Chapter VI

Policy Research on Energy Efficiency and Urban Development[1]

6.1 Energy Efficiency and Urbanization: Concepts and Methodology

6.1.1 Fundamentals in urban consuming sectors

6.1.1.1 Moderating energy consumption is a key issue for sustainability and economic development

The Kyoto Protocol objectives and, more recently, the constraints on energy supply have enhanced the priority given to energy efficiency policies. Almost all Organization for Economic Cooperation and Development (OECD) countries and an increasing number of non-OECD countries are implementing new or renewed energy efficiency instruments adapted to their national circumstances. Besides the pre-eminent role of market instruments such as voluntary agreements, labels, and information dissemination, regulatory measures also are widely implemented where the market fails to give right signals, such as with buildings and appliances.

In less developed countries, moderating or decreasing energy consumption is an important issue, but often with different driving forces compared to industrialise countries. In these countries, the need to reduce greenhouse gas (GHG) emissions and local pollution is probably less of a priority; alleviating the burden of oil imports, reducing energy investment requirements, and making the best use of existing supply capacities to improve access to energy are more important issues.

With the steep rise in oil price since 2003, the cost of oil imports has soared, with severe impacts on the economic growth of the world's poorest countries[2]. Any efficiency improvement in the oil consuming sectors will result in direct benefits in the balance of trade.

Moderating or reducing energy consumption, for instance, in electricity use, will have two benefits:

(1) Supplying more consumers with the same electricity production capacity, which is often the main constraint of many countries

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1 This Chapter is based on the research analysis of the Task Force on Energy Efficiency and Urban Development (Transportation and Building Sector). Task Force Co-chairs: Jiang Yi, Zhou Wei Laurence Tubiana; Task Force Members: Mao Qizhi, Li Qiang, Qi Ye, Jiang Yulin, Jiang Kejun, Bertrand Château, Albert Bressand, Shobhakar Dhakal, Nick Eyre, Lucienne Krosse, Partha Mukhopadhyay.

2 Almost a tripling between the beginning of 2003 26 US$/bl for the Brent) and August 2006 (73 USD/bl); since then the price is around 60 USD/bl, which is still twice higher than in 2003.

in Africa and Asia;

(2) Reducing the investment needed for the expansion of the electricity sector; this is especially important in countries with a high growth in electricity demand, such as China and many South East Asian countries.

6.1.1.2 Moderating or reducing energy consumption

Moderation or reduction in energy consumption can be achieved not only through technological improvements, but also through moderation in the needs for energy services or through better organization and management along with improved economic conditions in the sector, also known as "non-technical factors".

In some cases, because of financial constraints due to high energy prices or low income, consumers may decrease their energy consumption through a reduction in their standard of living, such as a reduction in heating temperature of car use. Such reductions, if not supported by changes in peoples' aspirations, are highly reversible.

Moderating or reducing energy consumption is, first of all, a matter of individual behavior and reflects the rationale of energy consumers. Avoiding unnecessary consumption of energy or choosing the most appropriate equipment to reduce the amount of the energy consumed contributes to decreasing individual energy consumption without decreasing individual welfare.

Avoiding unnecessary consumption is certainly a matter of individual behavior, but it is also, a matter of appropriate equipment: thermal regulators for room temperature and automatic switch-off lights for hotel rooms are good examples of how equipment can reduce the influence of individual behavior. But, similarly, the ability of individuals to reduce unnecessary consumption depends on the technical context where they live and move: badly insulated homes heated to 15°C in winter may consume a lot more energy than a similar home that is very well insulated and heated to 20°C; people can rely on public transportation rather than on cars for getting to work only if public transportation networks are available close enough to their home.

Moderation or reduction of energy consumption based on technical support proves to be long-lasting: a well insulated building built today will still be there in 50 years from now and will still generate low energy consumption at that date.

Moderation or reduction of energy consumption based on behavioral support does not provide any guarantee to remain active after some years: The increase in incomes or globalization through the internet and all kinds of media may result in behavioral changes in the wrong direction with regard to energy efficiency.

6.1.1.3 This is a policy issue

Any cost-related decision concerning energy consumption reduction at the individual level, is based, more or less, on a trade-off between the immediate cost and the future decrease in energy expenses expected from lower consumption. The higher the energy price is, observed or expected, the more attractive the energy efficient solutions are.

Making the "good" investment decision for domestic appliances or industrial devices, from the energy consumption moderation viewpoint, certainly relies on a sound economic rationale. Good price signals are necessary.

In market economies, where most energy prices to final consumers are unregulated, prices normally reflect the supply costs fairly accurately and are the main drivers of individual's behaviour regarding energy needs. However, for several reasons, prices often reflect only a part of the overall costs of fuels and electricity. They include none or few environmental externalities and long run marginal development costs.

As a result, behaviors that regard the needs for energy services and decisions made by final consumers when purchasing equipment or making an energy efficient investment, such as the retrofitting of dwelling, are rather far from global economic optimisation, thus creating a gap between actual energy consumption and what could be achieved through an accurate price system accounting for all costs involved.

Taxation is the usual means used by governments to reduce or suppress such price distortions at the consumer level. In that sense, taxation is always complementary to energy efficiency policies and measures. It is hardly just a component of these policies and measures, however, because of its much broader socio-economic aspects, but it certainly determines the effectiveness of such policies and measures.

6.1.1.4 Measuring energy consumption moderation

China is confronted with two major challenges related to energy:

(1) A rapid increase of imports of hydrocarbons is likely to raise severe and growing security and socio-economic concerns.

(2) A rapid increase in the emissions of pollutants and GHG related to energy is likely to raise severe and growing internal health concerns, social unrest, and growing foreign pressures.

Energy consumption moderation or reduction, as appraised by this task force, has to be placed in to this context and more generally in the context of sustainable socio-economic growth in China. This means that improving energy efficiency in cities in China has two main targets:

(1) Decoupling the demand for hydrocarbons from economic development and welfare improvement.

(2) Decoupling the emissions of pollutants and GHGs from economic development and welfare improvement.

Insulating a house makes it more energy efficient from an engineering point of view: less energy is consumed for the same comfort. But this technical improvement at the micro-level may be not visible at the macro-level, that is, the whole stock of dwellings, if, at the same time, more houses are built, dwellings are larger, and/or more appliances are used.

Energy efficiency is not just a technical matter, it is also a matter of efficient services: Making a phone call instead of paying a physical visit, using public transportation instead of a car to go to work, recycling bottles, reducing the heat at night and using timber instead of concrete for house construction all result in a decrease in energy consumption for identical or very similar services. Again, such improvements may exist at the micro-level but may not be directly visible at the macro-level. Assessing energy efficiency also means measuring the overall impact of all the improvements at the micro-level on the evolution of total energy consumption.

Of course, assessing energy efficiency from a policy view point does not mean reviewing each particular dwelling or factory, but rather, it means estimating or measuring how far all these improvements at the micro-level went to contribute to the actual evolution of energy consumption in the various sectors and for the whole country. This is the role of energy efficiency indicators, such as those developed in Europe (ODYSSEE), by the World Energy Council (WSC) or by the International Energy Agency (IEA).

In order to calculate such indicators, the prerequisite is to have detailed data on energy consumption per sector and per end-use.

6.1.2 Urban design and planning and energy consumption moderation

6.1.2.1 General concept

Moderating or reduce energy consumption in Chinese cities in relation to sustainability issues has three major meanings, according to the three main dimensions of sustainability:

(1) From an economic viewpoint, it means: 1) minimizing the energy bill of the Chinese urban citizens of a given standard of living; 2) minimizing the energy bill of China, in particular with regard energy imports.

(2) From an environmental viewpoint, it means: 1) improving the living conditions in cities—air quality, noise, and congestion; 2) minimizing GHG emissions of a given standard of living for the Chinese population.

(3) From a social point of view, it means: 1) favoring appropriate conditions for life styles and aspirations (standard of living) which minimizes energy needs for a given income: 2) reducing inequalities with regard to living standards.

There are two main levels where energy consumption moderation or reduce issues in cities should be tackled:

(1) The level of the urban citizen, both in her current living conditions and in his urban mobility, by minimizing her energy bill while increasing her living standard. It is both a matter of technology and of behavior and life-style.

(2) The level of the city as a whole by providing a spatial and functional organization of the city that is likely to minimize the needs for energy services and providing these energy services in a way that minimizes the requirement of imported energy and minimizes environmental impacts, both at local and global levels.

6.1.2.2 Energy consumption moderation or reduction in buildings and construction

(1) A technical perspective

From a technical perspective, energy consumption in buildings and construction can be moderated or reduction by three means:

1) The architectural and technical characteristics of the building itself, such as insulation, passive solar radiation, and exposure to the wind.

2) The technical performance of the appliances inside the buildings, in particular in relation to the heating and cooling demand

3) The supply of solar energy through dedicated panels on the building

Existing buildings offer much fewer possibilities for improving the technical efficiency than new constructions due to few possible modifications of architectural components, reduced possibilities for insulation and recourse to solar energy, and more constraints for changing the heating/cooling system. Among existing buildings, possibilities for improving energy efficiency also strongly depend on factors including the age of the building, its size, and its location.

(2) Behaviors and life styles

Behaviors and life-styles are likely to impact strongly the energy consumption of buildings, as shown in various surveys. Two aspects are particularly sensitive from this point of view:

1) The perception of comfort, for example, which inside temperature is desired in winter and which in summer.

2) The indoor management of energy requirements, for example, differentiating inside temperature requirements according to the various parts of the dwelling, according to the time of the day.

Moderating or reducing energy consumption, from this point of view, is not a matter of frustrating people, but of making them more responsible for their indoor management, including with the technical assistance of an efficient climate management systems, and of convincing them that overheating or overcooling may be just the contrary of comfort.

6.1.2.3 Energy consumption moderation or reduction in urban transport

(1) Technical perspectives

From a technical perspective, moderating or reducing energy consumption in urban transport has two main dimensions:

1) The technical performance of the vehicles used for urban transport.

2) The use of an energy type with fewer impacts on energy imports and on the environment.

The technical performance of vehicles is both a matter of engine and power-train efficiency and of vehicle size and power. Very few things can be done to improve the technical efficiency of existing vehicles, but a lot can be done for new vehicles as compared to the existing ones.

Biofuels and electricity are the most important options for reducing energy imports and the local environmental problems created by urban vehicles. However, attention should be brought to how biofuels and electricity are produced and how they affect global environment.

(2) Behaviors and lifestyles

There are three major aspects in this regard:

1) For those who purchase a car, the characteristics of the car purchased, including size, power, and energy.

2) For those who own a car, the decision to use it or not according to the travel type and purpose, and how the car is used, in-

cluding load factor, and driving attitude.

3) For all, the use of "soft" modes, such as walking or bicycling, according to travel distance.

