TASK FORCE

Energy efficiency and Urban Development

(the building sector and the transport sector)

Background Report 2008

CCICED 2008 Annual General Meeting

（2008.11.12-14）

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Excutive Summary

Currently, the proportion of both building and transportation energy consumption in social site energy consumption is as much as about 33%. Following the experiences from developed countries, the proportion would stably increase with the development of economy and the adjustments of industrial structure. For example, the proportions in OECD countries and EU member countries have 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 the whole world nowadays. Currently the urban building's scale continuously increases at the speed of 5%-8% in China and more than 1 billion m^2 of new buildings are built every year. This will not only lead to the double floor area of urban buildings and continuous increase of building operating energy consumption in the next 15 years, but also indirectly promote the fast development of energy-intensive building material (cement, steel, glass, etc.) industries. 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 Hongkong and is close to the average of Japan and Singapore (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, 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 operation 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.

Up to now, the building operating energy consumption per capita in China is 1/12 of that in USA 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 USA and 1/3.5 of that in west and north Europe; the operating energy consumption per unit floor area for

urban buildings in China is 1/3 of that in USA; the operating energy consumption per unit floor area for residential buildings in China is 1/3 of that in USA and 1/2 of that in Europe. However, recently, with the growth of the economic and the improvement of the life level and also the influence of the ideas of “joint track with international standard” and “30 years of no backwardness”, 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, declaims 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 most of the time in a 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 200~300 kWh/m^2•a, which has already reached the level of developed countries such as the USA, Japan and Europe. The commercial buildings in China like those accounts for less than 5% of the total building floor area, while accounts 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 USA, then the 30 billion urban buildings in China will consume 3 trillion kWh electricity annually in 2020, which is 1.5 times of the current total amount of electricity generation in China; If it reaches the building energy efficiency level in German (60 kWh/m^2•a), 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 whole year.

In addition, the fast urbanization fuels up the mechanization of China, especially the increment of private cars, which has increase from 5.78 million in 2003 to 13.25 million in 2005 at an annual growth rate of 31.9%. It challenges greatly the urban development. On one hand, there are more and more traffic jams in center area of cities. On the other hand, pollution emission increases with penetrating energy comsumption in transport sector. Actually, transport sector has ranked top in sectoral growth rate of energy consumption, due to its expanding scales. Its growth rate bypasses the social average value.

Researches in both domestic and abroad sufficiently evidents differences between industry sector and consuming sector concerning energy conservation issues. For transport and building sectors obviously featured with consuming charateristics, energy solutions could not entirely rely on technical breakthroughs. Optimized organization and management, hightened energy prices, favored lifestyles of energy conversation and so on, which are defined as non-technic factors, could also be solutions as equally effective. In most times, operation of energy carriers and systems, choice and use of vehicles are more important and decisive. Choosing public traffic instead of private cars for commutting, reducing properly the personal floor area of dwellings and offices, applying locally proper HVAC systems with part-time and part-space operation, lowering indoor set temperature, ventilating rooms in priority of natural ventilation and so on, can reduce energy consumption while maintaining same level of service. And they are the significant reasons why China consumes only 1/3 of USA in residential and 1/2 of USA in commercial.

Moreover, for cities economically dominated by consuming and service sector, urban building and transport energy consumption are closely related to scale of urban area, density of population and building stock, and lifestyles concerning individual living, transportation, work and leisure entertainments.

This task force aims at development of energy and resource conservative society and city, based on comprehensive understand of impacts of above energy solutions on urban energy consumption. Comparative analysis, based on large scale of typical cities of both domestic and abroad, on urban building and transport energy consumption with different scale of urban area, desity of building stock and population, distribution of population with different lifestyles and incomes, would be carry out for 1) modelling macroscopicly the energy consumption through individual living, work, entertainments and transportation aspcts, and 2) impacts of different distribution of different people with different energy consuming modes upon urban building and transport energy consumption.

And further research on inherent social culture and values behind existing social communities with different lifestyles and consuming patterns from sociological aspects would be carried out, too, for indepth analysis on proper solutions for China urbanization in future and relative policies and mechanism. For detail, quantified contribution of supposed microscopic energy solutions to energy saving of different sectors and the whole nation would be analyzed, from aspects of social community and policy, for evidenting concrete policies and mechanism.

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Part I: Energy efficiency and Urbanization: concepts and methodology

1.1 Fundamentals in urban consuming sectors

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 OECD countries and an increasing number of non-OECD countries are implementing new or renewed instruments adapted to their national circumstances. Beside a pre-eminent role of market instruments (voluntary agreements, labels, information dissemination), regulatory measures are also widely implemented where the market fails to give the right signals (buildings, appliances).

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

With the steep increase in oil price since 2003[1], the cost of oil imports has soared, with severe constraint for the economic growth of the poorest countries. Any efficiency improvement in oil consuming sectors will result in direct benefits in the balance of trade.

Moderating/decreasing energy consumption, for instance in electricity use, will have two benefits:

- Supply more consumers with the same electricity production capacity, which is often the main constraint in many countries of Africa and Asia;
- Reduce the investment needed for the expansion of the electricity sector; this is especially important in countries with high growth of the electricity demand, such as China and many South East Asian countries.

1.2 How moderating/decreasing energy consumption?

Moderation / reduction in the energy consumption can be achieved through technological improvements, but also from moderation in the needs for energy services or from better

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

organisation and management along with improved economic conditions in the sector ("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 of their standard of living (e.g. reduction of comfort temperature; of car mileage). Such reductions, if not supported by changes in people's aspirations, are highly reversible.

Moderating / decreasing energy consumption is first of all a matter of individual behaviour 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 individual energy consumption without decreasing individual welfare.

Avoiding unnecessary consumption is certainly a matter of individual behaviour, but it is also, often, a matter of appropriate equipment: thermal regulations of room temperature, or automatic switch off of lights in unoccupied hotel rooms, are good examples of how equipment can reduce the influence of individual behaviour.

