in Seoul (top) and Tokyo (bottom)

Table 3.3 Net GHG emission from source reduction and municipal solid waste management options (Emission counted from a waste generation reference point in MTCE/tonne)

Material	Source reduction	Recycling	Composting	Combustion	Landfill
Newspaper	-0.91*	-0.86	NA	-0.22	-0.23
Office paper	-1.03	-0.82	NA	-0.19	0.53
Aluminium cans	-2.98	-3.88	NA	0.03	0.01
Glass	-0.14	-0.08	NA	0.02	0.01
PET	-0.98	-0.62	NA	0.24	0.01

Source: USEPA (Sept. 1998). GHG emission from the management of selected materials in municipal solid waste. P. Es-12.

3.9 Climatic Factor

Lastly, one of the most important factors in determining energy use in and CO_2 emissions from each city is the prevailing climate. Heating and cooling services consume a major share of energy. In the winter, per capita heating energy needs in Beijing surpass those in Tokyo due to its cold climate but the hot and humid summers of Tokyo drastically increase energy consumption due to the use of air conditioners.

4 Energy Use and CO_2 Emissions in Cities and Future Challenges

4.1 Introduction

Although many analyses of energy use and CO_2 emissions on a national scale have been published, at the city scale there are very few such analysis. City-scale studies that cover urban sectors comprehensively are still in the stage of methodological development. Such analyses typically focus on urban energy CO_2 inventories of specific cities, most of which are outside of Asia (McEvoy *et al.*, 1997; Kates *et al.*, 1998; Baldasano *et al.*, 1997; Bennett and Newborough, 2001; Newman, 1999; ICLEI, 1997). This section presents a picture of energy use and energy-related CO_2 emissions in four Asian cities; it includes past trends and future scenarios. The focus is on CO_2 emissions from energy use rather than on energy use itself. This section also quantifies and analyses the role of selected driving factors in both total and sectoral (transportation, household, and business) CO_2 emissions. As mentioned above, the role of indirect emissions could be significant in cities as cities consume large qualities of material goods. Although a consumption-oriented analysis would have been more powerful, because of the limitations of existing studies this report relies on the outcomes of the I-O, table-based approach. The aim of this section is to clarify the current picture and future scenario of CO_2 emissions. It also discusses future local environmental challenges for cities which will result because the driving factors behind CO_2 emissions will exacerbate air pollution and urban warming.

4.2 Challenges for Achieving Exactness and Comparing Data

Estimates of CO_2 emissions are usually seriously limited because of the difficulty in obtaining city-scale data. One reason for this limitation is that major policy decisions on energy-related issues are made at the national level. Another handicap is the difference between the political and functional boundaries of a city. To circumvent these problems, most studies focus on selected sectors, usually transportation and building. This section, in contrast, examines comprehensive city-scale CO_2 emissions for selected East Asian cities that have seen unprecedented industrialisation in the last few decades.

The lack of quantitative and qualitative information at the city level poses a problem even though the four cities discussed in this report have the best data available in the Asian context. Obstacles to a comparative analysis include the incomparability of information, problems in defining data, and differences in the methods used to organise information and data. Urban-scale analyses of Asian cities share the following generic problems:

- Some information is available for the political boundaries of a city, while other information is available at a different scale (such as for a metropolitan region).
- Some cities, especially those in China, use unique definitions of terms and methods of aggregation into sub-sectors and sectors which do not follow definitions used internationally by the International Energy Agency or other multilateral institutions.
- The classification of various driving forces behind energy use and emissions, such as the structure of energy balance tables, vehicle categories, indicators for travel demand, the structure of regional I-O tables, etc., differs from city to city.
- Since a city is politically defined, it may have both rural and urban populations inside it. This is especially the case for Beijing and Shanghai. The mixture renders it difficult to explain analyses.
- Although emission factors are crucial for calculating estimates of energy emission, many are either unavailable (thus compelling the use of IPCC factors) or are too aggregated for use.

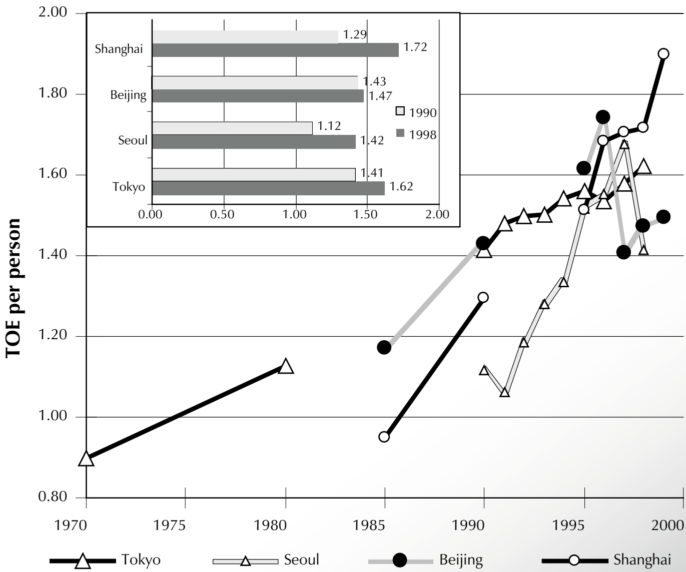
- Information gaps are so large in the majority of Asian cities that many ICLEI-sponsored estimates of energy and CO_2 emissions measure only corporate emissions from municipality services rather than emissions from the municipality as a whole.
- Comparing cities is a difficult task. The choice of indicators, such as total emissions vs. per capita emissions or emissions per capita vs. emissions per unit of economic activity, raises controversy as each indicator has different implications.
- The role of many Asian municipal governments within their political boundaries is undermined by the lack of management capacity and absence of proper decentralisation of governance. In addition, urban sprawl and expansion beyond original boundaries is common, but municipal governments do not govern those areas. As a result, analyses conducted within a city's political boundaries do not yield a complete picture of energy use or emissions. There are dual problems: in some cases municipal government governs a small section of the city (Dhaka, Bangladesh, is an example) while in others it covers areas which are too big and include surrounding rural (an example is Beijing).
- Since energy use and emission problems in one city are often interlinked with the problems of neighbouring cities, policies based on information from a single city often have limited impact.
- The political boundaries of cities often change, as is the case in Beijing. These changes make it difficult to compare information and data over time.

It is clear from this list of limitations that the scientific as well as the policy research community needs to create a consistent city-level information base and to make local policy makers aware of the need for sound analyses of options and measures. Despite these generic problems, the availability of information about Tokyo, Seoul, Beijing and Shanghai within their political boundaries is reasonably good. Even the two developing cities, Beijing and Shanghai, have a solid base because although they are cities they exercise the authority of a province. Most of the analysis in this report predates 1998 as that is the period for which data is readily available.

4.3 Energy Scenario in Cities

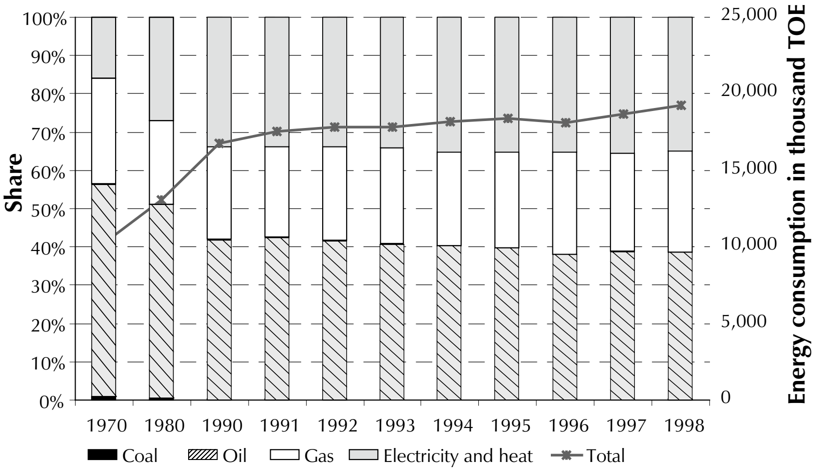
Energy consumption in Tokyo, Seoul, Beijing and Shanghai is, in general, increasing; exceptions are Beijing in 1997 and Seoul after the Asian financial crisis. Beijing seems to have followed the national trend, which is reported to be a decline in energy consumption and CO_2 emissions since 1996. This claim, however, is the subject of an ongoing controversy; it has often been suggested that the reduction in China is due to accounting problems. In Beijing, total energy consumption increased by 15% from 1998 to 2002 (Wu, 2004).