Average characteristics of a car purchased are strongly related to the communication of car manufacturers and vendors for selling cars and to fiscal dispositions regarding cars. Modal choices are partly constrained by the availability of transportation alternatives such as public transport and bicycle lanes, but also depend on social and cultural habits that can be influenced. For example, the bicycle may be perceived either as an old-fashioned means for poor people or as a new-fashioned means for modern people. For those who own a car, this choice also depends on the conditions for the use of cars, including tolls, parking availabilities, and fees.

6.1.2.4 Energy efficient urban design

(1) Heat density and heat supply

Among the three dimensions to be investigated with regards to efficient heat supply, the three factors are the geography of the city, its population, and its average heat density, since these characteristics impact directly the cost-effectiveness of the district heating systems. From this viewpoint, energy efficient urban design is both a matter of existing size and layout of the city and a matter of its future expansion. Since the existing size and layout are given, there are two main issues regarding energy efficient urban design:

1) The efficiency improvement of the heat supply in existing buildings.

2) The design of the future expansion of the city so as to minimize the cost of efficient heat supply services.

Concerning this second aspect, two main concepts are worth investigating:

1) Creating high heat density areas within high population density areas—a concentration of high buildings— in order to minimize the cost of district heating systems per dwelling.

2) In sunny regions with a lot of available space, favoring passive solar heating in highly insulated, low buildings.

(2) Population density, urban functionalities and mobility supply

Providing energy efficient mobility services raises the question of the allocation of the city space for transportation among competing infrastructures, such as allocating road space to cars versus for public transportation lanes versus as dedicated lanes for "soft" modes. This is a matter of existing size, geography and layout of the city and a matter of its future expansion. There are, therefore, two main issues regarding energy efficient transportation:

1) The possible reallocation of part of the street network in the existing part of the city for bus lanes, tramways, and "soft modes".

2) The energy efficient urban design of future expansion of the city.

An energy efficient urban design from the mobility viewpoint tries first to minimize the transport demand for daily mobility. This is a matter of appropriate zoning with provisions of goods and services close to the housing areas to minimize the distances to go to work, to school, and to shopping areas, etc. Second, it aims at creating appropriate conditions to make quality public transportation economically viable, in particular locating high transport demand at quality public transportation nodes, that are easily accessible by foot and bicycle.

For car owners, the attractiveness of public transportation is mostly a matter of availability and time spent in transportation as compared to using car. This is why public transport on separated, dedicated routes, like metro, light rail, or bus lanes, proves to be a much more attractive alternative than normal buses are. These require much more expensive infrastructures and equipment that just buses on normal streets, but they prove to be more cost-effective for the city if the passenger traffic is high enough. Passenger traffic is a matter of the population of the city and the concentration of traffic flows, which in turn is a matter of population density and functional layout.

6.2 Review of Situations and Trends of Energy Consumption and Energy Efficiency in Urban Areas in China and Worldwide

6.2.1 Introduction: characteristics of China's urbanization

Thirty years have been passed since China's Reform and Opening. During these years, China's urbanization is keeping a fast, increasing pace. The urbanization level was 17.92% in 1978, but reached 44.94% in 2007, an annual increment of more than 0.9%. If the increase in rate is stable, the urbanizing level in China will become 48% in 2010, reach the world average urbanization in about 2030, and synchronize with the world's increasing urbanization pace during the period of 2030-2050.

Between 1990 to 2005, China's urbanization level increased from 26% to 43%. The urbanization level is uneven between different places. On the top are Shanghai, Beijing, and Tianjin, which have rates above 70%. Next are Guangdong, Zhejiang, Jiangsu and the three provinces in northeast, whose rates range from 50% to 60%. Last are Guizhou, Yunnan and Xizang, with rates lower than 30%. Other places' urbanizing rates range from 30% to 50%. As can be seen, most places in China are still in the developing stage of urbanizing.

Accompanied with the fast pace of urbanizing, the per capita building area is increasing. According to the statistical data, the current urban floor area per capita of China is nearly 30 m^2, which exceeds the corresponding index of Hongkong and is close to the average of Japan and Singapore, about 36 m^2; the index of some provinces and cities even exceeds those of Japan and Singapore. But, as a whole, the floor area per capita of China is far lower than that of USA and Europe. However, in the recent 15 years, the urban building floor area doubled every 7 years and more than 1 billion m^2 of buildings were constructed every year. If 1 billion m^2 of buildings are built and the urban population increases 15 million every year, the urban floor area per capita of China will reach 42 m^2 and will be close to the European level. The total energy consumption for building operations will certainly increase with the increase of building scale. If the urban building scale increases one time, the building energy consumption will increase by one time or even more. Therefore, it is necessary to scientifically and reasonably control the urban construction scale and urban building scale and to control the urban building floor area per capita to be less than 35 m² and the new buildings constructed every year to be less than 0.7 billion m².

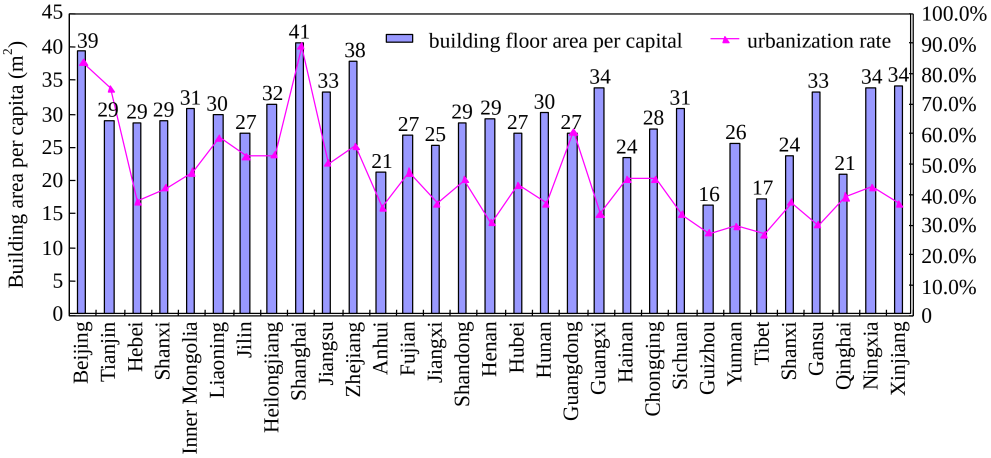


Figure 6-1 Building floor area per capita for each province or typical cities in 2005.

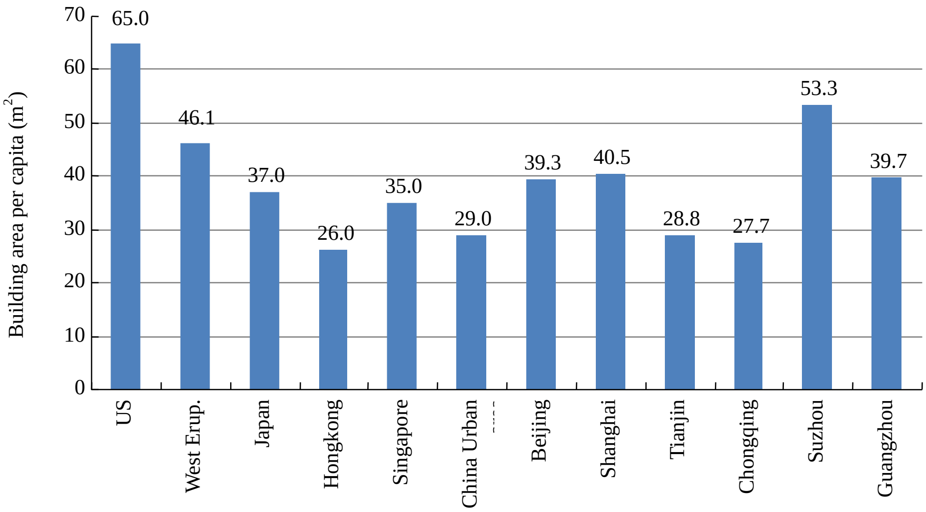


Figure 6-2 Comparison of per capita floor area with developed countries or areas in the world.

The population of cities in China will be increased to 77 million in the next five years, with average growth of more than 15 million. The concentration of such a large population into the cities directly and dramatically will increase the land of residences and various types of public infrastructure. However, the per capita building area will greatly affect city construction. For example, these are the city construction scope that can be found in three recent versions of the 11th Five-Year Plan development program proposal to the year of 2020:

Recently, 2 billion m^2 of city construction is being finished every year. At this speed, 10 billion m^2 of new construction will be built during the 11th Five-Year Plan. In 2020, 30 billion m^2 of building area in cities will be completed and at that time, there will be 45 billion m^2 of building area with 54 m^2 per capita.

Of the 2 billion m^2 of new construction, half will be in the cities. With this speed, in 2020, 15 billion m^2 of building area in cities will be completed and at that time, there will be 30 billion m^2 building area, with 35 m^2 per capita.

New construction area is 0.7-1 billion m^2 per year. With this speed, in 2020, up to 10 billion m^2 of building area in cities will be completed and at that time, there will be 25 billion m^2 building area, with 30 m^2 per capita.

Now that the development of city construction is fast gathering momentum, should China indulge and ride with a loose rein so as to reach or even exceed the first prediction above, or shall China bring the development under control?

As shown in Figure 6-2, compared to the data of some advanced countries and districts, the building area per capita and the domicile area per capita of China's cities are in the forefront. Even if there will be a 1.5 million increase in urban population per year coming from village immigrants, only 500-600 million m^2 of new buildings built each year will suffice to keep the building area per capita, and domicile area per capita will reach the level of advanced countries in Asia; if 1 billion m^2 of new building is built each year, then building area per capita will have reached the level of west Europe in 2025. If 2 billion m^2 of new building is built each year, then in 2030, the building area per capita will exceed the level of America. However, China is unable to reach the level of western Europe countries or America because it is beyond the capacity of China's land, resources, energy, and environmental conditions.

Moreover, not only does the fast urbanizing pace promote the development of the building industry, it also boosts the development of building material industry. Many materials used in buildings like steel, cement, and glass, are all industrial products that consume large amount of energy. The resources and energy consumed and the pollution emitted during the production process will reach a level unacceptable within society if building rates are unchecked.

Take the data of 2005 as an example. The 320 Mt of steel production this year consumed 224 Mt of standard coal, which equalled 11% of the China's merchandise energy consumption. Among the 320 Mt of steel, 150 Mt was used for building, which equalled 47% of the production. With the steel used in the railroad, highway, street, bridge and dam added, the steel used for construction equally 70% of the total. In addition to this, the large-scale production of plate glass, architectural ceramics, architectural plastics, and architectural non-ferrous metal material, and other building materials, also came with large energy consumption. Tentative estimate shows that these required 4%-5% of China's total merchandise energy consumption. According to this calculation, the direct or indirect energy consumption in building and transportation construction required a total of 20% of China's merchandise energy consumption during year 2005. If the construction scale was decreased to half of that, then the China's merchandise energy consumption can be reduced by 10%.