But, similarly, the ability of individuals to reduce unnecessary consumption depends on the technical context where they live and move: badly insulated homes heated at 15°C in winter may consume a lot more than a similar home very well insulated and heated at 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 / 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 / reduction of energy consumption based on behavioural support does not provide any guarantee to be still active after some years: increase in incomes or globalisation through internet and all kinds of media, may result in behavioural changes in the wrong direction as regard energy efficiency.

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, observed or expected, the more attractive are the energy efficient solutions.

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 deregulated, prices normally reflect fairly accurately the supply costs, and are the main drivers of individual's behaviour as regard energy needs. However, for several reasons, prices often reflect only a part of the overall costs of fuels and electricity. It includes none, or just a few, environmental externalities and long run marginal development costs.

As a result, behaviours as regard the needs for energy services and decisions made by final consumers when purchasing equipment or making an energy efficient investment (e.g. retrofitting of dwelling) are rather far from global economic optimisation, creating a gap between the 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 because of its much broader socio-economic aspects, but it certainly determines the effectiveness of such policies measures.

1.4 How to measure energy consumption moderation?

China is confronted with two major challenges related to energy:

- A rapid increase of imports of hydrocarbons, likely to raise severe and growing security and socio-economic concerns
- A rapid increase in the emissions of pollutants and GHG related to energy, likely to raise severe and growing internal health diseases and related social unrest, and growing foreign pressures.

Energy consumption moderation / decrease, as appraised by the TF, have to be replaced in this context, and more generally in the context of the sustainable socio-economic growth in China.

This clearly means that improving energy efficiency in cities in China has two main targets:

- « decoupling » the demand for hydrocarbons from the economic development and the welfare improvement ;
- « Decoupling » the emissions of pollutants and GHGs from the economic development and the welfare improvement.

Insulating a house makes it obviously 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 - the whole stock of dwellings - if, at the same time, more houses are built, dwellings are larger, more appliances are used and/or if the comfort is improved.

Energy efficiency is not just a technical matter, it is also a matter of efficient services: making a phone call instead of a physical visit, using public transport instead of a car to go to work, recycling bottles, reducing heat at night, 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 the energy consumption

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

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

1.2 Urban design/planning and energy consumption moderation

1.2.1 General concept

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

- From an economic viewpoint, it means: a) minimizing the energy bill of the Chinese urban citizens for a given standard of living; b) minimizing the energy bill of China, in particular as regard energy imports.
- From an environment viewpoint, it means: a) improving the living conditions in cities (air quality, noise, congestion); b) minimizing the GHG emissions for a given standard of living of the Chinese population.
- From a social point of view, it means: a) favoring appropriate conditions for life styles and aspirations (standard of living) which minimize energy needs for a given income : b) reducing inequalities as regard living standards.

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

- The first level is that of the urban citizen, both in his current living conditions (the dwelling) and in his urban mobility: minimizing his energy bill and improving his

living conditions while increasing his living standard. It is both a matter of technology and of behavior and life-style.

- The second level is that of the city as a whole: providing a spatial and functional organization of the city likely to minimize the needs for energy services, and providing these energy services minimizing the requirement to imported energy and minimizing the environmental impact, both at local and global levels.

1.2.2 Energy consumption moderation / decrease in buildings and construction

1.2.2.1 A technical perspective

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

- The architectural and technical characteristics of the building itself: insulation, passive solar, exposition to the wind, etc…
- The technical performance of the appliances inside the buildings, in particular in relation to heat and cooling demand
- The supply of solar energy through dedicated panels on the building

Existing buildings offer much less possibilities for improving the technical efficiency than new constructions: no possible modification of architectural components, reduced possibilities for insulation and recourse to solar energy, more constraints for changing the in-door heating/cooling system.

Among existing buildings, possibilities for improving energy efficiency also strongly depend on the age of the building, its size, its location, etc…

1.2.2.2 Behaviors and life styles

Behaviors and life-styles are likely to impact strongly the energy consumption of the buildings, as shown in various surveys.

Two aspects are particularly sensitive from this point of view:

- The perception of comfort : for example, what inside temperature is desired in winter, in summer ;
- The in-door management of the energy requirement: for example, differentiation in inside temperature requirement according to the various parts of the dwelling, according to the time of the day, etc…

Moderating / decreasing energy consumption, from this point of view, is not a matter of frustrating people, but to make them more responsible of their in-door management (maybe with the technical assistance of efficient climate management systems), and to convince them that overheating or overcooling may be just the contrary of comfort.

1.2.3 Energy consumption moderation / decrease in urban transport

1.2.3.1 Technical perspectives

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

- The technical performance of the vehicles used for urban transport
- The use of energy with fewer impacts on energy imports and on environment.

The technical performance of the 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 the new vehicles as compared to the existing ones.

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

1.2.3.2 Behaviors and lifestyles

There are three major aspects in this regard:

- For those who purchase a car, the characteristics of the car purchased (size, power, energy,)
- For those who own a car, the decision to use it or not according to the travel type and purpose, and how (load factor, driving attitude…)
- For all, the use of soft modes (walking, bicycle) according to travel distance.

Average characteristics of the 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 transport alternatives (public transport, bicycle lanes…), but also depend on social/cultural habits that can be influenced (bicycle may be perceived either as an old-fashioned mean for poor people or by a new-fashioned mean for modern people). For those who own a car, it also depends partly on the conditions of use of cars (tolls, parking availabilities and fees).

1.2.4 Energy efficient urban design

1.2.4.1 Heat density and heat supply

Among the three dimensions to be investigated as regard efficient heat supply, the third one (trade-off) is strongly dependant on 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 as regard energy efficient urban design:

- The efficiency improvement of the heat supply in existing buildings
- The design of the future expansion of the city so as to minimize the cost of efficient heat supply services.