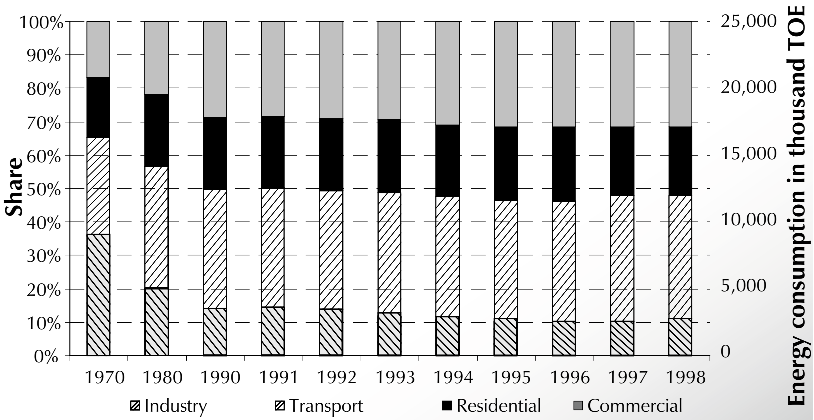
Figure 4.1 shows that the per capita energy consumption of all four cities is consistently increasing and that it has been converging towards a common point in recent years. This means that energy use in developing cities such as Beijing and Shanghai is rapidly approaching and even surpassing that in developed cities such as Tokyo and Seoul. (Since 1998, Seoul's per capita energy consumption has decreased due to the financial crisis in 1997. It is still recovering.)



Source: Internal database compiled from published energy balance tables of the four cities

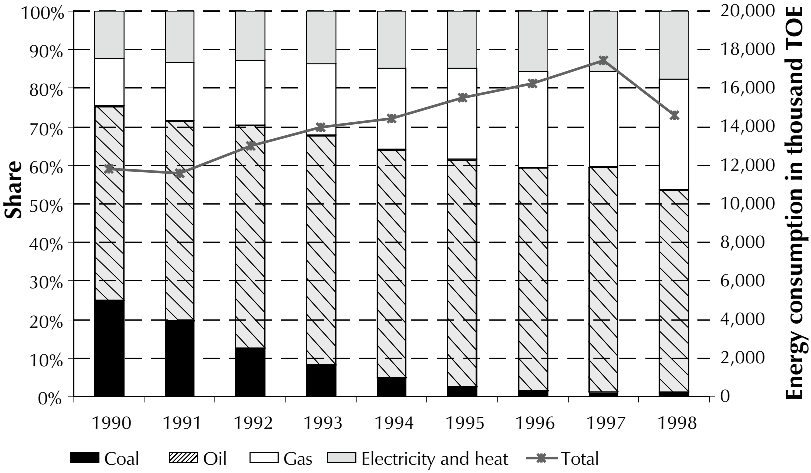
Figure 4.1 Per capita energy consumption

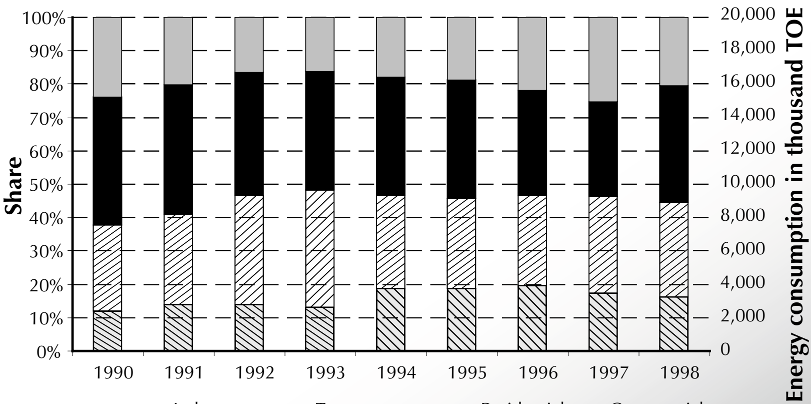




Source: Internal database compiled from energy statistics of cities

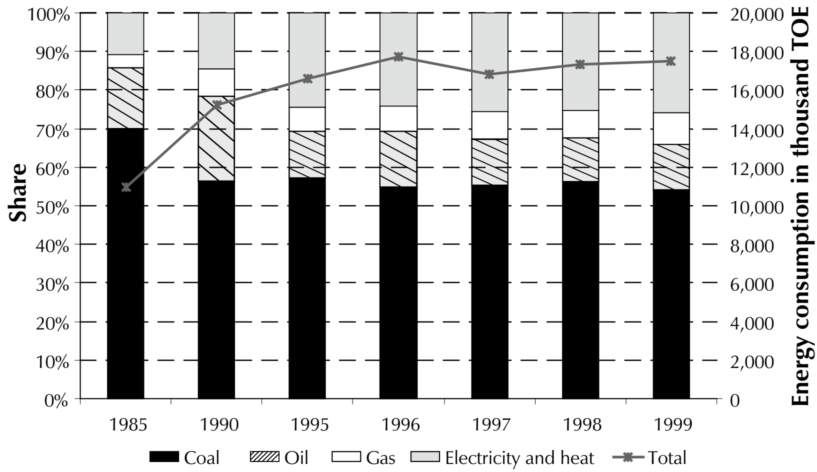
Figure 4.2A Energy consumption in Tokyo

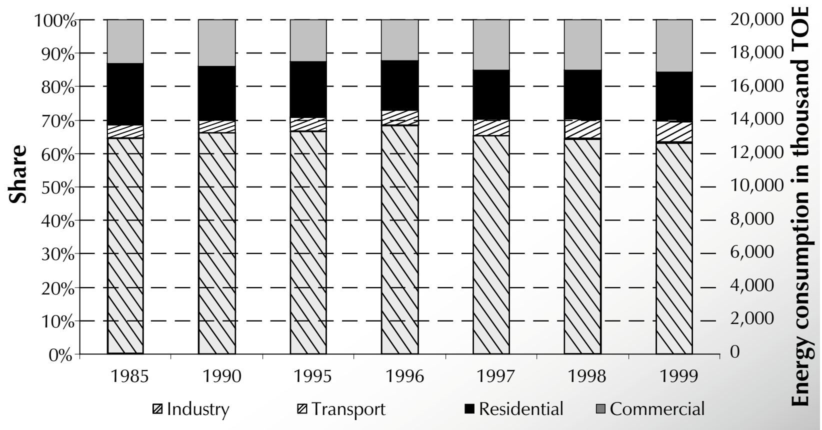




Source: Internal database compiled from energy statistics of cities

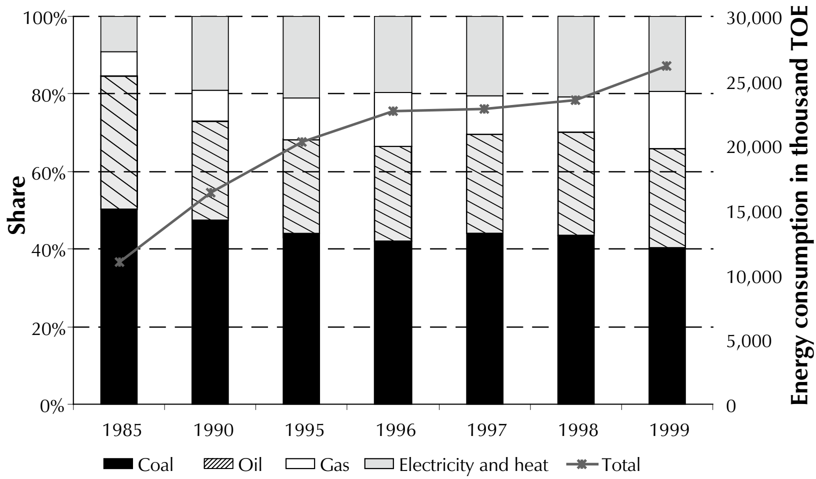
Figure 4.2B Energy consumption in Seoul

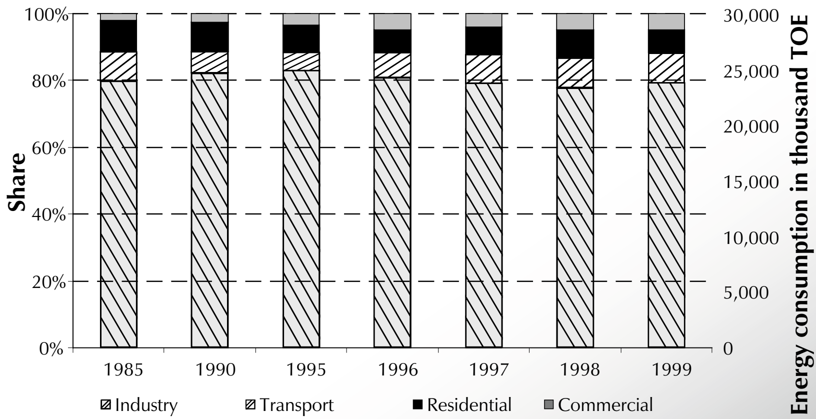




Source: Internal database compiled from energy statistics of cities

Figure 4.2C Energy consumption in Beijing





Source: Internal database compiled from energy statistics of cities

Figure 4.2D Energy consumption in Shanghai

In Tokyo, energy consumption has increased about 85% over the last three decades. Oil, urban gas and electricity are the major sources; reliance on coal has almost been eliminated. The use of electricity is rising in terms of both its share and absolute volume, and the use of oil is decreasing. Industry has played a nominal role in Tokyo in recent years (about 10%; the national share is about 40%), whereas in Beijing and Shanghai it contributes over 65% and 85%, respectively. Most energy use in Tokyo is by transportation and businesses. Within the business sector, offices consume the majority, followed by restaurants; the gap in usage has widened significantly in the last two decades due to the increasing share of energy consumption by offices. Energy consumption by restaurants, on the other hand, has decreased since 1995, most likely due to the economic recession.