The overheated city construction has a close relationship with the social consumption idea and culture. In fact, from 2001, China showed a first sign of emphasizing the heavy industry development. Domains like steel, building construction materials, and real estate showed a high growth rate, which rarely was seen during the last 20 years. Gone, along with the vigorous market economy, are the unremitting improvements of the living standard and the continuous increment of consumer durable goods like housing, automobiles, or household appliances. The livelihood consumption pattern in China cities is advancing towards the direction of "high standard", "super-lavish" and so-called "international". As a whole, China's economy is entering the stage of heavy industry development, which is driven by the upgrading of consumer structure.

Consumer cultures employ high material consumption as one of the most important factors of self-aggrandizement. The upper class displays their identity and status with lavish consumption. China's society is in a special state of transition and the social units, including government officers, entrepreneurs, and ordinary citizens, resulted from the rapid changing of social structure learned from advanced countries without deep understanding. This will lead to dramatically increasing building energy consumption resulting from the high living standard and lavish building and architecture environments, such as big glass walls, maintained by the American building system. In addition, citizens admire the American car culture, even with the resultant traffic jams, heavy pollution and fuel bottlenecks.

In fact, after experiencing the horrific energy, economic emergency, and environment pollution problem in the last century, the western world is seriously rethinking the competing and lavish way of living of the last 50 years and new, healthy living campaigns have launched. Some people in the United States and Europe are voluntarily converting to a more spartan, low material consumption lifestyle. For example, they prefer clotheslines to driers, bikes and public transportation to cars, and open windows to air conditioners, not only because they are quiet, convenient for operating, fire-free, not noxious to ozone and climate, cheap to buy, and easy to repair, but also because they maintain a closer link to the natural environment.

6.2.2 Actual energy consumption of households in urban areas in major countries around the world

6.2.2.1 Energy consumption status in China and developed countries

Compared to other places in the world, China, as the biggest developing country, is still at a relatively low level of urbanization, and the energy consumption per capita is not high. However, China is accelerating its urbanization process and if no continual measure is taken during the process of high-speed economic growth, it will face the rigorous challenges of energy consumption and environmental destruction.

In industrialized countries, the share of building and transportation in total energy consumption has been growing steadily with the GDP per capita for the last 4 decades. In OECD countries as well as in the EU, energy consumption in building and transportation is, today, close to two-thirds of total energy consumption. If we just consider urban areas, the energy consumption in building and transportation is almost half of the total consumption of the country. The main drivers of these evolving patterns have been consumption patterns and urban sprawl, which are closely inter-related. This is a rising challenge for China that must be addressed today.

Table 6-1 Energy consumption statuses for building and transport sectors in developed countries.

	1971	1980	1990	2000	2005
OECD	54%	56%	61%	62%	64%
EU-25	48%	54%	59%	62%	64%

Sourse: Enerdate.

It is worth mentioning that during the 30 years of Reform and Opening, with the development of the economy and the improvement of urban function, China's tertiary industry proportion is increasing rapidly, the secondary industry proportion remains almost the same, and the primary industry proportion is decreasing. According to official announcements by the State Statistic Office in April, 2008, the proportion of the primary; secondary; tertiary industry in 2006 was 11.3:48.7:40.0.

In a nutshell, the secondary and tertiary industrial sectors in China are the leading industrial sectors of cities. What is more, in some parts of same provinces, the tertiary industry proportion tends to surpass the secondary industry proportion. For example, tertiary industry in Beijing, Shanghai, Nanjing, and Guangzhou has already become the major part of the industry. According to international benchmarks for economic development and urbanization, most cities' functions will change from manufacturing to service and tertiary industry will become the most important contributor to business activities. As to the cities with the largest tertiary industry, building and transportation will become the most significant composition of urban energy consumption.

In China today, building and transportation industry only takes up 33% of the total energy consumption, which is at the same level as the EU in 1960s. However, since the 1990s, the energy consumption of transportation and service is increasing by 8% per year. At the same time, the total energy consumption is only increasing by 3.4% annually. Between 2003 and 2005, the direct livelihood energy consumption increased by 13.1%, 7.3%, and 9.9% each year compared to the previous. The total direct livelihood energy consumption in China is 530 Mt of standard coal in 2005, which took up 24% of the total, and the number increased by 10% in 2006.

Transportation and building energy consumption took up more than 50% of the total in the advanced cities, which is as the same level as the EU in 1980s. For example, after statistically counting the tertiary industry (building and transportation) energy consumption we can find that the tertiary industry proportion amounts for 70% of industry in Beijing and the high number comes with the highest energy proportion of 50%.

The tertiary occupation energy proportion is less than 20% in Chongqing, which is relatively low. In Shanghai, Tianjin, Suzhou, and Guangzhou, the building energy consumption ranges from 30%-40%. As to the building-related electrical power consumption, Beijing (55%) also has the highest share. Guangzhou and Shenzhen range from 30%-40%. In Shanghai, Tianjin, Suzhou and Guangzhou, the share ranges from 20%-30%. Nanjing's is lower than 20% (Figures 6-3, 6-4).

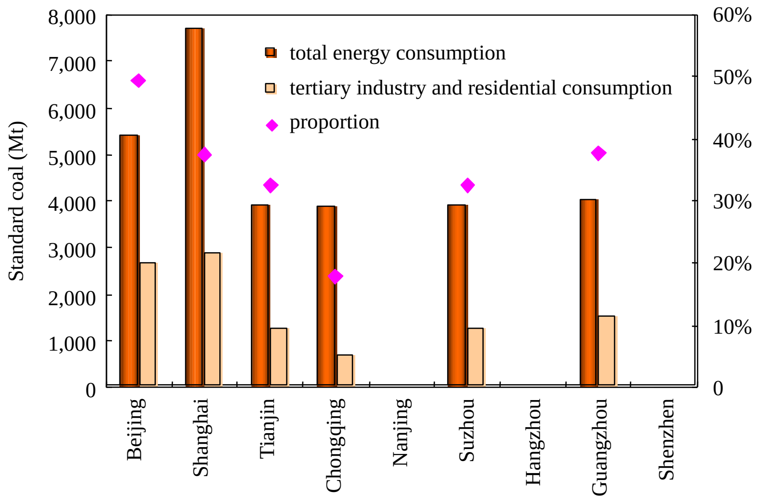


Figure 6-3 Energy consumption for building and transport sectors in typical cities of China.

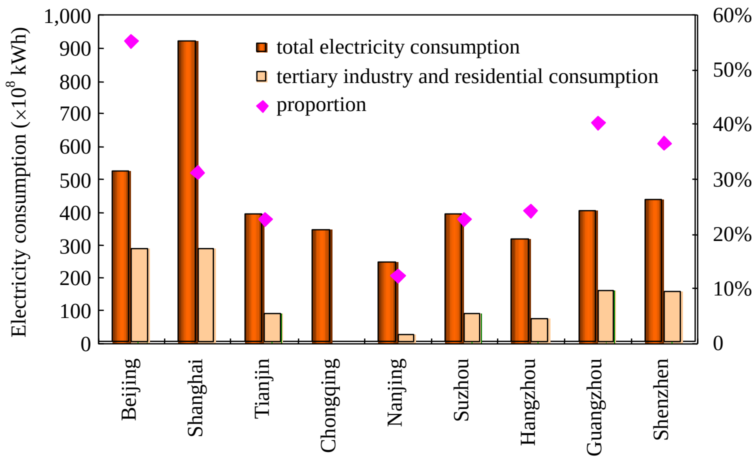


Figure 6-4 Electricity consumption for building and transport sectors in typical cities of China.

6.2.2.2 Urbanization and energy consumption: comparisons between countries

Research in urbanization finds that large cities provide very positive side effects to economy. Large cities can produce more specialized goods and services for the local market, can accumulate more financial service provision and an educated labor force, and can concentrate administrative functions.

More generally, it might be possible that smart urbanization has an impact on the competitiveness of a country. For instance, urbanization can be determinant to have high-quality system of transportation, and the mobility of goods and people is an important condition to economic development. Moreover, oil procurements are a source of impoverishment for many countries where oil is mostly imported. Because of its impact on energy demand, urbanization is then, once again, linked to competitiveness. GDP per capita, size, population density, and urban pattern seem to be the key determinants of energy consumption.

(1) Density of urban areas across the world

In the world, Asian countries have the most dense cities as is shown in Figure 6-5. Mumbai and Kolkata in India (not in the graph) appear to the most dense cities in the world, with nearly 30,000 inhabitants per km². Karachi in Pakistan, Lagos in Nigeria, Shenzhen in China, and Seoul in South Korea are also very dense cities. On the contrary, American cities are less dense.

This comparison is, however, difficult, because the borders of cities may differ. American and European cities are large, while some cities in Asia are more narrowed. For instance, the density of Paris stood at 3500 inhabitants per km² in the database, while in the core of Paris, density is 20,000 inhabitants per km².

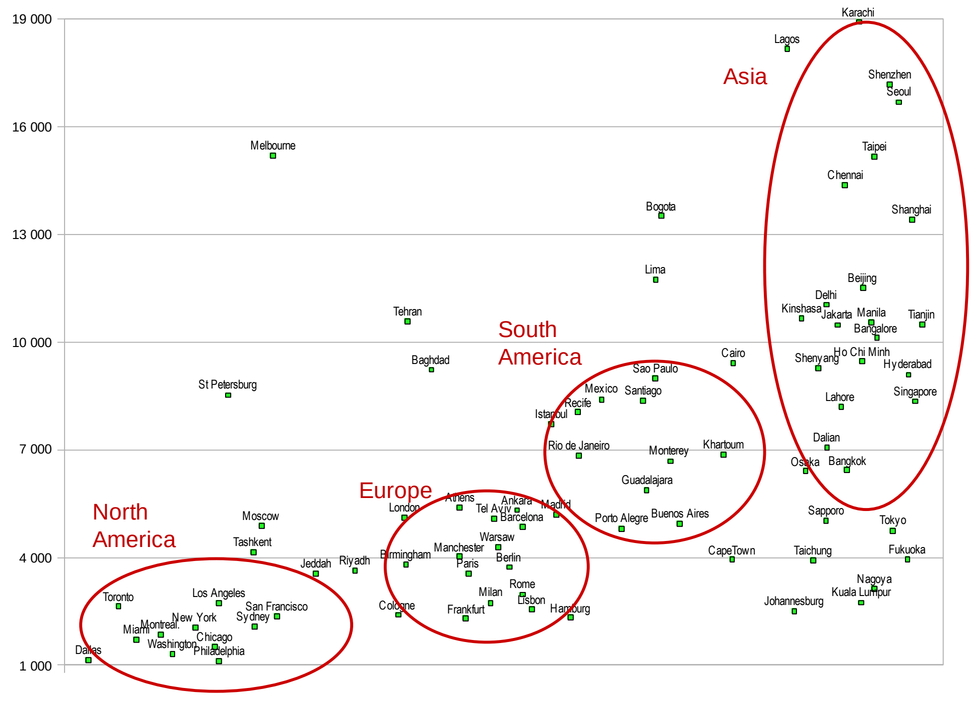


Figure 6-5 Different density for international countries or areas (Source: Enerdata).