As regard this second aspect, two main concepts worth while being investigated:

- Creating high heat density areas within high population density areas (concentration of high buildings) in order to minimize the cost of district heating systems per dwelling ;
- In sunny regions with a lot of available space, favoring solar passive highly insulated low buildings.

1.2.4.2 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 (street for cars versus public transportation lanes versus 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 as regard energy efficient mobility supply:

- The possible reallocation of part of the street network in the existing part of the city for bus lanes, tramways and « soft modes » ;
- The energy efficient urban design of the future expansion of the city

An energy efficient urban design, from the mobility viewpoint, tends first at minimizing the transport demand for daily mobility : it is a matter of appropriate zoning, with provisions of goods and services close to the housing areas, minimizing the distances to go to work, to school, to shopping areas, etc….Second it aims at creating appropriate conditions for to make quality public transportation economically viable, in particular locating high transport demand at quality public transportation nodes, easily accessible by walk 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, tramway or bus lanes, proves to be much more attractive than normal buses. These require much more expensive infrastructures and equipment that just buses on normal streets, but they prove to be altogether more cost-effective for the city if the passenger traffic is high enough. This is a matter of population of the city and concentration of traffic flows, which in turn is a matter of population density and functional lay-out.

Part II: Review of situations and trends of energy consumption and energy efficiency in urban areas in China and worldwide

2.1 Introduction: Character of China urbanization

30 years have been passed since China's Reform and Opening. During these years, China's urbanizing is keeping a fast increasing pace. The urbanizing level was 17.92% in 1978, but reached 44.94% in 2007, so the annual increment is more than 0.9%.

If the increase rate is stable, the urbanizing level in China will become 48% in 2010, reached the world average level in about 2030, and synchronize with world's increasing pace during year 2030-2050.

During 1990 to 2005, china's urbanizing level increased from 26% to 43%. The urbanizing level is uneven among different places. On the top are Shanghai, Beijing, and Tianjin, which is above 70%. Next are Guangdong, Zhejiang, Jiangsu and the three provinces in northeast, with levels ranging from 50% to 60%. On the bottom are Guizhou, Yunnan and Xizang, with levels lower than 30%. Other places' urbanizing levels 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 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, 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 operation 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 control the urban building floor area per capita to be less than 35 m^2 and the new buildings constructed every year to be less than 0.7 billion m^2.

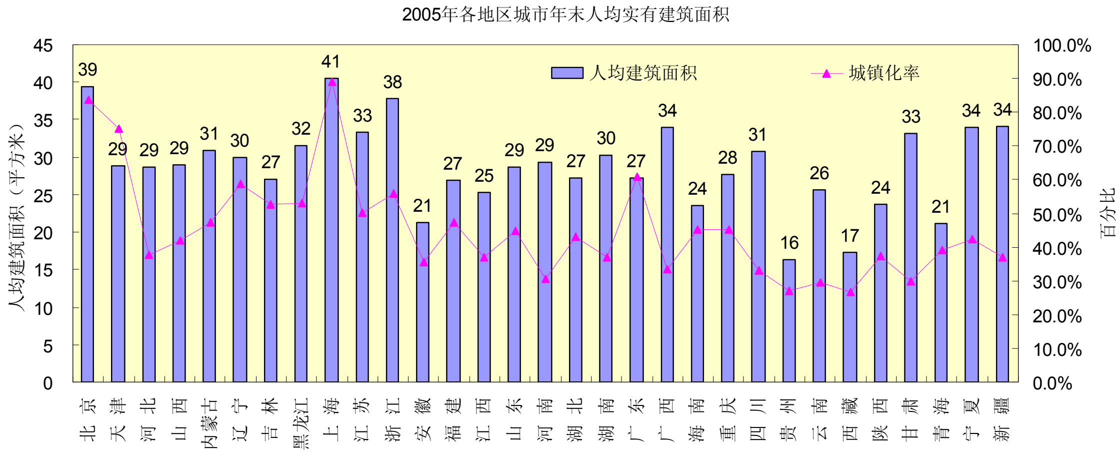

Fig 2-1 Building floor area per capita for each province or typical cities

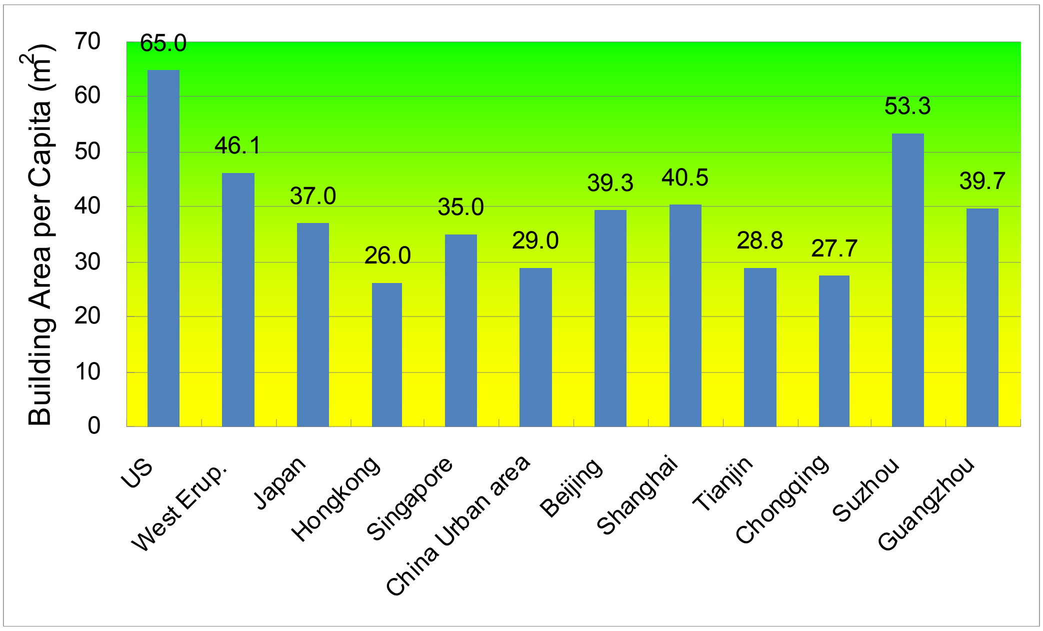

Fig. 2-2 Comparison with developed Countries or areas in the world

The population in 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 large population into the cities will directly increase dramatically the land of residence and various types of public infrastructure. However, the per capita building area we seek will greatly affect the city construction. For example, these are the city construction scope which can be found in three recent versions of “eleventh five-year plan " development program proposal to the year of 2020:

Recently, 2 billion square meter city construction is finished every year. With this speed, 10 billion square meter new construction will be done during the "eleventh five-year plan" program. In 2020, 30 billion square meters building area in cities will be completed and at that time, there will be 45 billion square meter building area, with 54 square meters per capita.

Of the 2 billion square meter's new construction, 1 billion will be in the cities. With this speed, in 2020, 15 billion square meters building area in cities will be completed and at that time, there will be 30 billion square meter building area, with 35 square meters per capita.

New construction area is 0.7-1 billion square meters. With this speed, in 2020, 10 billion square meters building area in cities will be completed and at that time, there will be 25 billion square meter building area, with 30 square meters per capita.

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

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

Moreover, not only does the fast urbanizing pace promote the development of 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 take up a very high proportion in the society.

Take the data of 2005 as an example. The 320 million tones steel production this year consumed 224 million tones standard coal, which took up 11% of the China's merchandise energy consumption. Among the 320 million tones steel, 150 million was used for building, which took up 47% of the production. With the steel used in the railroad, highway, street, bridge and dam added, the steel used for construction took up 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, etc., also came with large energy consumption. Tentative estimate shows that these took up 4%-5% of China's merchandise energy consumption. So according to this calculation, the direct or indirect energy consumption in building and transportation construction took up 20% of the 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 constructions have close relationship with the social consumption idea and culture. In fact, from 2001, China showed the first sign of emphasizing the heavy industry development. Domains like steel, building construction material and real estate showed the high increasing rate which rarely 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, automobile or household appliances. The livelihood consumption pattern in China cities is advancing towards the direction of "high standard", "super lavishing" and so-called "internationalization". As a whole, China's economy is entering the stage of heavy industry development which pulls by the consumption structure upgrading.

It can be found in a study of consumption culture, consumption as an operating symbol of systematization, has became one of the most important factors for self-recognizing. The upper class always shows off their identity and status by lavishing consumption. China's society is in a special procedure of transition and the social unit (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 of building energy consumption resulted from the high standard and lavish building and architecture environment (like big glass curtain wall), as well as the American way of building system maintain. In addition, admiring the American car culture even resulted to traffic jams, heavy pollution and fuel bottleneck.

In fact, after experiencing the horrific energy and economic emergency and environment pollution in the last century, the western world deeply meditate the competing and lavishing way of living in the last 50 years, and the brand-new healthy living campaign had launched. Some people in the United States and Europe are voluntary converted to stoic. For example, they prefer clothes drying rope, curtain, and bicycle to cloth drying machine, air-con and car, 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 are not that "convenient" to use inasmuch as depending on the prediction of weather, which trains the essential human feeling of space and time.

2.2 Actual Energy consumption of households in urban areas in major countries around the world

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 urbanizing, and the energy consumption per capita is not high

However, China is accelerating its urbanizing process, and if no continual measure is taken during the process of high-speed increasing economic growth, it will face rigorous challenge of energy consumption and environmental destruction.

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

Tab. 2-1 Energy consumption statuses for Building and Transport Sectors in developed countries (by Enerdata)

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

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

In a nutshell, the secondary industry and the tertiary industry in China is the leading industry of cities. What's more, in some parts of the provinces, tertiary industry proportion tends to surpass the secondary industry proportion. For example, tertiary industry in Beijing, Shanghai, Nanjing, and Guangzhou have already become the major part of the industry. According to the international convention, with the economy development and urbanizing, most cities' functions will be changed from manufacture to service, and the tertiary industry will become the most important business activities.

As to the cities with largest tertiary industry, building and transportation will naturally become the most significant composition of the city energy consumption.

The situation in China is quite different, building and transportation industry only takes up 33% of the total, which is as the same level of the EU in 1960s. However, since 1990s, the energy consumption of transportation and service is increasing by 8% per year. At the same time, the total energy consumption only increases 3.4% annually. During 2003 to 2005, the direct livelihood energy consumption increased 13.1%, 7.3%, and 9.9% compared to the last

year. The total direct livelihood energy consumption in China is 530 million standard coals in 2005, which took up 24% of the total, and the number increased by 10% in 2006.

The transportation and building energy consumption took up more than 50% of the total part the advance cities, which is as the same standard of 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% in Beijing and the high number come with the highest energy proportion of 50%.