Seoul is distinct in its heavy reliance on oil; in recent years, coal has been replaced by gas and electricity. Residential households consume the majority of energy in Seoul; transportation is the second biggest user. Provisions for district heating are rapidly expanding. In 2001, over 350,000 households used district heating; this figure is expected to increase to over 430,000 households by 2007 (Jung, 2004).

The structure of energy use in Beijing and Shanghai did not change significantly in the period from 1985 to 1998. The major characteristics of the energy profile in these cities are (1) the share of electricity usage is increasing somewhat, (2) coal dominates energy use, and (3) the share of the transport sector ranges from 5 to 10%. Primary industry is shrinking in Beijing and Shanghai and significant economic growth now stems from the tertiary sector. This change has balanced the energy profile to some extent so that increasing economic growth has not resulted in huge growth in per capita energy consumption. In Beijing, for example, the share of coal consumption by secondary industries in total consumption has grown, a fact consistent with the economic growth of secondary industries. After Beijing replaced small coal-fired boilers with gas-fired boilers in residential sectors, coal consumption in this sector dropped from 4.0 million tonnes in 1995 to 2.8 million tonnes in 1999[8]. The use of natural gas has risen dramatically in Beijing and Shanghai in recent

8. Beijing Statistical Yearbook 2000, Beijing Statistical Bureau: Chinese Statistical Press, 2000.

years but still accounts for a very small share of total energy usage. In Shanghai's energy structure, the share of coal in total consumption dropped about 7% from 1995 to 2000; it was replaced largely by oil. In sum, rapid changes in the energy structures of Beijing and Shanghai have taken place only lately, after 1998.

4.4 Patterns of CO_2 Emissions in Cities[9]

The patterns of CO_2 emissions from energy use in the four selected cities are like those of energy consumption although choosing alternative fuels results in differences (see Figures 4.2 and 4.3). Tokyo emits 1.5 times more CO_2 from energy use than Seoul does, while Beijing and Shanghai respectively emitted 1.4 and almost 2 times more than Tokyo in 1998. Emissions from Tokyo have increased more than two times in the last three decades, with an annual average growth rate of about 2% between 1970 and 1998. During that same period, the annual average growth rate of the economy (GRP) was 6.87%. Between 1990 and 1998, the annual average growth rates of CO_2 emissions for Tokyo and Seoul were estimated at 0.7% and 0.8%, respectively. The emission growth rate before the Korean financial crisis in 1997 was almost 4.5%.

Economic growth is one of the major determinants of emission levels. The economic recession in Tokyo did not reduce the volume of emissions because emissions in Tokyo are strongly related to lifestyle (automobiles and transportation), office automation and building systems. In Seoul, on the other hand, the economic collapse has had a major impact on emissions. The growth of emissions in Beijing and Shanghai decreased in recent years despite rapid economic growth due to ongoing fuel switching, rises in productivity, improvements in energy efficiency and changes in the economic structure; the decrease in Shanghai was particularly notable.

In Tokyo, the transportation and commercial sectors, mainly offices, are responsible for the majority of CO_2 emissions. In the last three decades, the share of the industry sector has declined steadily from 30% to 10%;

9. The numerical estimates for CO_2 emissions given in Sections 4.4, 4.5 and 4.6 were carried out in collaboration with Dr. Shinji Kaneko.

the absolute volume of emissions from industry has also decreased. This is due to the relatively small scale of industrial activities in Tokyo; it is principally a commercial city and the tertiary sector has gradually dominated the industrial sector. The share of tertiary industries in the total industrial value added increased from 67% in 1980 to 77% in 1998.[10] Oil and electricity (CO_2 emissions are based on an average electricity generation mix) are responsible for the majority of CO_2 emissions.

Table 4.1 Economic and emission transitions in cities

City	1970-80	1980-90		1990-1998	
		1980-85	1985-90	1990-97	1997-98
Tokyo	High economic growth (8.5%) Moderate emission growth 2.5%	High economic growth (6.3%) Moderate emission growth (2.3%)		Negative economic growth (-0.4%) Low emission growth (0.7%)	
Seoul				High economic growth (5.9%) Moderate emission growth (4.5%)	Negative economic growth (-16.3%) Negative emission growth (-19%)
Beijing			High economic growth (7.5%) High emission growth (6.5%)	High economic growth (14.5%) Low emission growth (2.7%	
Shanghai			Low economic growth (2.3%) High emission growth (11%)	High economic growth (20%) High emission growth (5.6%)	

The definitions of high and low growth are subjective; for the purpose of comparison, over 5% was considered as high in this table.

In Seoul, transportation and residential households not only consume the most energy but are also are responsible for the highest emissions. The residential sector's share and volume has, however, decreased in recent years. The economic collapse in Korea seems to have contributed

10. TMG : Tokyo Statistical Yearbook, Annually published (1970-2001) by Tokyo Metropolitan Government, Tokyo, Japan.

greater to the reduction of emissions from businesses and transportation than from other sectors. The small contributions of the industrial sector to total emissions can be partly explained by the dominance of the tertiary sector. The share of the tertiary sector in industrial valued added increased from 74% in 1980 to 81% in 1997 (Korea National Statistical Office, 2000 and 2001). Similarly, oil contributes to over 55% of total CO_2 emissions because its use dominates in the building and transport sectors. Unlike in Tokyo, in Seoul most large buildings use oil-based centralised heating systems. The rising share of emissions from gas and electricity has replaced the share of coal (which dropped from 35% to 3% in the period from 1990 to 1998) while the share of oil has not changed considerably.

Emissions in Beijing and Shanghai are dominated by industrial activities, whose shares in 1999 were as high as 80% in Shanghai and 65% in Beijing. The share of transport was about 5 to 6% in 1999. The structure of emissions in these cities changed only slightly between 1985 and 1999, with the exception of a nominal increase in the share of businesses and transportation. Although the share is very small, the annual average emission growth in the transport sector (about 11% in both cities) is high enough to alarm policy makers. The increasing use of gas has raised its share in total emissions in recent years, but coal is still the major cause of emissions since most electricity is coal-generated. Shanghai is distinct from Beijing in its emission structure by fuel types in that it has a larger share of emissions from oil and gas.

The fuel mix of electricity production is an important determinant of the volume of CO_2 emissions. The majority of electricity in Beijing and Shanghai comes from coal, but in Tokyo and Seoul, nuclear energy, natural gas and oil account for significant shares[11].

11 City scale figures for Seoul and Tokyo are not available in this report. The national average energy mix in electricity production for 1998 in Japan is coal (19.5%), oil (16.5%), gas (21%), nuclear (32%) and others (11%); and in Korea is coal (42%), oil (7%), gas (11%), nuclear (37.5%) and others (2.5%).