The average population density per continent has been calculated on the basis of the main cities in each country. The database compiled more than 250 cities spread all over the world. The results show the following figures:

Table 6-2 Average density in main cities.

Asia	8,200	inhab. / km²
Europe	3,200	inhab ./ km²
Africa	5,300	inhab. / km²
Pacific	2,000	inhab. / km²
Middle East	4,300	inhab. / km²
Russia and Central Asia	5,000	inhab. / km²
North America	1,300	inhab. / km²
South and Central America	5,900	inhab. / km²

Source: Enerdata

European cities were denser in the past than they are now. Over the last decades, cities have grown more horizontally than vertically in Europe and the US. Thus, core cities have lost population, while suburban areas have grown significantly. Paris illustrates this evolution; the core Paris counted 3 million inhabitants in the beginning of 1900's, without any suburbs. Now, the core of Paris counts 2 million inhabitants and the suburbs have around 8 millions.

The term "urban sprawl" describes this evolution towards very spread out cities. People tend to live outside cities and then becoming commuters. Urban sprawl has a few characteristics:

1) It is an often of single-use zoning: commercial, residential, and industrial areas are separated from one another. As a result, the places where people live, work, shop, and find recreation are far from one another, usually to the extent that walking is not practical. Therefore, many of these areas have few or no sidewalks.

2) It is low-density land use: sprawl consumes much more land than in traditional urban developments because new developments are of low density. The exact definition of "low density" is arguable, but a common example is that of single family homes, as opposed to apartment buildings.

3) It is based on car-dependent communities: areas of urban sprawl are also characterized as highly dependent on automobiles for transportation, a condition known as automobile dependency. Most activities, such as shopping and commuting to work, require the use of a car as a result of both the area's isolation from the city and of the isolation the area's residential zones have from its industrial and commercial zones.

(2) Evidences of the link between density and energy consumption in transport

The following figures reveal that public transportation is more developed when cities are dense. The graph below shows the market share of public transport and density in main cities. In Asia, public transport is relatively high and cities are dense.

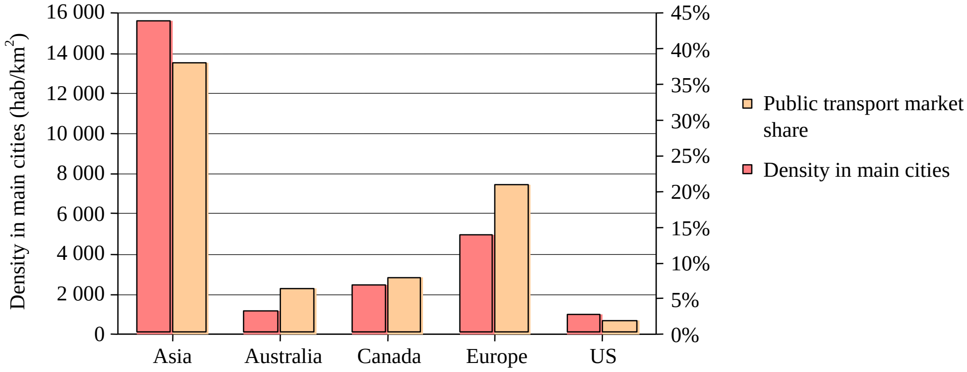


Figure 6-6 Comparison about the density and public transport.

The two maps below deliver the same conclusion. Data of density and data of percentage of people using their car to go to work on the other hand are shown an separate maps. The French national statistical system source allows high accuracy in terms of geography, as Paris and its suburbs are divided into more than 400 sub-elements.

As the maps shown where density is high, people tend to use alternative means of transportation over a car; on the contrary, where density is low, car use becomes predominant. Thus, in the core Paris and the neighbourhood just outside, density is around 20,000 people per km² and approximately 25% of commuters use their car to go to work. On the contrary, in the distant suburb, density is around 500 people per km² and 70% of commuters use their car.

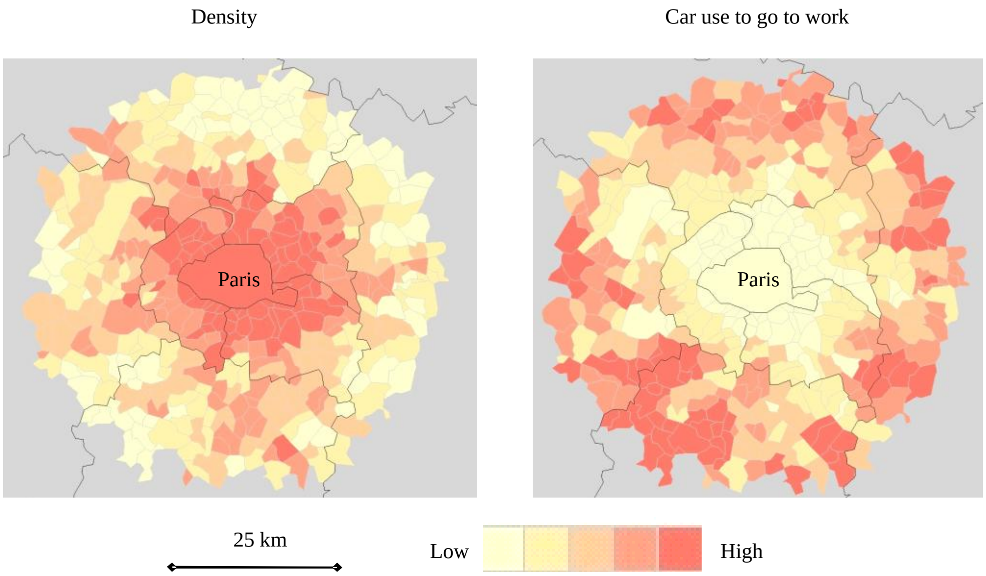


Figure 6-7 Changes of car use and population density in Paris.

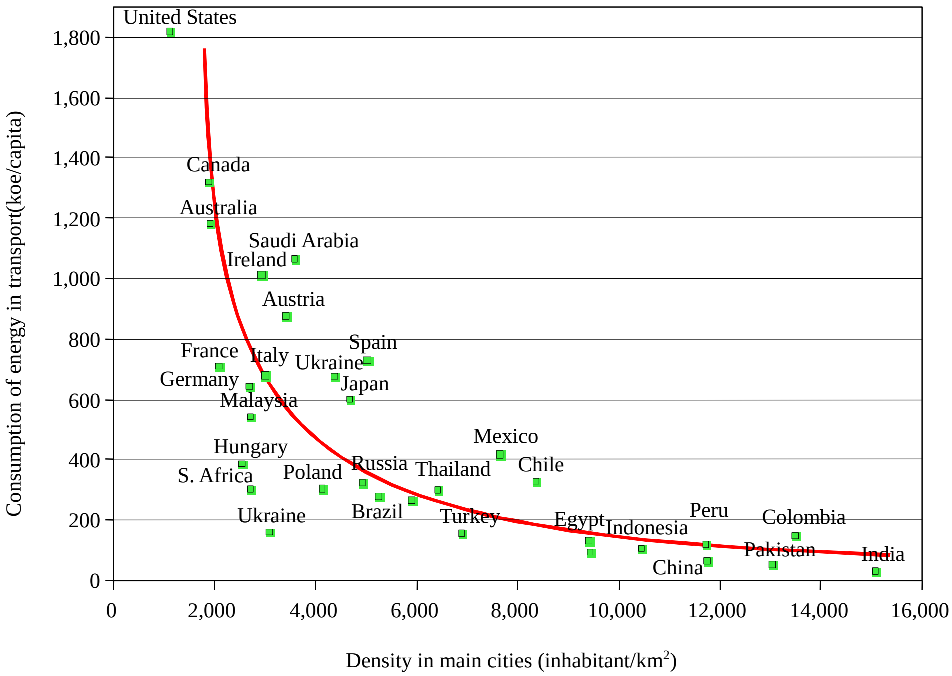


Figure 6-8 Density in main cities.

The same idea can be stressed by other indicators. Figure 6-8 emphasizes the link between density and the consumption of energy in transport. It appears that, in a given country, energy consumption for transport needs is high when density is low. For instance, an average US consumes 1, 8 toe in transportation per year. This is more than twice that in Europe, despite the standard of living being quite similar. This difference is due to urban planning specificity in each continent; the European population is more located in cities and those cities are denser than in the US.

The comparison between the US and Japan is very emblematic of how urbanism can impact energy consumption for transportation. In Japan, cities are very dense and urban sprawl described before is far less, or prevalent. In the US, the culture is very different: Urban sprawl is part of the national spirit; Los Angeles often being quoted as the paradigm of urban sprawl.

Table 6-3 Figures at national level for both countries illustrate this difference.

	USA	Japan
GDP per capita	43,000 USD	37,000 USD
Average density	31 inhab./km²	350 inhab./km²
Cars per household	2.4cars	1.2 car
Consumption of road transport per capita per year	1,820koe	600koe

Source: Enerdata

(3) Evidence of the link between density and energy consumption in households

Does density also have an impact for energy consumption in dwellings? As insulation of buildings is better in collective than in individual dwellings, the answer might be positive as well. A French study has estimated the average consumption of collective dwellings for space heating at 125 kWh/m^2 per year. For individual dwellings, the energy needed has been estimated at 174 kWh/m^2 per year, 40% higher.

As a result of that, it is expected that low-density zones, which are characterized with many more individual dwellings, will generate more energy consumption.

(4) Energy used for transport and space heating in relation to urbanization in Paris:

Previous analysis outlines the importance of urbanism in energy consumption for space heating and transportation. It might be interesting to estimate the energy consumption for those needs in both cases, a city characterized with low density and on the contrary a high density city.

Paris' urban area is divided into three parts, the core Paris, the 1st ring suburb, and the distant suburb, as Shown in figure 6-9.