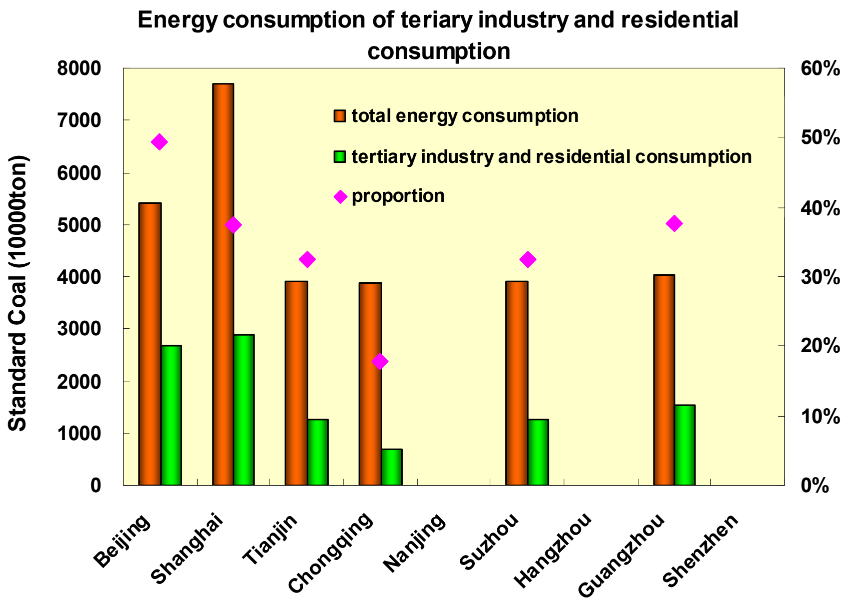

Fig 2-3 Energy Consumption for Building and Transport Sectors in Typical cities of China

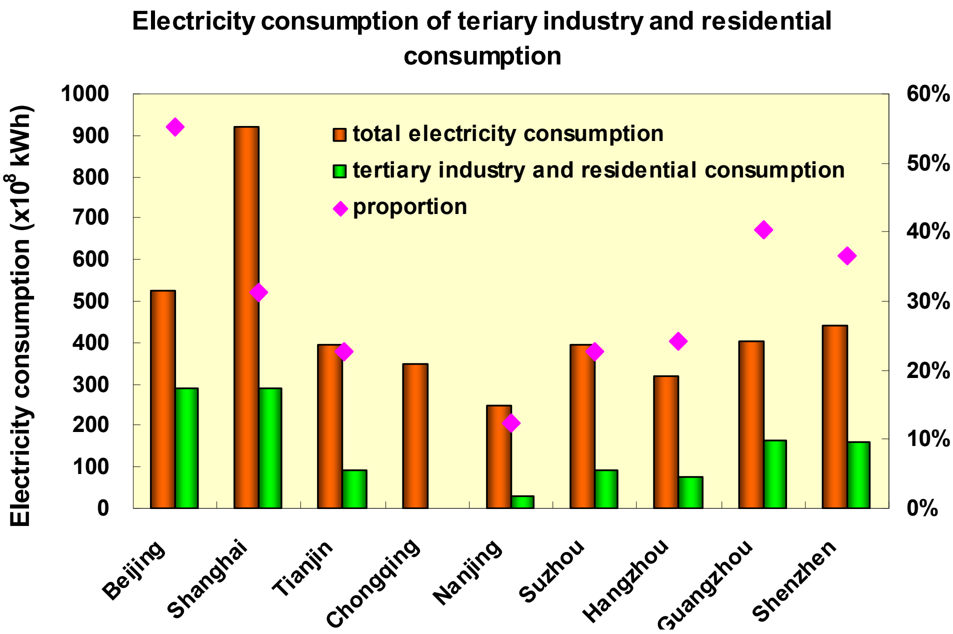

Fig 2-4 Electricity Consumption for Building and Transport Sectors in Typical cities of China

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 shares the highest. Guangzhou and Shenzhen range from 30%-40%. In Shanghai, Tianjin, Suzhou and Guangzhou, it ranges from 20%-30%. Nanjing's is lower than 20%. See figures 2-3, 2-4.

2.2.2 Urbanization and energy consumption: comparison among countries

Research in urbanism finds that large cities provide very positive side effects on economy. Large cities can produced more specialized goods and services to the local market, can accumulate more financial service provision and an educated labour force, as well as often concentring administrative functions.

More generally, it might be possible that smart urbanism has an impact on the competitiveness of a country. For instance, urbanism can be determinant to have high-quality system of transport, and we know that mobility of goods and people is an important condition to economic development. Moreover, oil procurements are a source of impoverishment for many countries, while oil is mostly imported. Because of its impact on energy demand, urbanism is then, once again, linked to competitiveness.

For similar GDP/capita, size, density and urban pattern seem to be the key determinants of energy consumption.

Density of urban areas across the world

In the world, Asian countries have the more dense cities as it is shown in the graph below. Mumbai and Kolkata in India (not in the graph) appear to the more dense cities in the world: near 30.000 habitants per square kilometres. Karachi in Pakistan, Lagos in Nigeria, Shenzhen in China, and Seoul in South Korea are also very dense cities. On the opposite, American cities are less dense.

This comparison is however difficult because borders of cities may differ. American and European cities are pretty large, while some cities in Asia are more narrowed. For instance, the density of Paris stood at 3500 inhabitants/km^2 in the database, while in the core Paris; it is 20.000 inhabitants/km^2.