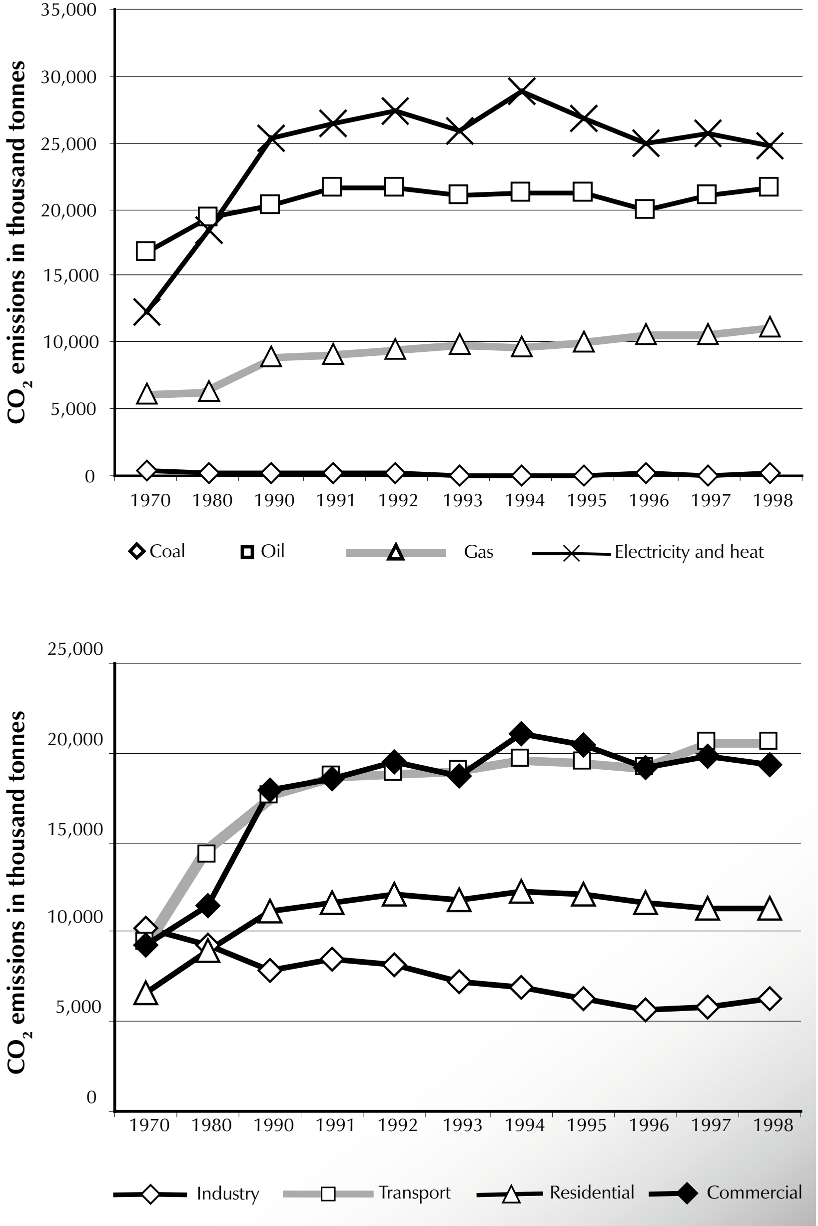


Figure 4.3A CO_2 emission from energy use in Tokyo

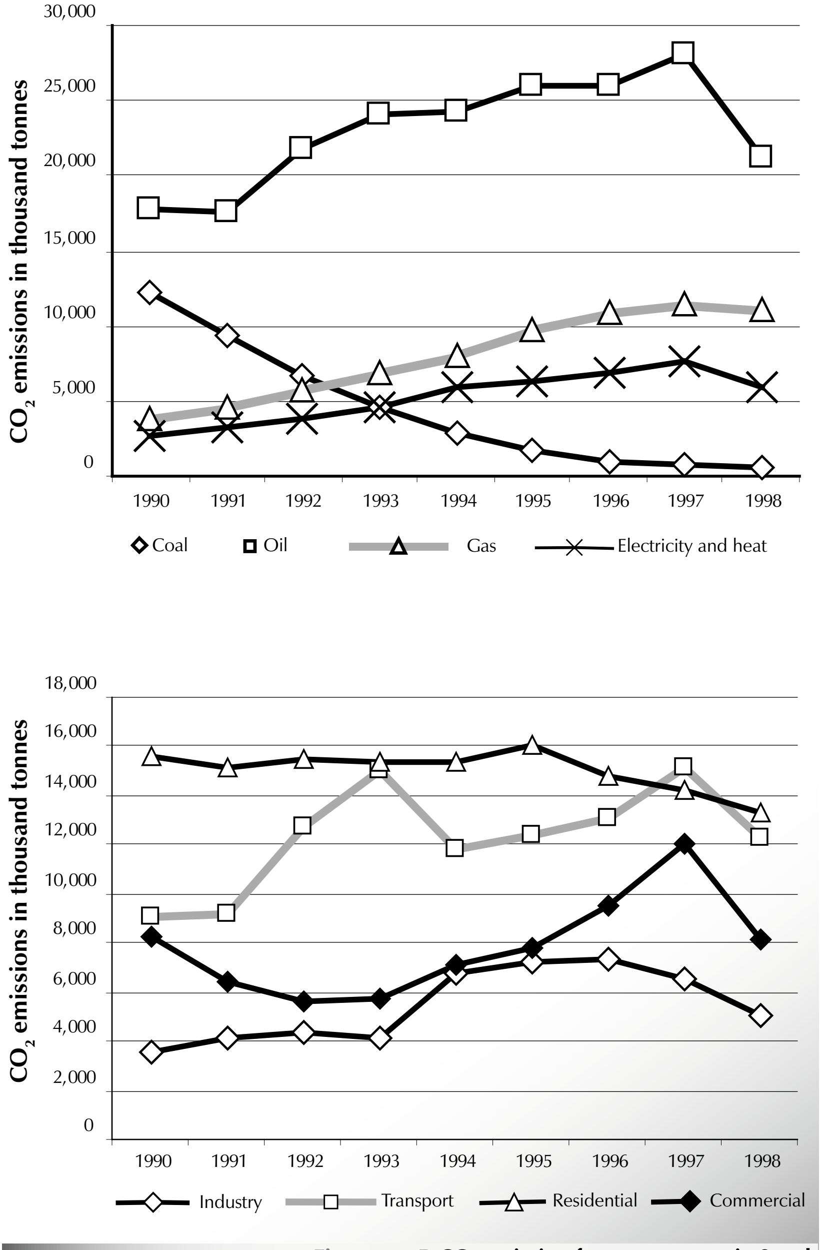


Figure 4.3B CO_2 emission from energy use in Seoul

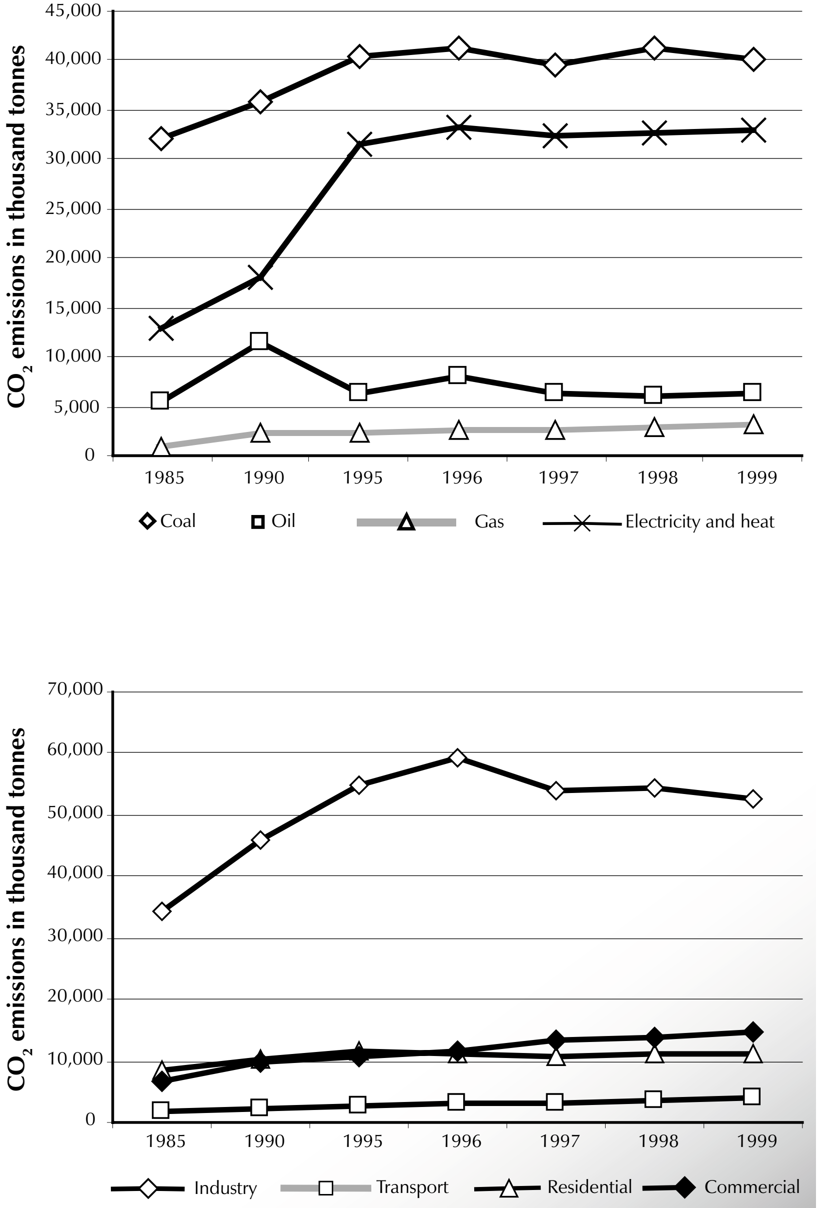
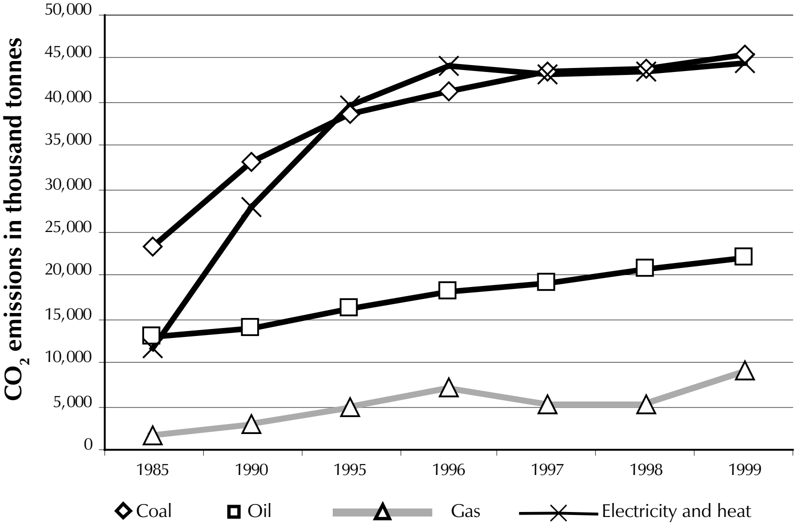