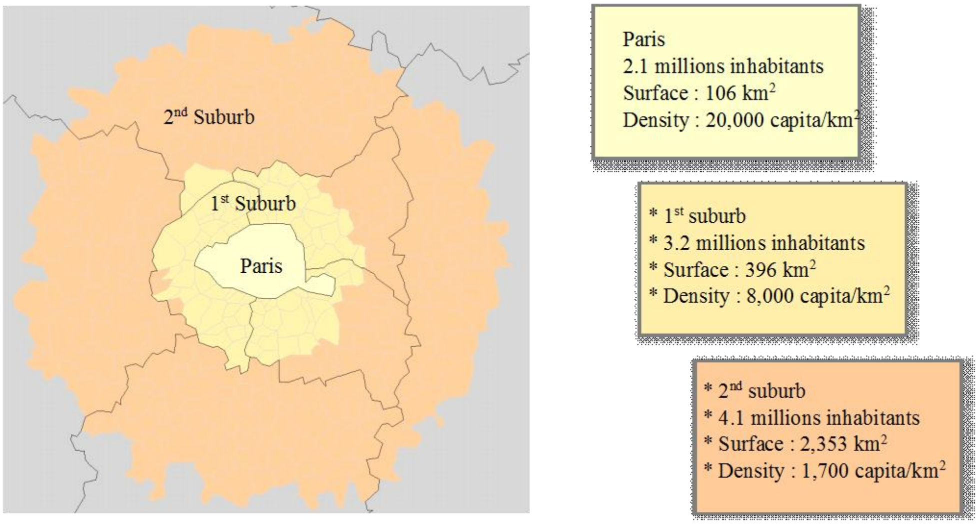


Figure 6-9 Changes in Paris about the suburb area and inner city.

We see in the table below that energy consumption per capita for space heating and commuting is 80% higher in the 2nd suburb than in Paris. Indeed, estimates show that energy consumption per capita in core Paris is 0.43 tep per year, while it is 0.73 tep per year in the distant suburb.

Table 6-4 Changes about the city and space heating.

Energy used in toe per year	Paris (2.1 M inhab.)	1st suburb (3.2 M inhab.)	2nd suburb (4.1 M inhab.)
Work commuting	120,000	280,000	470,000
Space heating	800,000	1,500,000	2,500,000
Total	920,000	1,780,000	2,970,000
Total per capita	0.43	0.57	0.73

6.2.3 Energy consumption in the building sector in China

Energy consumption in relation to building includes embodied energy — building material production, building material transportation, construction, and maintenance and operating energy for building operation during its life time. The fast urbanization of China has accelerated the rise of the building material industry and the construction industry and the subsequent energy consumption has occupied 20% of the total commercial energy consumption of China. However, as this part of embodied energy consumption has already been generally discussed in chapter 6.1, here the focus will be on the operating energy consumption. This includes energy consumed for lighting, heating, cooling, and electrical appliances during the whole lifetime of buildings.

6.2.3.1 Overall building energy consumption

In 2004, the total building area of China was 38.9 billion m^2 and consumed about 0.51 billion tons coal equivalent (tce) of commercial energy, which accounts for 25.5% of total commercial energy consumption as shown in Table 6-5. Energy consumptions in detail are listed as follows:

Table 6-5　China building energy consumption, 2004.

<table>
<tr><th></th><th>Area</th><th>Elec.</th><th>Coal</th><th>LPG</th><th>NG</th><th>Coal gas</th><th>biomass</th><th>Total commodity</th></tr>
<tr><th></th><th>billion m²</th><th>TWh</th><th>Mtce</th><th>Mtce</th><th>Mtce</th><th>Mtce</th><th>Mtce</th><th>Mtce</th></tr>
<tr><td>Rural</td><td>24</td><td>83</td><td>153.3</td><td>9.6</td><td>-</td><td>-</td><td>266</td><td>192</td></tr>
<tr><td>Urban res. (excl. heating)</td><td>9.6</td><td>150</td><td>4.6</td><td>12.1</td><td>5.5</td><td>2.9</td><td>-</td><td>78.2</td></tr>
<tr><td>Residential heating along Yangtze River</td><td>4</td><td>21</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>7.4</td></tr>
<tr><td>North China urban heating</td><td>6.4</td><td>-</td><td>127.4</td><td>-</td><td>-</td><td>-</td><td>-</td><td>127.4</td></tr>
<tr><td>Ordinary commercial</td><td>4.9</td><td>202</td><td rowspan="2">17.4</td><td>-</td><td rowspan="2">5.9</td><td>-</td><td>-</td><td>94.7</td></tr>
<tr><td>Large scale commercial</td><td>0.4</td><td>50</td><td>-</td><td>-</td><td>-</td><td>17.6</td></tr>
<tr><td>Total</td><td>38.9</td><td>506</td><td>302.7</td><td>21.7</td><td>11.4</td><td>2.9</td><td>266</td><td>517.3</td></tr>
</table>

Note: Fuel and heat consumption are converted to standard coal equivalent according to their gross caloric values. When calculating the total energy consumption, electric power is converted to standard coal equivalent according to the conversion coefficient subject to the mean plant coal consumption in thermal power plants in China of the year 2004, i.e. 1 kWh electrical power is equivalent to 354 g coal equivalent

Data source: 1) Rural data: Sustainable energy source development financial and economic policies research reference documents, data of 2005, Wang Qingyi, Oct. 2005; 2) Other data: China Statistic Yearbook, 2005.

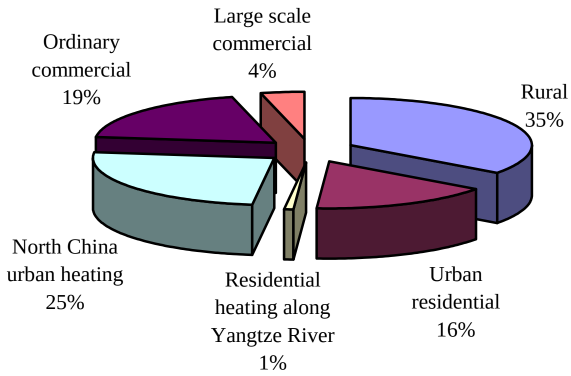


Figure 6-10 Sectoral energy consumption of China, 2004.

6.2.3.2 Lower energy consumption in China than in developed countries

As shown in Figure 6-10, despite having already reached 510 Mtce, China building energy consumptions are far lower than those of developed countries. Even compared with European countries, which have fairly good policies on building energy efficiency, China's unit area consumption is only 1/5 of Europe and the per capita value is only 1/7 of European level. Even if the energy consumption of the less developed rural areas is excluded, there are still folds in the gap between China and developed countries. Although the energy statistical methods and systems of each country are different, all the data are matched with each other in their quantities and developing trends. Thus, according to the energy consumption data comparison between China and major developed countries, it can be reasonably concluded that unit area building energy consumption of China is currently only 1/2- 1/3 of the developed countries' levels.

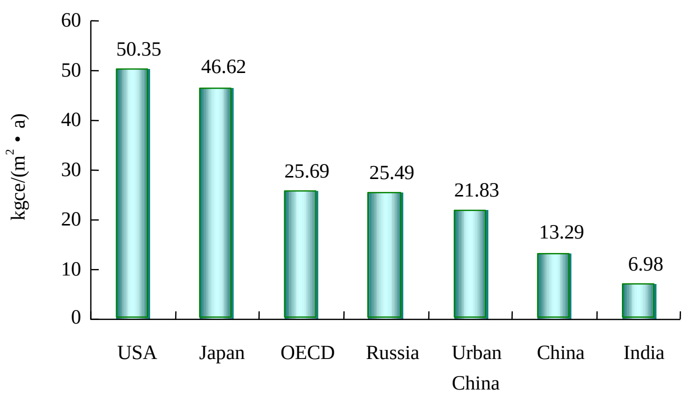


Figure 6-11 Per unit area building energy consumption, 2004.

More ever, the China heating consumption is half of developed countries with similar climate. Table 6-6 shows the heat demand of buildings in over 100 residential quarters in Beijing when the room temperature is maintained at 18℃. The data source is real consumption in the year 2006 and amended according to the outer temperature and the design climate parameters of Beijing. The highest values and the lowest values, respectively, occupying 10% of the statistical samples are excluded from the date. Table 6-7 shows the heating consumption of some European countries. Concerning the climatic differences, amended consumption data are also provided in the table. According to comparisons of Tables 6-6 and 6-7, the conclusion that there are no great differences of heat demand between Beijing and European countries could be made.

Table 6-6 Heating demand in Beijing buildings (room temperature 18℃).

Building category	Heating demand scope kWh/(m^2 a)
Common residential building	50-100
Common office building	30-90
Hotel	40-90
Emporium	10-120
School	30-100

Table 6-7 Heating consumption in surveyed countries.

Year	Building type	Country	Heating degree days	Heating consumption [kWh/(m^2 a)]	Heating consumption after climatic correction [kWh/(m^2 a)]
2004	Residential	Beijing	2450	83	83
1998	Residential 1	Poland	4043	124	75
2004	Residential	Germany	3126	185	145
1998	Residential 2	Germany	3430	57	41
2004	Residential	France	2747	150	134
1998	Residential 3	Finland	5303	55	25
1998	Residential 11	Sweden	3230	20	15
2004	Residential	Greece	1565	120	188
2004	Office	Germany	3126	120	94
2004	Office	France	2747	166	148
2004	Office	Holland	2784	310	273
2004	Office	Greece	1565	100	157
2004	Hotel	Germany	3126	225	176
2004	Hotel	France	2747	179	160
2004	School	Germany	3126	160	125
2004	School	France	2747	118	105

Year	Building type	Country	Heating degree days	Heating consumption [kWh/(m² a)]	Heating consumption after climatic correction [kWh/(m² a)]
2004	School	Holland	2784	145	128
2004	School	Greece	1565	55	86

Note:

(1) Energy consumption data source:

a) 1998 data from the survey on a batch of energy efficient buildings: Indicators of Energy Efficiency in cold-climate buildings, Results from BCS Expert Working Group, http://eetd.lbl.gov/.

b) 2004 data is the statistical data from: Beijing – Report on Beijing residential building heating test in 2005-2006 by Tsinghua University; other countries – Applying the EPBD to improve the Energy Performance Requirements to Existing Buildings- ENPER-EXIST, Intelligent Energy of EPBD, 2007.

(2) Climate data source:

Beijing data is sourced from "civil building energy saving design standard JGJ26-95", based on 18℃; USA data is from "monthly state, regional, and national heating degree days weighed by population", National Climate Data Centre, USA, 2006, based on 18.3℃; Japan data is sourced from "Handbook of Energy and Economic Statistics of Japan", energy conservation centre, 2006, based on 14℃; Other European countries are sourced from 2007 Earth Satellite Corporation (www.earthsat.com), based on 18.3℃.

(3) Methodology:

(Amended energy consumption of region A)=(heating consumption of region A)/(heating degree days of region A)×(heating degree days of Beijing).

Among the reasons that explain these discrepancies despite far better insulations in European buildings: building shape coefficient, ventilation and infiltration, and maintained room temperature. European residential buildings are mostly detached houses and their shape coefficient is approximately 2 times that of high-rise apartments in China (12 floors); the shape coefficient of most office buildings in Europe is over 1.5 times that in China. In addition, in recent years, indoor air quality of European buildings has been controlled strictly by the application of mechanical ventilation with an exhaust volume generally over 100% of the building volume per hour. Besides, the set temperature in European residences varies from 21℃ to 24℃, which shall consume approximately 15% more energy than at 18℃.