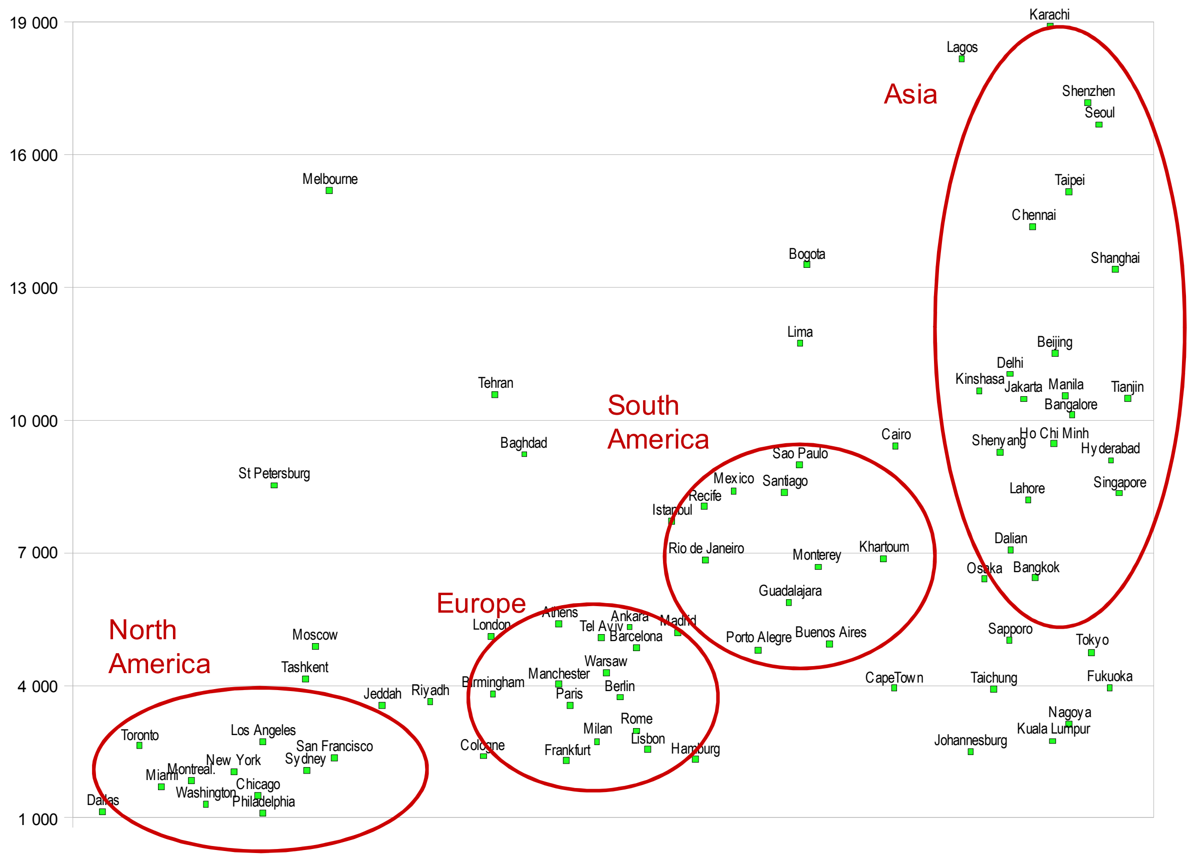

Fig.2-5 Different density for international countries or areas (Source: Enerdata)

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

Tal. 2-2 Average density in main cities

Asia	8200	inhab / km^2
Europe	3200	inhab / km^2
Africa	5300	inhab / km^2
Pacific	2000	inhab / km^2
Middle East	4300	inhab / km^2
Russia and Central Asia	5000	inhab / km^2
North America	1300	inhab / km^2
South and central America	5900	inhab / km^2

Source: Enerdata

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

The term "urban sprawl" describe this evolution towards very spread out cities. People tend to live outside the city, nearby, they are then becoming commuters. Urban sprawl has few characteristics that are reminded below:

- **It is an often a single-use zoning:** commercial, residential, and industrial areas are separated from one another. As a result, the places where people live, work, shop, and recreate are far from one another, usually to the extent that walking is not practical. Therefore, many of these areas have few or no sidewalks.
- **It is a low-density land use:** sprawl consumes much more land than 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 apartments.
- **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 the isolation the area's residential zones have from its industrial and commercial zones.

Evidences of the link between density and energy consumption in transport

We have collected figures revealing that public transportation is more developed when cities are dense. The graph below shows the market share of public transport (train, tube, bus...) and density in main cities. In Asia, public transport is relatively high; it is precisely where cities are dense:

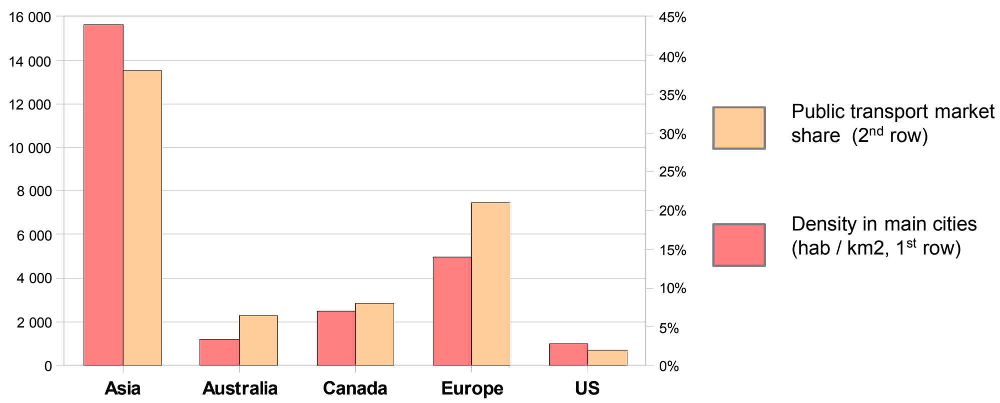

Fig. 2-6 Comparison about the density and public transport

The two maps below deliver the same conclusion. We have collected data of density on one hand, and data of percentage of people using their car to go to work on the other hand. The French national statistical system allows us to gather those figures with high accuracy in terms of geography (Paris and his suburb is divided in more than 400 hundreds sub-element).

We can notice that where density is high, people tend to use other mean of transportation rather than car, and on the contrary, where it is low, the car use become predominant. Thus, in the core Paris and the neighbourhood just aside, density is around 20,000 people per km^2 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 km^2 and 70% of commuters use their car.