Figure 4.3C CO_2 emission from energy use in Beijing



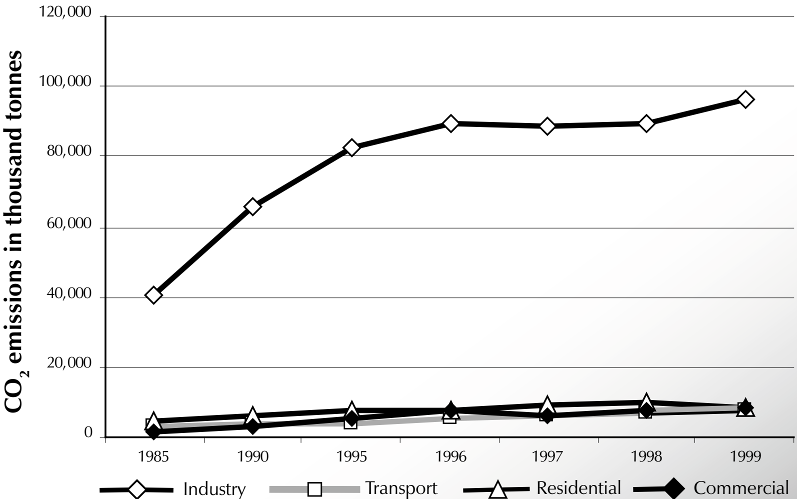
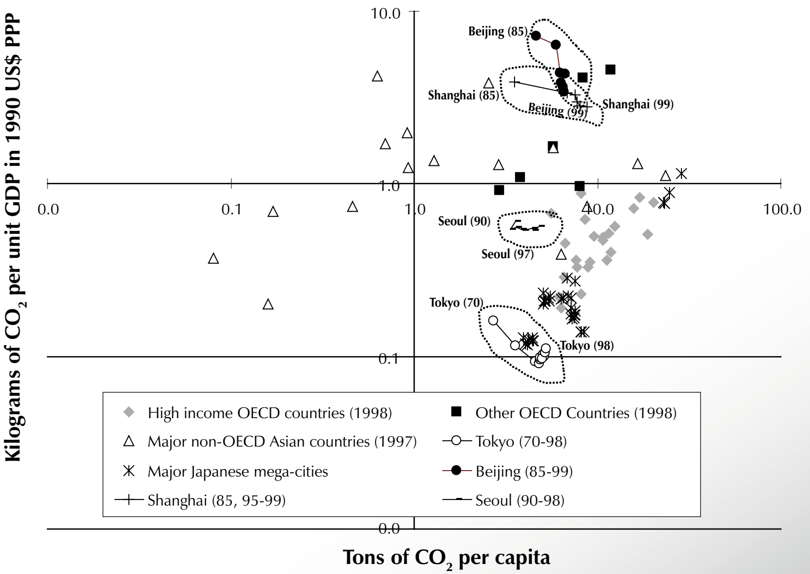


Figure 4.3D CO_2 emission from energy use in Shanghai

4.5 CO_2 Emissions of Cities Per Capita and Per Unit of Economic Activity

Figure 4.4 evaluates the performance of the cities in terms of CO_2 emissions per capita and CO_2 emissions per unit of economic activity. Due to an insufficiency of data, CO_2 emissions could only be depicted for selected North Asian cities (Tokyo, Seoul, Beijing, Shanghai, and large Japanese cities), OECD countries and major non-OECD countries.

The comparison reveals that the performance of large Japanese cities is, in general, better than that of other cities and countries. The performance of Tokyo is outstanding. In recent years, especially after 1990, the performance of Tokyo has worsened slightly mainly due to the slowing down of the economy and the inability to cut down on CO_2 volume. In Tokyo, economic recession has not reduced emissions significantly because the share of the industrial sector in total CO_2 emissions is small. CO_2 per unit of economic activity in Seoul stagnated between 1990 and 1997 but



Source: Internal database compiled from statistical yearbooks

Figure 4.4 CO2 emissions per capita and per unit of GRP/GDP (in log-log scale)

CO_2 per capita increased. Beijing and Shanghai's CO_2 performance in terms of economic activity is improving rapidly. Reducing CO_2 emissions per capita seems to pose a major challenge to cities, all of which have clearly failed in that pursuit.

In deriving the per capita CO_2 emissions used in Figure 4.4, the daytime population was considered. However, studies report that 33% of the workforce of Tokyo commutes from outside Tokyo[12]. The ratio of the daytime and nighttime populations in Tokyo and Seoul were 1.25 and 1.04 respectively in 1999 (Yoon and Araki, 2002). Should commuting populations be included in per capita estimates, the performance of Tokyo would improve further (not shown in figures here). Since Tokyo is already operating at a relatively high level of performance, it may be able to serve as a model for rapidly developing mega-cities, particularly cities in Northeast Asia. Though every city grows differently and, in reality, no city can serve as a complete model for another, suitable elements can be utilised.

Tokyo is different from other cities as it belongs to Annex I countries in Kyoto Protocol. Accordingly, the responsibility for future CO_2 emission reductions by Tokyo may be higher than other cities due to its anticipated contribution towards meeting Japan's Kyoto commitment (reducing emissions by 6% of the 1990 level). Since Russia's recent ratification, the Protocol will enter into force and Tokyo may be further required to take specific steps to reduce CO_2. Already, bottom-up modellers have demonstrated that significant reductions in Tokyo are possible with different technological measures (Hanaki, 2002). If these measures are implemented in the future, Tokyo's performance in Figure 4.4 might improve further.

Despite the fact that these four cities have yet to converge in terms of per capita emission, they are converging in terms of per capita energy consumption, as Figures 4.5 and 4.6 show. The structure of energy use, therefore, clearly plays a very important role in the profile of emissions. Tokyo and Seoul, in particular, seem to converge in emissions, while emissions in Shanghai are rapidly growing. As it is less industrialised than Shanghai, per capita emissions in Beijing are growing at a slower rate than they are in Shanghai.

12 TMG: TDM Tokyo Action Plan. Tokyo Metropolitan Government, Tokyo, 2000.

4.6 Factors Contributing to CO_2 Emissions in the Past

The factor decomposition method is a widely used tool for determining the relative contributions of various factors toward CO_2 emissions. In this section, CO_2 emissions have been decomposed into four factors: carbon intensity effect, energy intensity effect, income effect and population effect.

Economic activity, or the income effect, was the major driving force behind the changes in CO_2 emissions in Seoul during periods of economic growth as well as economic recession. In Tokyo, economic activity was responsible for the majority of emissions in its period of rapid growth, but its contribution toward reducing emissions in the economic recession was smaller (see Figure 4.7). Tokyo experienced an economic recession after the so-called bubble burst in the late 1980s, while Seoul experienced an economic collapse in 1997 (see Figure 4.7).

The carbon intensity effect indicates the effect of fuel choices on emissions: movement up the fuel ladder to cleaner fuels results in lower emissions. In Tokyo, though carbon intensity effects and population effects were responsible for slightly increasing emissions in the 1970s and