And another important reason could be the Central heating plant (CHP) sourced district heating system in North China, which makes full use of exhaust heat of coal-fired CHP to maintain total energy efficiency as high as in developed countries. Primary energy consumption of optimized CHP for heat production is only 70%-85% of water source heat pumps that are regarded as currently the most energy efficient. Consequently, although the envelope in China is worse insulated, the overall heating consumption appears lower compared with developed countries.

6.2.3.3 Great individual differences in domestic buildings in China

It could be concluded that China consumes much less energy than developed countries in buildings, compared either in unit area or in per capita building energy consumption. However, great discrepancies of individual building energy consumption occur, even among buildings serving the same function in the same geographical region of China. Figure 6-12 shows the surveyed annual electricity consumption of some residential buildings in Beijing, Shanghai and Chongqing, including all household electric end-uses such as air conditioning (AC), lighting, and household electric appliances. Three to five-fold individual differences easily are found.

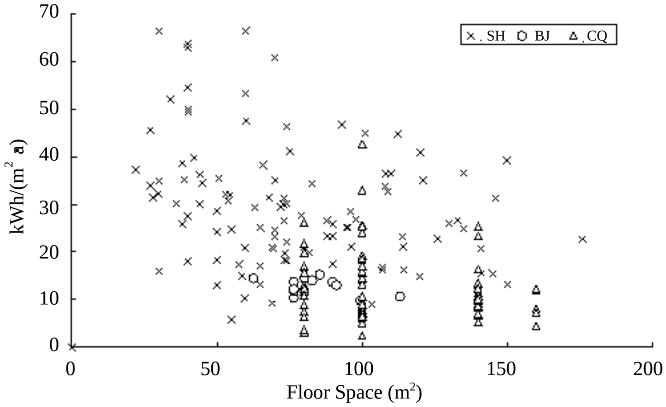


Figure 6-12 Surveyed residential electricity consumption (Beijing, Shanghai and Chongqing).

Figure 6-13 offers the whole year AC electricity consumption of medium-income families in a Beijing residential building, with the application of split AC respectively measured in 2007. Household electricity consumptions differ greatly from flat to flat, although all the dwelling families share the same envelope insulations, earn approximately the same income, and use the same cooling device, a split air conditioner. Further analysis suggests that the over ten-fold difference in Figure 6-13 are not greatly concerned with the incomes of each family but with the ages of the residents;. the older person will have lower AC energy consumption.

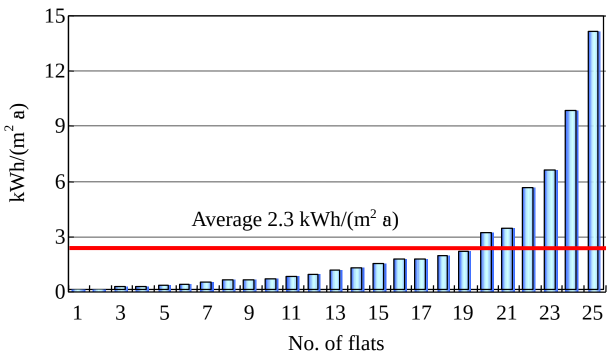


Figure 6-13 Electricity consumption of split ACs in a Beijing residential building.

6.2.3.4 Differences in commercial sector are also largely determined by energy consumption modes

Impacts of energy consuming modes on residential energy consumption are as discussed in the above paragraphs. Generally, the same conclusion could be drawn in the commercial sector. Orders of magnitude differences of energy consumption in commercial buildings can be, for the most part, attributed to how people use buildings rather than what technical solutions are equipped in buildings.

Figure 6-14 is the comparison on annual electricity consumption of some office buildings in two famous campuses of Beijing and Philadelphia. An office building, in Beijing with an electricity consumption near to the average level of the whole campus was selected for in-depth comparative analysis of the energy consumptions of a Philadelphia campus building. This building was built in 2002 with very good insulation and Variable Air Volume (VAV) Systems for air conditioning. The main differences between the buildings are lighting and appliances, cooling, and the ventilation fans in a centralized AC system.

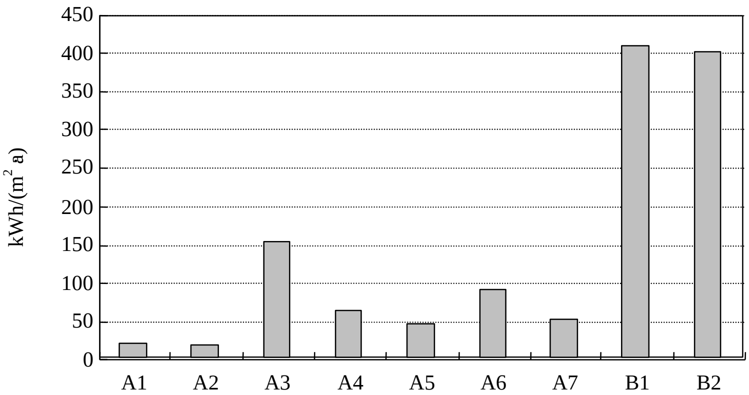


Figure 6-14 Annual electricity consumption of campus office buildings in Philadelphia (B) and Beijing (A).

Figure 6-15 illustrates the cooling consumption of several Beijing government office buildings applying centralized AC systems. Individual floor area of these buildings is similar to this case, but there is gap greater than one-fold of cooling consumptions among them. The reasons are ranked in descending order of their influences as: total operation time, fan electricity consumptions, mechanical ventilation volume of outdoor fresh air, and indoor temperature and humidity. Differences of these factors would result in different levels of indoor thermal comfort, such as satisfaction rate of all air conditioned rooms, satisfaction hours in the whole cooling period, and satisfaction level of all occupants.

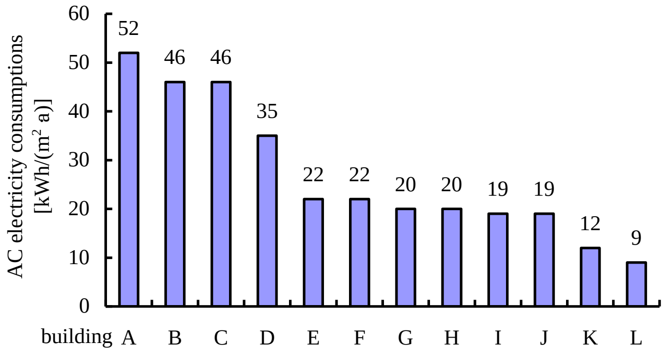


Figure 6-15 AC electricity consumptions of some government office buildings, Beijing.

6.2.3.5 Impacts of different routines for indoor environment maintenance on building energy consumption

Generalizing the above discussions, there are now two different routines for good indoor environment: 1) a mechanical one, which consumes great amount of energy, and 2) a natural one, which is mainly in virtue of natural means, with complementary mechanical solutions.

Mechanical routine: The "Most Comfort" indoor environment is maintained by artificial mechanical ventilation, cooling and heating, so that the indoor physical status is rigidly controlled. The industrial revolution, with its developing scientific technologies, has greatly enabled people to maintain good indoor environments. The concept of "human will overwhelm natural forces" gradually prevailed, which is the consequence of unreasonable expansion of energy consumption from the industrial sector to the building sector. Various environmental parameters such as temperature, humidity, air flow and indoor luminance are rigidly implemented and maintained by mechanical AC, ventilation, and lighting, so as to provide the optimal services for residents. However, they ignore the adaptability and regulation capacity of the human body and their positive regulation of the environment. Then two consequences emerge: 1) an enormous amount of energy is consumed; if all people followed this living mode, it would consume 130% of currently produced energy in the whole world; and 2) the residents are not very satisfied for lacking free choices of individual control upon the indoor environment, which is actually not coherent with human beings' requirements after millions of years' evolution, especially the requirements for physical health. The energy consumption can be reduced to a certain degree through various technical breakthroughs, yet it is almost an infeasible dream to lower the proportion to 30% to 40% from the 130% at present merely by technical solutions. Indeed, endowing the residents with abilities of regulation upon preferred environmental conditions may be more psychologically appropriate and will be fulfilled by technical innovations. Yet, completely relying on a mechanical approach to maintain such environment may further increase the demands of energy resources.

Natural routine: in the natural mode, various passive means and self regulations of the residents, such as opening window for ventilation and sunshades, should be used for appropriate indoor environment. Also, they should be coordinated with and adapted to the natural environment through the self-regulation and adaptability of the human body. If these means finally cannot meet environmental requirements, they shall be complemented by mechanical or manual means, such as heating. The mechanical dominating mode usually assures an invariable indoor status with constant environmental parameters, while the nature dominating mode aims at being harmonious with the variable natural environment. In fact, in the days before modern society, this mode was widely used, which has supported the breeding and civilization development of the human being. The residential environment under this mode does not consume too much natural resources, has lower levels of destructive externalities upon the global environment, and can be regarded as more sustainable.

To sum up, it is the choice between these two routines that causes up to ten-fold, differences of building energy consumption.

6.2.4 Current status of China's urban transport and energy consumption

Rapid urbanization and motorization, especially the rapid growth of private cars, has brought great challenges to urban transportation systems. Figure 6-16 shows the growth of vehicle ownership in recent years. From the early 1990s to today, China has maintained a high annual growth rate of 13% in vehicle ownership. By the end of 2006, the total number of registered vehicles was close to 37 million; furthermore, of the vehicles registered, ownership of private vehicles experienced an annual growth rate of 23%, far higher than that of total vehicle ownership. In Figure 6-16, the civil vehicle fleet includes the passenger vehicles and truck which provide commercial transport service, vehicles belonging to commercial enterprises and government institutions, and private vehicles. It does not include vehicles for special purpose, such as fire trucks, municipal sanitation, and military fleets. Furthermore, the private vehicle fleet includes the vehicles belonging to private individuals.

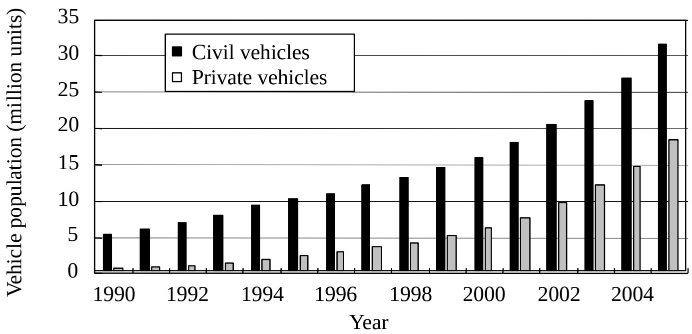


Figure 6-16 Growth of registered motor vehicles in China.