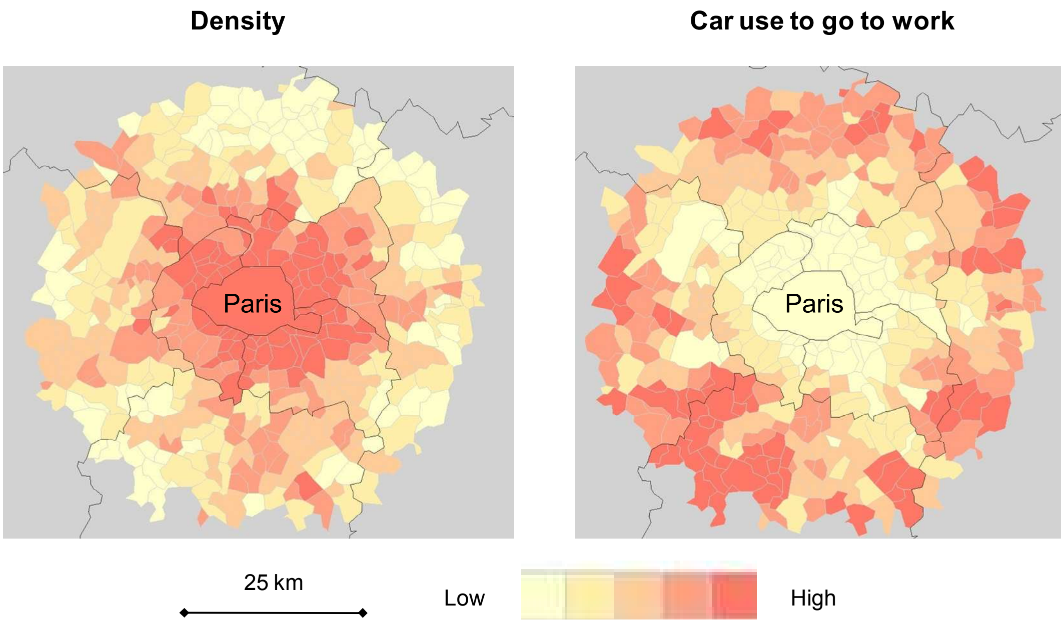

Fig.2-7 Changes of Car use in Paris

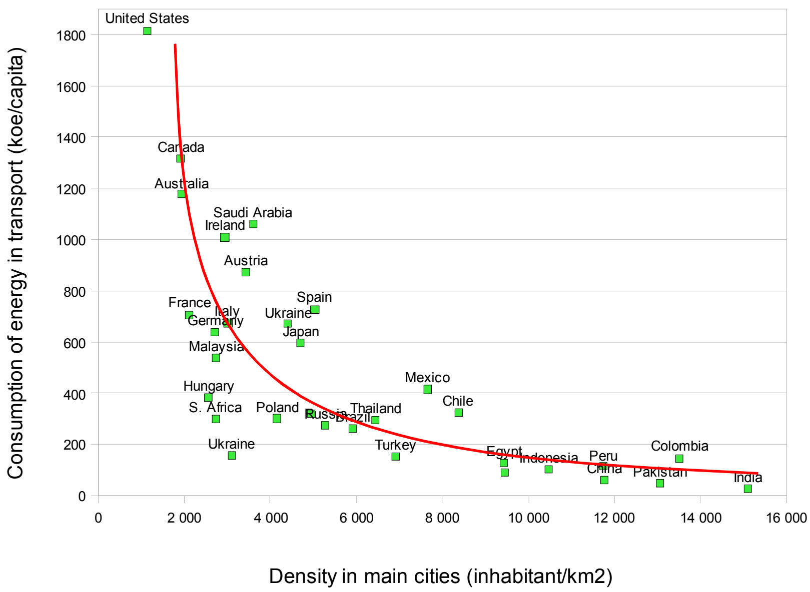

Fig.2-8 Density in main cities

The same idea can be stressed by other indicators. The following graph emphasizes the link between density (axe X) and consumption of energy in transport (axe Y). It appears that, in a country, energy consumption for transport need is high when density is low. For instance, an average American consume 1, 8 toe in transport per year. It is more than twice less in Europe, while the standard of living is quiet similar. This difference is due to urban planning specificity in each continent, European population is more located in cities, and those are denser than in America.

The comparison between USA and Japan is very emblematic of how urbanism can impact energy consumption for transport. In Japan, cities are very dense and the urban sprawl described before has not occurred, or almost not. In USA, the culture is very different. Urban sprawl is part of the national spirit, Los Angeles being often quoted as the paradigm of urban sprawl.

Tab.2-3 Figures at national level for both countries illustrate this difference:

	USA	*Japan*
GDP per capita	43 000 $	37 000 $
Average density	31 inhab. / km^2	350 inhab. / km^2
Number of cars per household	2.4 cars	1.2 car
Consumption of road transport per capita and year	1 820 koe	600 koe

Source: Enerdata

<u>Evidences of the link between density and energy consumption in households</u>

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

As a result of that, we can expect that low density zone, which are characterized with much more individual dwellings, might generate more energy consumption.

<u>Energy used for transport and space heating in relation to urbanization: Paris example</u>

Analysis done before outlines the importance of urbanism in energy consumption for space heating and transport. It might be interesting to estimate the energy consumption for those needs, in both cases: a city characterised with low density, and on the contrary a city highly dense.

Paris urban area, our example, is spitted in three parts: the core Paris, the 1st ring suburb and the distant suburb (<=30 km).