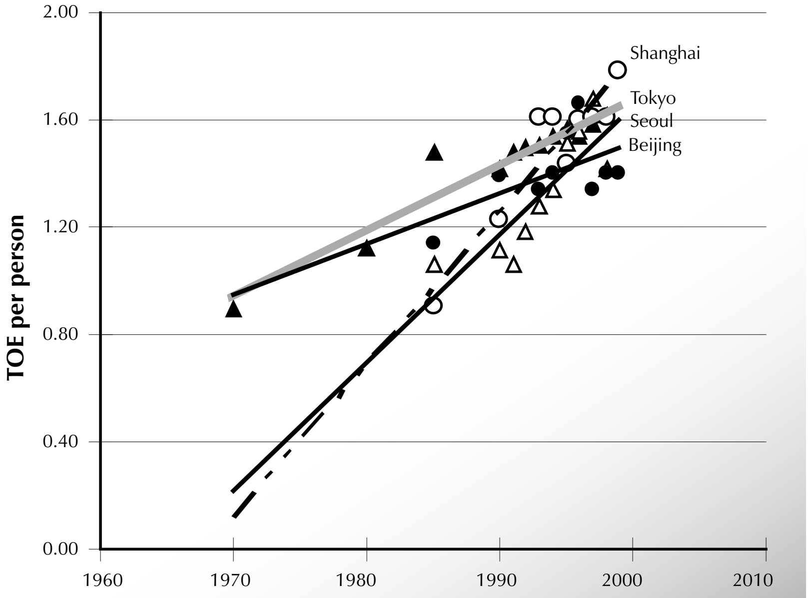


Figure 4.5 Trend of per capita energy consumption

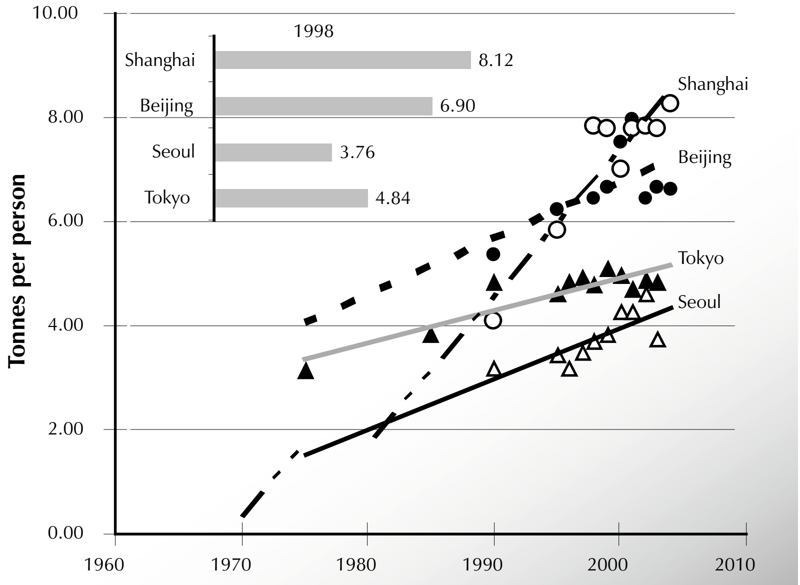


Figure 4.6 **Trends of per capita CO_2 emissions consumption**

1980s, their contribution was negligible in the 1990s. In Seoul, however, the carbon intensity effect was responsible for reducing a large amount of emissions during its period of rapid growth (1990-97), but its contribution was negligible in the recession of 1997-98. Shifting the structure of energy consumption from coal to oil and electricity is a major reason behind the positive contribution of carbon intensity (The share of coal decreased from 28.8% in 1990 to 1.3% in 1998 (KEEI, 1998).)

Energy intensity, which indicates the direction of technological changes and structural shift of activities, was responsible for the reduction of emissions by large amounts in Tokyo during the period of economic growth. During the recession, however, it had the opposite effect. The role of the energy intensity effect in Seoul was the reverse: it produced a negative effect (increased emissions) during the period of economic growth but had a substantive positive effect (reduced emissions) in the economic recession of 1997-98.

The income effect seems to be responsible for the reduction in CO_2 emissions in Tokyo in the 1990s. The contribution of energy intensity toward reducing emissions has decreased over time in Tokyo since the

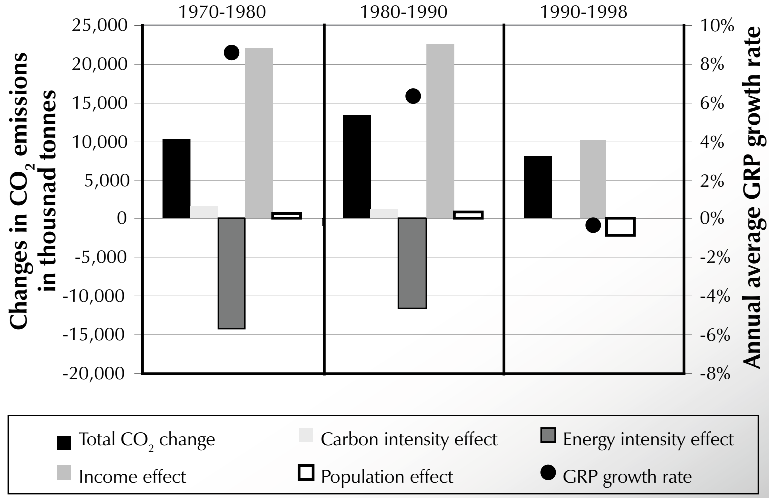


Figure 4.7A Factor decomposition of total CO_2 emissions from various energy uses in Tokyo

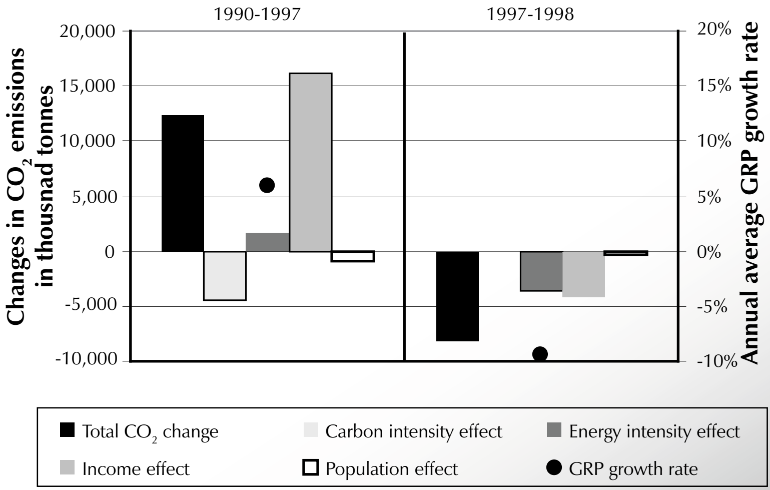


Figure 4.7B Factor decomposition of total CO_2 emissions from various energy uses in Seoul

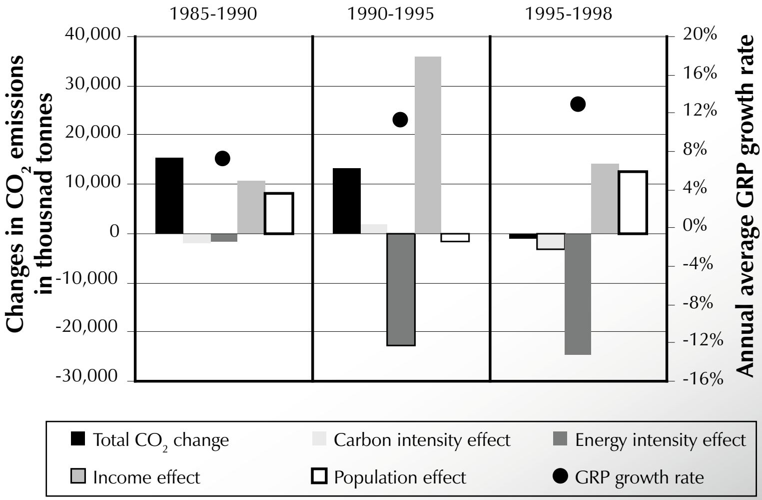
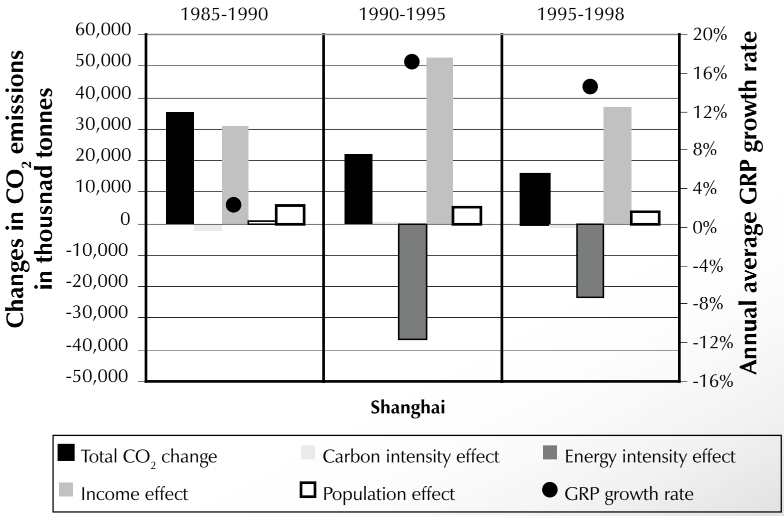


Figure 4.7C Factor decomposition of total CO_2 emissions from various energy uses in Beijing



Source (for all figures in 4.7): Dhakal S., S. Kaneko and H. Imura (2003). CO_2 emissions from energy use in East Asian mega-cities: Driving factors, challenges and strategies. Proceedings of IGES/APN International Workshop on Policy Integration towards Sustainable Energy Use for Cities in Asia, 4-5 February 2003, East West Center, Honolulu, Hawaii.

Figure 4.7D Factor decomposition of total CO_2 emissions from various energy uses in Shanghai

early 1970s; in fact, it was responsible for a major increase in CO_2 emissions in the 1990s.

Due to unprecedented economic growth, it is obvious that the income effect is the major factor behind increasing emissions in Beijing and Shanghai, while energy intensity was the major factor behind the reduction of emissions after 1990. Increasing productivity and improvements in energy efficiency might be responsible for these effects. Since coal continues to dominate the energy sector, CO_2 emission benefits from the carbon intensity effect are evident only after 1995, when fuel switching began. The role of the population effect is small in Shanghai but in Beijing it contributes significantly (this could be due to change in the political boundary).

In the transportation sector (not shown in any figures, see Dhakal *et al.* 2003), the number of vehicles is responsible for the majority of CO_2 emissions in all four cities. In Seoul, the vehicle utilisation effect (travel demand per vehicle) was primarily responsible for reducing emissions, but in Tokyo, it was the energy intensity effect which was primarily responsible.