Motorization will continue to grow rapidly in the next 10-20 years, yet vehicle ownership in China is much lower compared with that in other developed countries. International experience shows that there will be a vehicle purchase peak in a country when its per capita GDP reaches 3,000-4,000 USD, which China will attain in 20 years. Thus, vehicle ownership, as an important indicator for standard of living, will continue to rise.

6.2.4.1 Overview of China's transport development

Urban transport development was catalyzed by its own conflicts along with its evolution. The urban transportation development process can be viewed as following four main phases due to different conflicts in the case of China cities.

(1) Initial Phase

Before industrialization and motorization, urban populations increased slowly and people traveled by foot, animal, or bicycle. Most available transportation modes were at a low speed and the travel distance was generally short. The conflict of transportation was not evident in this phase. The travel time and distance were tolerable to most people.

(2) Startup Phase

Along with the development of urban economies, GDP, and public living quality, urbanization and motorization began taking place. In this phase, the major conflict was between the rapid increase of motorized transport's demand and relatively limited road resources. Therefore, a motor focus transport development plan was in a great need. Many cities started construction of new, broader vehicle lanes, expressways, separation bridges, and other motorization infrastructure. The development of those infrastructures further accelerated the motorization process in cities. Congestion became worse. Lessons were that the free development of small cars was not beneficial.

(3) Rapid Development Phase

In order to accommodate the rapid motorization and the healthy development of urban transportation, China's cities began to implement series of policies and measures for the Smooth Project and to bring attention to public transport's priority. Ministry and other national government office created relative regulations and raised a goal of establishing a public transportation-focused system by 2010. During this phase, the conflict between public and private transport became more evident in addition to besides the supply-demand conflict. As motorization developed dramatically and brought significant impact to the urban living condition, many cities added special items to their urban transportation management frame to restrict the over development of small cars and to promote prior development of public transport. Those measures adopted brought important positive affects to urban transportation issues, but faces many challenges. More effort should be enhanced to strategic planning and land use to meet development objectives eventually.

(4) Maturation Phase

After the conflicts between urban transport demand and supply and between private and public transportation are alleviated, some new issues may take place, such as transportation systems' service level and the variety of resident travels. Therefore, a fast, safe, diverse, efficient and highly accessible transport system should be provided. Social and economic resources are in need of optimal utilization to satisfy people's updated transportation demand, whether motorized or non motorized and private or public transport is adopted.

6.2.4.2 Demand of resident travel keeps increasing

Rapid urbanization and the improvement of citizens' standards of living will lead to increasing travel distances and time. Such situations may stimulate the use of motor vehicles and travel by other motorized modes. The experience of developed countries indicates that there is a growing trend of trips for leisure purposes; with the improvement of standard of living, average daily trips by urban citizens gradually will be rising, therefore travel distance and reliance on vehicles will rise, as well. It is estimated that, on the basis of the macro-economic development scenarios, passenger trips in Chinese urban areas will be 951.7 billion person-trips by 2020, including 255.7 billion person-trips by public transport and automobiles, with an expected annual growth rate of 9% from 1998 to 2020 (Figure 6-17).

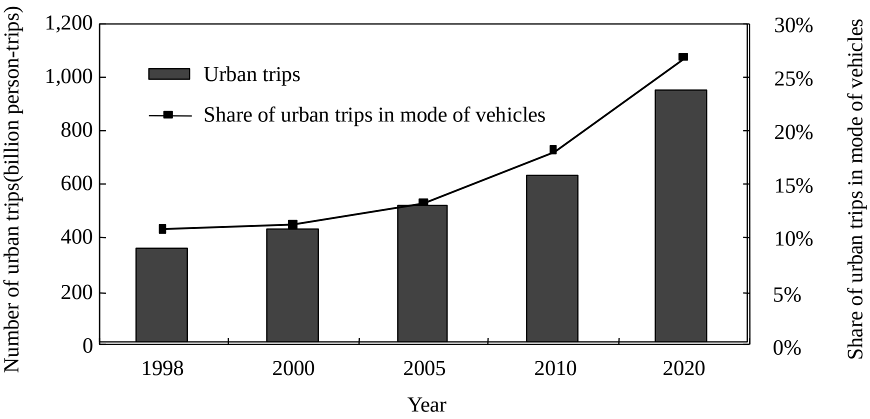


Figure 6-17 Future personal trips in China.

6.2.4.3 Urban passenger transport volume increases rapidly

The urban public transportation volume, including bus, metro, and rails, kept increasing since 1980, because the demand of resident travel rose, with 48,369.30 million people in 2005 increased 1.6 times of 1980. Especially in latest 10 years, it grow by 7.4% per year, which is close to the rate of GDP increase (Figure 6-18). Urban passenger transport is a major petroleum consumer in China, while it consumes a relative smaller ratio of diesel. The petroleum consumption of Beijing was 1.06 million tons in 2000 and increased 122% to 2.35 million tons in 2005. Shanghai consumed 1.33 million tons of petroleum in 2000 and 2.42 tons in 2005. Over 90% of petroleum was used for transport. Most of that was used for urban passenger transport, though small portions were taken by inter-city passenger transport and freight transport. According to the study of China National Development and Reform Commission, Beijing's petroleum consumption was 900,000 tons in 2000 and 2.1 million tons in 2005. Correspondingly, the figures for Shanghai are 1.06 and 2 million tons, respectively. Small cars used 80% of the total petroleum consumption.

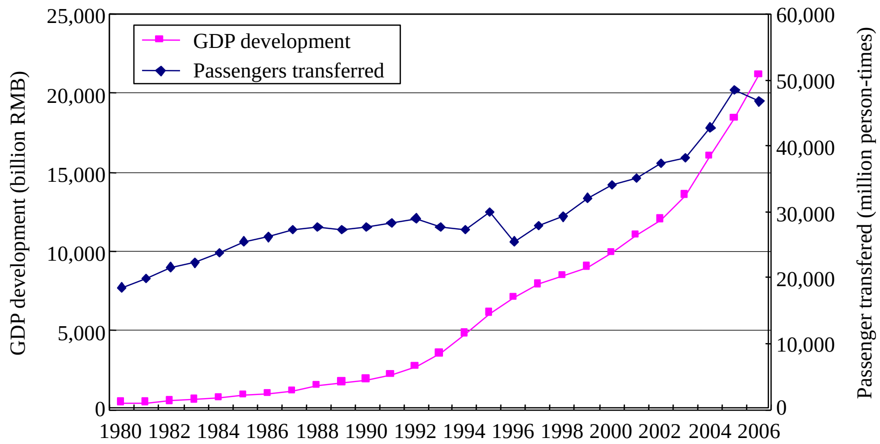


Figure 6-18 Passenger volume of public transport in China.

6.2.4.4 China's transport energy consumption increases the most compared with other sectors

The transportation sector is significantly dependent on energy resources. Energy consumption for transportation increases dramatically along with China's economic development and has become one of the most rapidly growing industries in terms of energy consumption. Data reveals that the transportation industry consumed 7.55% of total energy used by the nation. Of oil-related consumption, transportation takes 31.45%. These two figures have increased 10.75% and 12.16% respectively since 2000 (Figure 6-19). There is still an evident gap between China and developed countries regarding unit energy consumption, utilization rate, and equipment efficiency of the transportation industry.

It should be noted that the data in China's statistics system only includes those operational transport enterprises whose energy consumption is counted. The current data does not contain non-transport vehicles and their consumptions. As the estimation by international standards, the energy consumption of transport would take 10% of the nation's total. The transportation industry consumes almost all gasoline, 60% of diesel, and 80% of coal oil. China's petroleum consumption is dependent on foreign imports at the high rate of 40% and the dependence is growing. In order to ensure the nation's energy security and to reach the energy conservation goal for the 11th Five-Year Plan of reducing energy consumption 20% per unit GDP, the transportation industry must bring more effort on energy conservation.

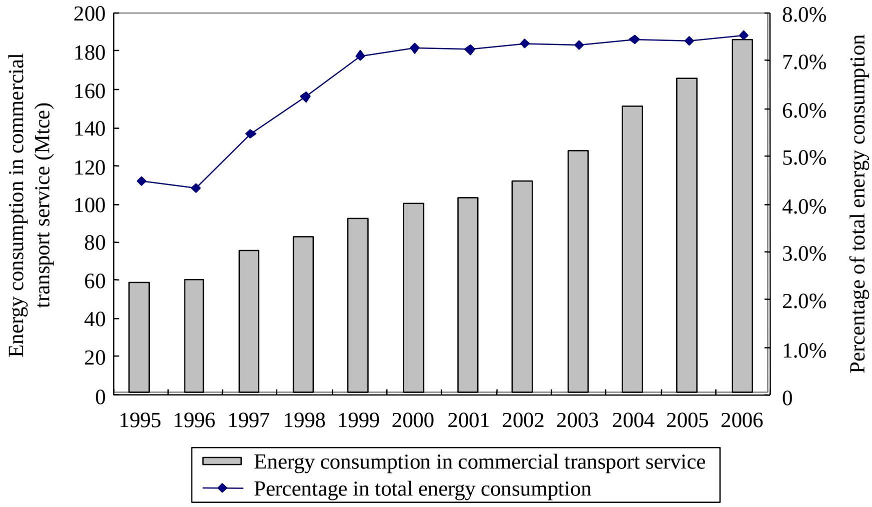


Figure 6-19 Transport energy consumption in 1995-2006.

6.2.4.5 Cars consume most energy in all transport modes

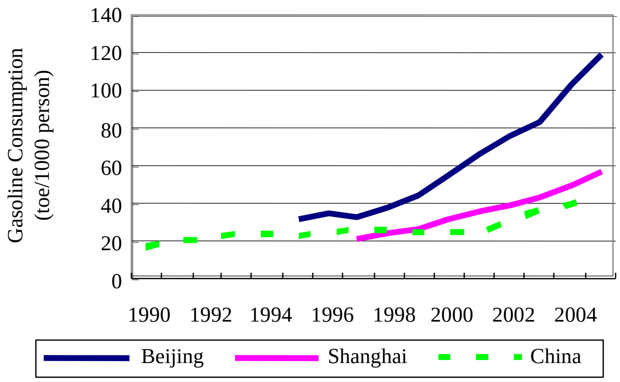
Different modes of transport differ drastically in energy consumption in urban transport system. Table 6-8 shows that cars consume the most energy per passenger-kilometer. The energy consumption per passenger-kilometer of light rail, subway and tramcar is only 6% that of cars' and single bus is 10% of the cars'. Cars produce the largest CO_2 emissions per passenger-kilometer among the six modes of transportation and 7 times that of buses. Thus, from views of both environmental benefit and of transportation efficiency, the promotion of mass public transfer tools such as light rail, subway and tramcar is one the measures to establish an energy-efficient urban transportation system in the future.

Table 6-8 Comparison of energy consumption among various transport modes (energy intensity per person-kilometer of single bus set at 1).

Transport means	Energy consumption per person-kilometer	Transport means	Energy consumption per person-kilometer
Bike	0	Electric trolley bus (hinge joint)	0.8
Motorcycle	5.6	Electric trolley bus (BRT)	0.7
Car	8.1	Tram	0.4
Bus（single）	1	Light rail transit	0.45
Bus（hinge joint）	0.9	Subway	0.5
Bus（BRT）	0.8		

6.2.4.6 Transport energy consumption per capita is less than developed countries, but increasing rapidly

Fuel consumption per capita in China had been increasing steadily from 1990 to 2005 (figure 6-20), where Beijing consumes the most fuel—as much as 3 times of the nation's average level, which is still less than Japan and Korea. Figure 6-20 shows that Tokyo's fuel consumption per capita was less than the national average until 1999. One of the reasons for this is the change of preferences of car buyers in Tokyo. It is common for families in Japan to have two vehicles. Most of the families wanted to buy bigger cars at first, so fuel consumption kept increasing. When families purchased their second car, they came to prefer small or economy-model ones in light of tax costs and environmental issues. Hence, Tokyo's car population increased continuously, but its fuel consumption per capita stayed at a relative steady rate.



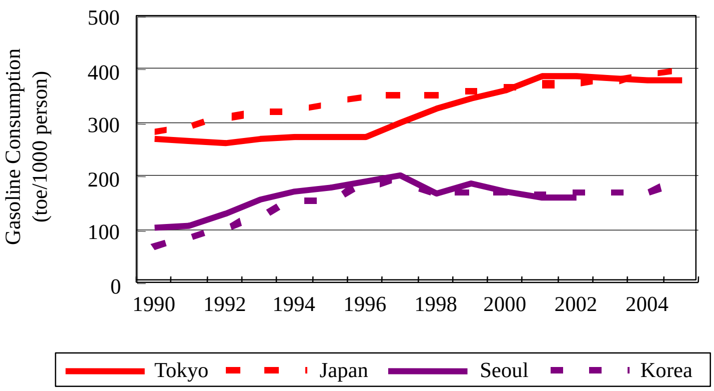


Figure 6-20 Urban passenger transport energy consumption of China, Japan, and Korea.

6.2.4.7 Cars take largest portion of urban passenger transportation energy consumption

China's urban passenger transportation consumed 7.9 million tons of oil in 2000, and the increasing rate from 2000 to 2030 will be 5.9% per year. 45.3 million tons of oil will be consumed in 2030, as six times the amount of 2000, and small cars take 80% of total urban transportation energy consumption, which is undoubtedly the largest consumer of energy (Figure 6-21).

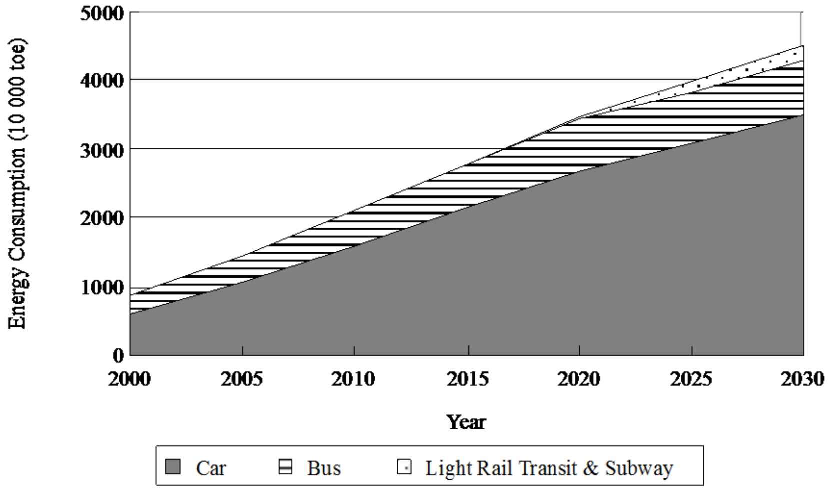


Figure 6-21 Energy consumption of China's urban passenger transport in 2000-2030.

6.3 Conclusions

Currently, the proportion of both building and transportation energy consumption in social site energy consumption is as much as 33%. Following the experiences of developed countries, this proportion will steadily increase with the development of the economy and adjustments of industrial structure. For example, this same proportion of social site energy consumption in OECD countries and EU member countries has reached about 2/3, among it the proportion concerning only urban building and transportation is more than 1/2.

Chinese urbanization is currently a great challenge for itself as well as for the whole world. Currently, the urban building rate continuously increases at the speed of 5% to 8% in China and more than 1 billion m^2 worth of new buildings are built every year. This will not only lead to the doubling of floor area of urban buildings and a continuous increase of building operating energy consumption in the next 15 years, but also indirectly will promote the fast development of energy-intensive building material industries, such as cement, steel, and glass. Statistical data shows the energy consumption of the cement, steel, glass, and China used for urban construction account for 20% of the total energy consumption in China in 2005. If the urban construction scale can be decreased half, the total energy consumption can be decreased 10%.

Various types of new buildings are the main part of urbanization. According to the statistical data, the current urban floor area per capita of China is nearly 30 m^2, which exceeds the corresponding index of Hon Kong and is close to the average of Japan and Singapore of about 36 m^2; the index of some provinces and cities even exceeds that of Japan and Singapore. But, as a whole, the floor area per capita of China is far lower than that of USA and Europe. However, in the recent 15 years, the urban building floor area doubled every 7 years and more than 1 billion m^2 of buildings were constructed every year. If 1 billion m^2 of buildings are built and the urban population increases 15 million every year, then urban floor area per capita of China will reach 42m^2 and will be close to the European level. The total energy consumption for building operations will certainly increase with the increase of building scale. If the urban building scale increases one time, the building energy consumption will increase one time or even more. Therefore it is necessary to scientifically and reasonably control the urban construction scale and urban building scale and to control the urban building so that floor area per capita remains less than 35m^2 and that new buildings constructed every year are less than 0.7 billion m^2. This should be the important part of the construction in a resource-saving society and it is the basic necessity to realize the sustainable development of urban construction according to a scientific development view.

Up to now, the building operating energy consumption per capita in China was 1/12 of that in the US and 1/6 of that in west and north Europe; the building operating energy consumption per capita of cities in China is only 1/7 of that in the US and 2/7 of that in western and northern Europe; the operating energy consumption per unit floor area for urban buildings in China is 1/3 of that in US; the operating energy consumption per unit floor area for residential buildings in China is 1/3 of that in the US and 1/2 of that in Europe. However, recently, with the growth of the economy, the improvement of living standards, and the influence of the ideas of "joint track with international standard" and "30 years of no backwardness", a great amount of high standard residential and office buildings that pursue to be different and large have been built. The operating energy consumption for these buildings realizes the conception of "joint track with international standard": The energy consumption per unit floor area has increased greatly. For example, a so-called high-grade residential building in a certain place of China claims that it has applied the most advanced energy saving technique for air conditioning and heating. Its heating and air conditioning system runs all day long for most of the year and its energy consumption reaches 20kWh/(m^2 a), which is 7-10 times that of common residential buildings and is equivalent to that of the high-grade residential buildings in developed countries. Also, the electricity consumption standard per unit floor area of large-scale commercial buildings in most cities of China is 200kWh/(m^2 a) to 300kWh/(m^2 a), which has already reached the level of developed countries such as the USA, Japan, and in the EU. Those commercial buildings in China account for less than 5% of the total building floor area, but account for more than 10% of the total building energy consumption.

If the urbanization idea of "joint track with international standard" spreads widely, building energy consumption in China will reach the high level of the "developed countries". Take the urban building electricity consumption per unit floor area in China for example: If it reaches the current level of that in the US, then the 30 billion urban buildings in China will consume 3 trillion kWh of electricity annually in 2020 – 1.5 times the current total amount of electricity generated in China; if it reaches the legal building energy efficiency level in German of 60 kWh/m^2a, then in 2020, the electricity consumption for urban buildings in China will be equivalent to the current total amount of electricity generation for the whole country in a year.

Moreover, rapid urbanization and the improvement of citizens' standards of living will lead to increased travel distances and travel time. Such situations may stimulate the use of motor vehicles and travel by other motorized modes. The experience of developed countries indicates that there is a growing trend of trips for leisure purposes; with the improvement of the standard of living, average daily trips by urban citizens gradually will be rising, therefore travel distance and reliance on vehicles will rise, as well.

However, it should be noticed the expanding trend of luxury consumption in China beginning in 2001. The improved living standards of citizens due to the great economic achievements of China inherently increase the requirements for daily consumables such as dwellings, cars, and domestic appliances. Generally, motivation for industry development is transferring to updating the structure of consuming sectors of China's economy. This necessitates research on: 1) impacts of living, work, leisure entertainment and individual transportation on urban building and transportation energy consumption; 2) categorization and distribution of different consuming patterns and their inherent social impacts; 3) objective policies and social guidance for an energy-conserving society in China; 4) possible consuming patterns in terms of energy- and resource-conservation in future society; 5) proper energy consuming modes in building and transportation sectors. These will be essential to achieve social development and better citizen life while consuming less energy compared with developed countries.

Both international and domestic research and experiences show energy consumption moderation or reduction can be achieved, as well, by more efficient technologies to satisfy one's needs and by more efficient organization, lifestyles, and consumption patterns. Moderation or reduction in the energy consumption in the social consumption sector, especially for the building and the transportation sectors, can be achieved through technological improvements, and from moderation of the needs for energy services or from non-technical factors such as better organization and management or improved economic conditions in the sector. Moderating or reducing energy consumption is first, a matter of individual behaviors and reflects the rationale of energy consumers. Avoiding unnecessary consumption of energy or choosing the most appropriate equipment to reduce the cost of the energy contributes to decrease in individual energy consumption without decreasing individual welfare. On the other hand, it seems that the urban design also has influences on energy consumption in the transportation sector and in household space heating.

This recommended task force will emerge with a common and clear understanding of the role of energy efficiency in relation to sustainability, especially the relationships between urban design and planning and life styles and energy efficiency, and the relationship between urban design and planning and transport and energy networks by reviewing the relationships from history and from experiences from international and domestic cities.

A general mathematical model for China's urban buildings and transportation energy consumption should be founded after city-level energy surveys and individual surveys for household and behaviour distribution. By analytical comparison of typical urban policy backgrounds and the implementation results of both domestic and foreign cities, that is, the implemented strategies, mechanisms, and inspiriting measurements for urban development and structural adjustments aiming at reducing energy consumption, possible policies should be advised for controlling urban development speed, encouraging suitable lifestyle, and developing corresponding technologies.