In the residential sector (not shown in any figures, see Dhakal *et al.* 2003), the effects of contributing factors to CO_2 emissions are different for Tokyo and Seoul, primarily due to differences in building heating and cooling systems and fuel switching. In Tokyo, most emissions from the residential sector are attributed to the household income effect, unlike the scale effect (household population effect) operational in Seoul. Similarly, in Tokyo, the energy intensity effect is responsible for reducing emissions, but in Seoul, the fuel quality and income effects are responsible. In Beijing and Shanghai, carbon and energy intensity effects contributed to the reduction of emissions, while income and household population effects were mostly responsible for increasing emissions from 1985 to 1990. In Shanghai, unlike in Beijing, the volume of emissions, under the influence of energy intensity effects, actually increased from 1995 to 1998.

In the commercial sector in Tokyo and Seoul (not shown in any figures, see Dhakal *et al.* 2003), the labour productivity effect is dominant in increasing CO_2 emissions during periods of rapid growth periods and the energy intensity effect is key in reducing CO_2 emissions. In Beijing and

Shanghai, the energy intensity effect contributed to reducing emissions only in the period from 1990 to 1995. The labour productivity effect contributed to increasing emissions in the 1990s (less labour but more machines and energy).

Decomposition analyses need to be interpreted with caution. For example, the energy intensity effect of transportation resulted in changes in CO_2 emissions in transportation that could have resulted solely from changes in gross energy consumed per unit of passenger travel demand while keeping all other decomposed factors constant. Such changes are speculative in nature and must be closely co-related with actual policies and situations to yield correct interpretations.

4.7 Indirect CO_2 Emissions Embedded in Material Consumption[13]

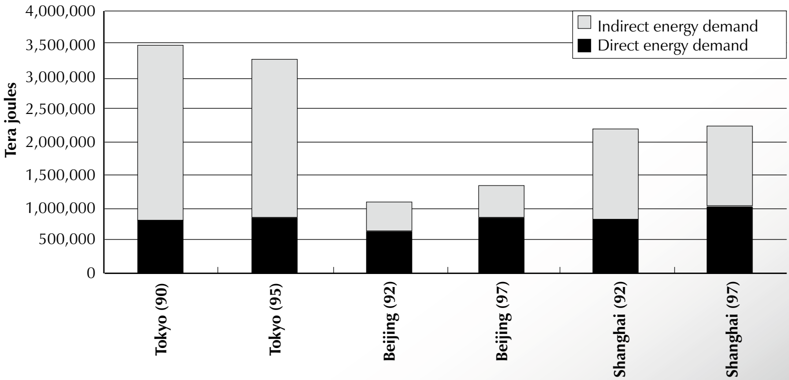
To minimise the contributions of cities to global environmental change, reductions in direct emissions alone are not enough. The consumption of large amounts of material goods by cities has an indirect effect on places outside cities where manufacturing and resource extraction take place. Since, on a global scale, it does not matter where emissions originate, cities should be judged by their contributions to the total environmental load. The impact of indirect emissions embedded in the consumption of goods could, in fact, be large enough to outweigh the impact of direct emissions. A similar concept is now being used while analysing other sectors, such as water use. "Virtual water" is a term commonly used by professionals who seek to reduce water use in cities.

An I-O table-based estimate of indirect energy demand shows interesting results for Tokyo, Beijing and Shanghai. In Tokyo and Shanghai, indirect energy demands are more significant than direct energy demands (see Figure 4.8).

A city does not always consume material goods; it also supplies them in the form of exports. The relationship between the direct and indirect energy consumption for which a city is responsible differs from city to

13 Indirect energy and emission analyses were principally carried out in collaboration with Dr. Shinji Kaneko.

city depending on its scale of industrialisation and type of industries. The CO_2 emissions for which a city is responsible are those which are emitted as a result of direct emissions plus the net value of CO_2 emissions embodied in material goods that are consumed in a city after subtracting exported material goods. Table 4.2 shows that indirect emissions in Tokyo surpass emissions, while Tokyo is responsible for about 68% of the total emissions.



Source: *Kaneko S, H. Nakayama and L. Wu (2003). Comparative study on indirect energy demand, supply and corresponding CO2 emission of Asian mega-cities. Proceedings of IGES/APN International Workshop on Policy Integration towards Sustainable Energy Use for Cities in Asia, 4-5 February 2003, East West Center, Honolulu, Hawaii.*

Figure 4.8 Direct and indirect energy demands of selected cities

Table 4.2 Direct and indirect CO_2 emissions in selected Asian cities

	Tokyo		Beijing		Shanghai	
	1990	1995	1992	1997	1992	1997
Total emissions (1990 Tokyo as 1), direct and indirect	1	0.9	0.5	0.4	1.2	0.98
Share of indirect emissions, %	78	71	50	43	66	49
Share of responsible emissions in total emissions %	68	72	96	82	69	80
Responsible emissions (1990 Tokyo as 1)	1	1	0.7	0.5	1.2	1.1

The figures in this table are preliminary estimates based on I-O table analyses. The figures should be taken as indicative only.

In earlier sections, we showed that the emission volumes of Beijing and Shanghai are 1.4 and 2 times that of Tokyo, respectively. If indirect emissions are accounted for, however, it is clear that Tokyo's contribution to CO_2 emissions has greatly underestimated (see Figure 4.9).

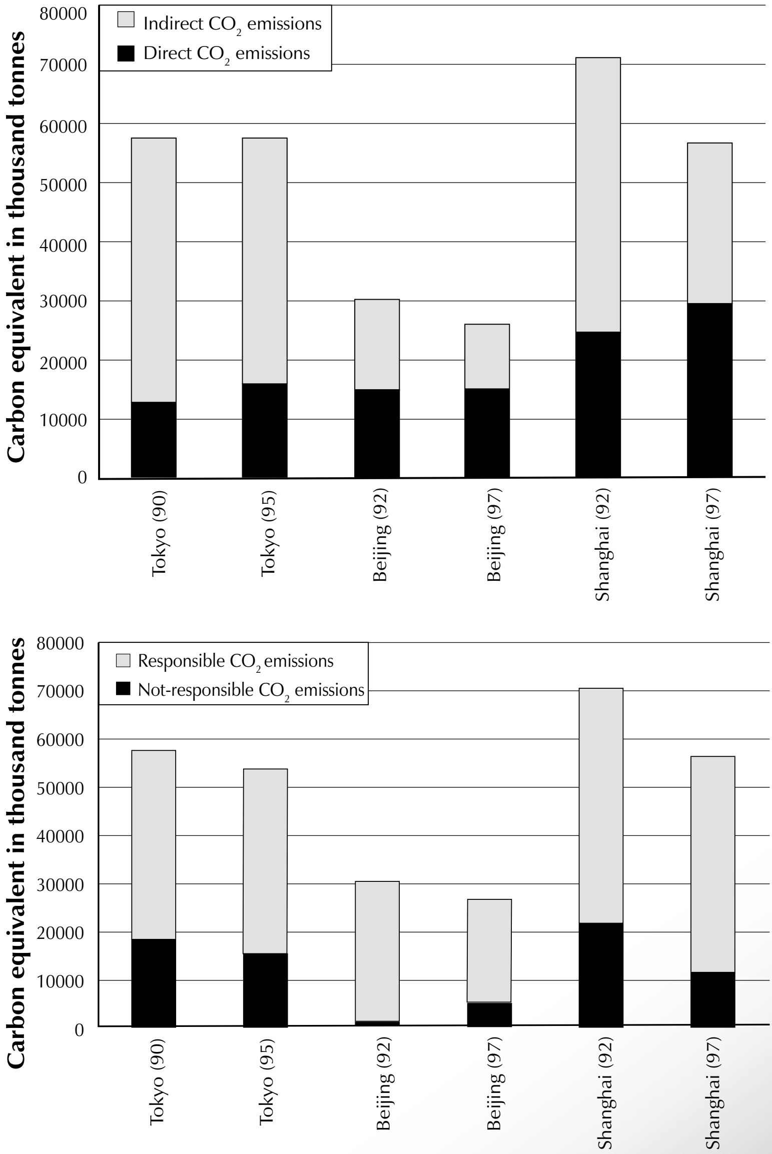
4.8 Sectoral CO_2 Emissions and Future Scenarios

Road transport

Bottom-up modelling for energy use and CO_2 emissions for road transportation in all four cities reveal interesting results.

- The number of vehicles in Beijing and Shanghai is as few as one-tenth the number in Tokyo, but their total fuel consumption is one-third to one-half that of Tokyo because of lower fuel efficiency and greater mileage of vehicle travel.
- Growth in the number of vehicles in Tokyo and Seoul is slow and structural changes in vehicle composition are few.
- The relatively small number of vehicles in Beijing and Shanghai emitted a relatively large amount of pollution (in 2000).
- The contribution of light-duty gasoline vehicles to emissions is expected to rise dramatically in Beijing and Shanghai in the future.
- In Beijing, oil consumption in road transportation is expected to increase 2.4 times between 2000 and 2020; oil consumption in Shanghai is to double[14] (Figure 4.10).
- Even if all the expected measures (see footnote 15) are implemented—and that may be the wishful thinking of policy makers—future emissions of CO_2 from urban transportation in these cities will still be tremendous. Figure 4.11 shows that the absolute volume of emissions is far from decreasing. In the case of Tokyo, it considers only the number of vehicles, which will soon be saturated; then, gradual improvements in energy performance will reduce emissions. Other factors such as structural changes towards larger-sized engines, which

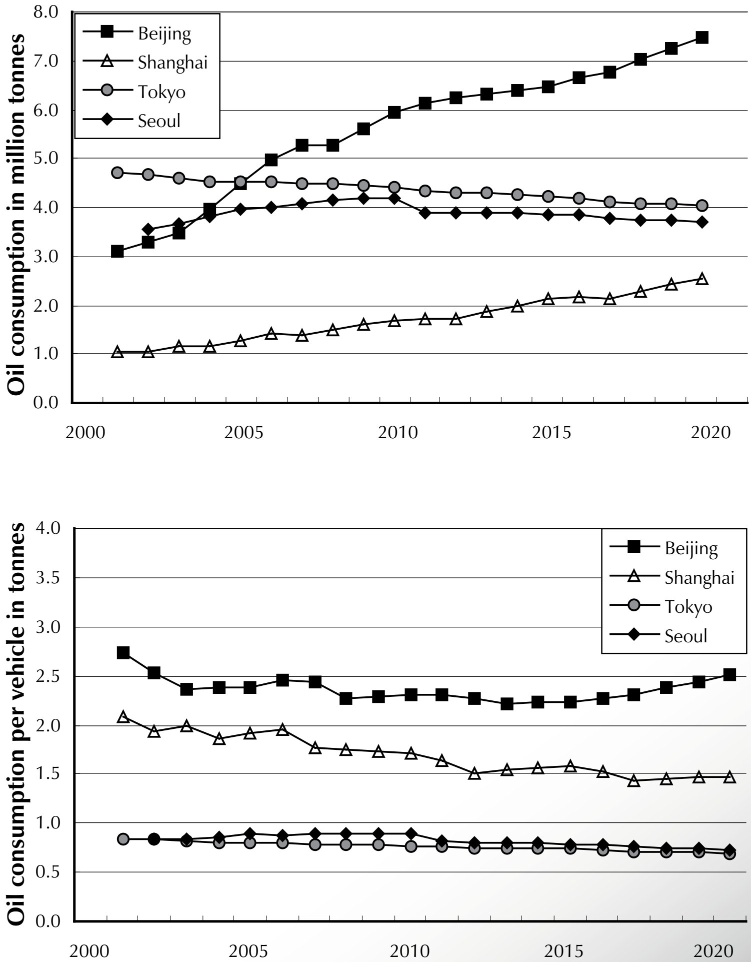
14 Beijing and Shanghai: Progressive implementation of EURO 2, EURO 3, EURO 4 and EURO 5 in 2003, 2005, 2010 and 2015, respectively, for new vehicles; controlling the emissions of in-use vehicles strictly; full shift to CNG buses and taxies by 2020; 200 km of urban railway; increase in vehicle speeds, etc.



Source: *Kaneko S, H. Nakayama and L. Wu (2003). Comparative study on indirect energy demand, supply and corresponding CO2 emission of Asian mega-cities. Proceedings of IGES/APN International Workshop on Policy Integration towards Sustainable Energy Use for Cities in Asia, 4-5 February 2003, East West Center, Honolulu, Hawaii.*

Figure 4.9 CO_2 emissions in selected Asian cities

is Tokyo's present trend, are not included. The aim of this figure is to show the speed with which CO_2 emissions from cities, especially Beijing and Shanghai, might increase.



Source: *Commissioned report prepared by Dr. Kevin He for this project*

Figure 4.10 Oil consumption of road transport

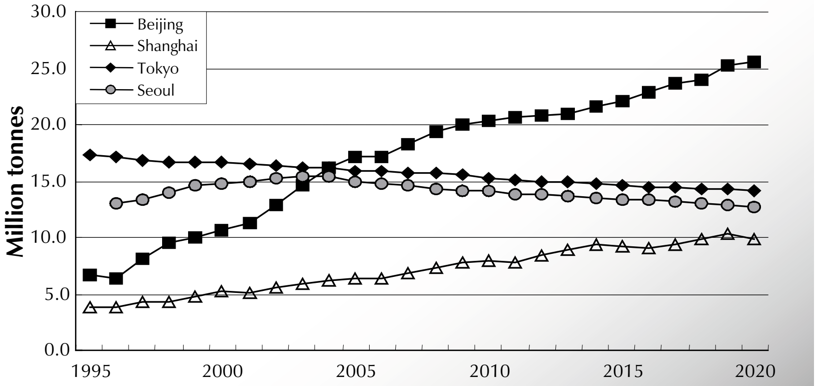


Figure 4.11 CO_2 **emissions from road transportation (indicative only)**

Households and businesses

The residential CO_2 emissions of Beijing are expected to surpass those of the other three cities in the future, while Shanghai is likely to catch up Tokyo[15]. Changing lifestyles[16] and improving appliance efficiency[17] are measures that could reduce the maximum volume of emissions in Tokyo. In the commercial sector, the emission volume of Shanghai is expected to increase drastically. Stabilising the absolute volume of emissions is likely to be a very difficult task in Tokyo and Seoul as CO_2 emissions from residential households and commercial sectors are already saturated; although emissions are not increasing greatly, reducing them will not be an easy task. Japan has committed itself to the Kyoto Protocol, which calls for reducing reduce GHG emissions by 6% of the 1990 level. Large cities such as Tokyo play a key role in any effort to reduce global emissions; stabilisation alone will not be enough.

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15 From the work of Dr. Toru Matsumoto commissioned for this study.

16 Promotion of energy-conservation in residences, such as switching off unnecessary lights, efficient use of heating and cooling equipment, etc. (An attitude survey conducted by the by Japanese government suggests that 16% of total energy consumption can be saved by such conservation behavioural factors).

17 Efficient air conditioning devices (compressor improvements, heat exchangers, intelligent control), refrigerators (conversion of DC motors, better insulation, door gaskets, inverter-technology), efficient lighting and improved standby power.

4.9 Waste Treatment Methods and Utilising Waste Heat for District Heating[18]

As discussed earlier, the volume and composition of waste and its method of disposal have a key impact on GHG emissions. In Tokyo, 18 incineration plants operated by the Bureau of Waste Management of the Tokyo Metropolitan Government have been processing about 87% of post-recycled and 100% of Bureau-collected wastes since 1998. In Seoul, only 5% of the total waste is incinerated, but Seoul had 27 incinerators with a total capacity of 52,957 kg per hour in 1999 (with the exception of the incinerators in Yangchun and Newon, all are small). The utilisation of the waste heat and steam from the incinerators in other services such as district heating could play an important role in reducing GHG emissions. In Tokyo, heat generated from incinerators at Ohi, Hikarigaoka and Ariake plants is supplied to Tokyo Heat Supply Co., Ltd., and the Tokyo Seaside Heat Supply Co., Ltd., for heating and cooling cultural centres, citizen halls, and sports centres in neighbouring areas. Steam from the incinerators is converted into electricity and sold to Tokyo Electric Power Co., Ltd. In FY 1996, 690,980,000 Kwh of energy was generated, 45% of which was sold at a total value of 2.69 billion yen in 1996 (TMG, 1999).

Using IPCC-recommended methods, the author carried out a study comparing the utilisation of waste heat for running district heating systems with its utilisation for operating a LNG-based centralised system. The Newon incineration plant in Seoul (1999: capacity 33,333 kg/hour; treatment amount 79,936 tons; construction cost 64,666 million won; 1,200 won = US$1) was contrasted with the Minato incineration plant in Tokyo (capacity 600 tonnes/day). The reduction in CO_2 emissions and possible benefits from Clean Development Mechanism (CDM) at the rate of US$50/tC are estimated as is given in the table 4.3.

The results above are not detailed, but, as intended, they do show that GHG benefits from such utilisation should be an important consideration, especially since CDM and emission trading are emerging as a tool to facilitate the reduction of GHG emissions. The cost and viability of district heating depends on a number of factors, including the matching of supply and demand.

18 This research was carried out in collaboration with Dr. Eui-Yong Yoon.

Table 4.3 Comparison between two incineration plants in Seoul and Tokyo respectively

	Newon plants, Seoul		Minato plant, Tokyo	
	Utilising waste heat directly	LNG-based boiler for centralised heating	Utilising waste heat directly	LNG-based boiler for centralised heating
LNG (toe)	211	10,589	105	3,215
Total GHG in tC equivalent[a] (emitted from waste input[b])	134 (14,983)	6,800	67 (52,654)	2,064
CDM gains (with US$ 50/tC)	US$ 333,300		US$ 99,850	

[a] Including CO_2, CH_4 and N_2O

[b] This is excluded because this carbon will be emitted anyway for treatment whether heat is extracted or not

Source: Work carried out by Dr. Eui-Yong Yoon for the project.

The utilisation of gases from landfill sites, especially methane, could also be a viable option for reducing emissions and is of special concern to Seoul, Beijing and Shanghai, which rely more on landfills than incinerators.