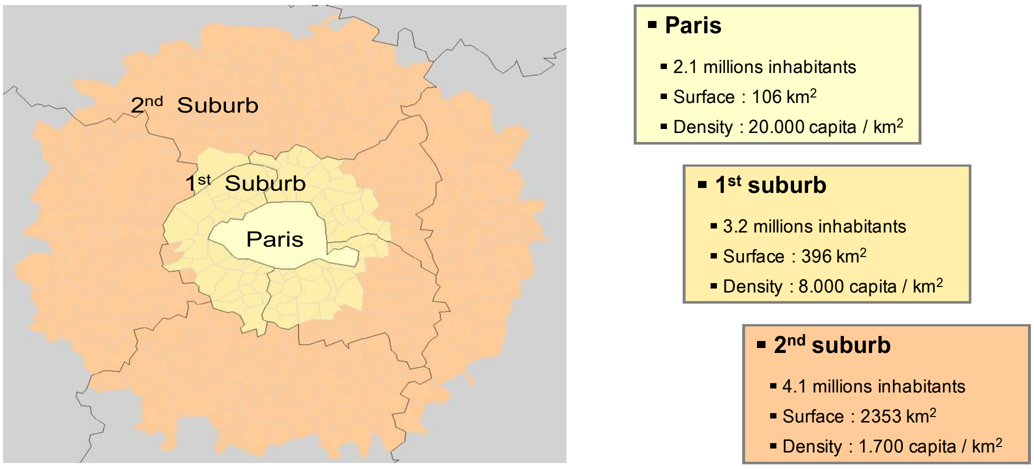

Fig.2-9 Changes in Paris about the suburb area and inner city

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, our estimation shows that energy per capita in core Paris is 0.43 tep per year, while it is 0.73 tep per year in the distant suburb.

Tab.2-4 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**

2.3 Energy Consumption in Building Sector in China

Energy consumption in relation to building includes embodied energy (referring to energy used for building material production, building material transportation, housing construction and maintenance) and operating energy (for building operation during its life time). The fast urbanization of China accelerates the rise of building material industry and construction industry, and the subsequent energy consumption has occupied 20% of total commercial energy consumption of China. However, as this part of embodied energy consumption is generally discussed in chapter 1, it will be focusing on the operating energy consumption in this chapter. The rest and most part of operating energy, in detail, include energy consumed for lighting, heating, cooling and electrical appliances and so on during the whole life time of buildings.

2,3.1 Overall building energy consumption

In 2004, the total building area of China is 38.9 billion m^2, and consumed about 0.51 billion tons coal equivalent of commercial energy, which accounts 25.5% of social total energy consumption, as shown in Table 2-5. Energy consumptions in sectoral detail are listed as following:

Table 2-5 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><td></td><td>billion m2</td><td>TWh</td><td>Mtce</td><td>Mtce</td><td>Mtce</td><td>Mtce</td><td>Mtce</td><td>Mtce</td></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 Yangzi 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 consumptions are converted to standard coal equivalent according to their gross calorific values. And when calculating the total energy consumptions, the 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.

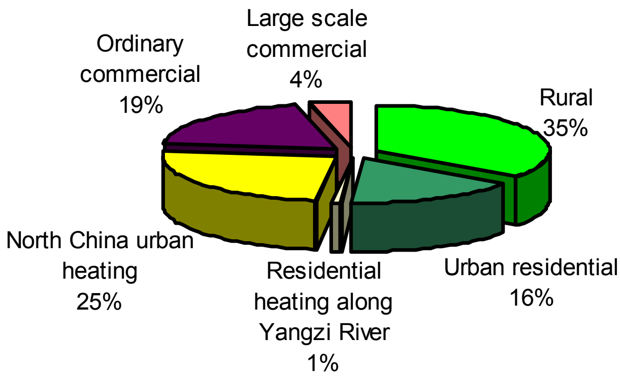

Fig. 2-10: Sectoral energy consumption of China, 2004

2.3.2 Lower energy consumption in China than in developed countries

As shown in Fig. 2-7, although having already reached 510 Mtce, yet China building energy consumptions are far lower than that of developed countries. Even compared with European countries, where there are fairly good policies on building energy efficiency, China's unit area consumptions are only 1/5 of Europe, the per capita value only 1/7 of European level. Even the energy consumption of the less developed rural areas is excluded; there are still folds of gap between China and developed countries. Although the energy statistical methods and

systems of each country are different, yet all the data are match 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' level.

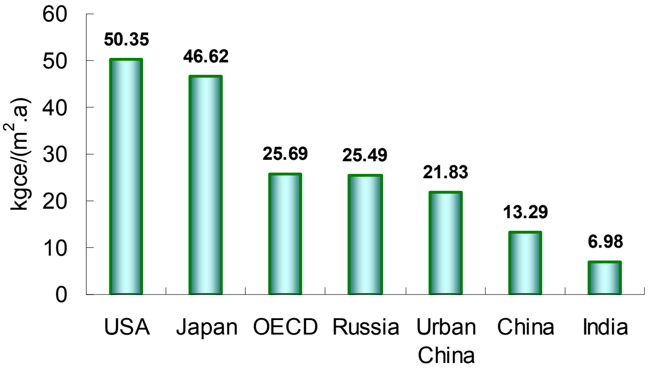

Fig. 2-11: Per unit area building energy consumption, 2004

What is more, in fact, the China heating consumption is not double, as known currently world wide, of developed countries with similar climate. Table 2-2 shows the investigated heat demand of buildings in over 100 residential quarters in Beijing when the room temperature is maintained 18℃. The data is sourced from the real consumption in the year 2006 and amended according to the outer temperature (the correction coefficient is above 1 concerning that the winter of 2006 is fairly warmer than usual, and the outer temperature is higher than design climate parameters of Beijing). And, further, the highest values and the lowest values respectively occupying 10% of the statistical samples are excluded. Table 2-3 shows the heating consumption of some European countries. Concerning the climatic differences, amended consumption data are also provided in the table. According to comparison of Table 2-5 and 2-6, the conclusion that there are no great differences of heat demand between Beijing and European countries could be drawn.

Table 2-5 Heating demand in Beijing buildings (room temperature18℃)

Building category	Heating demand scope kWh/m^2. year
Common residential building	50～100
Common office building	30～90
Hotel	40～90
emporium	10～120
school	30～100

Table 2-6 heating consumption in surveyed some countries

Year	Building type	Country	Heating degree days	Heating consumption (kWh/m^2 year)	Heating consumption after climatic correction (kWh/m^2 year)
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
2004	School	Holland	2784	145	128
2004	School	Greece	1565	55	86

Note:

(1) Energy consumption data source:
(a) 1998 data are from the survey on a batch of energy efficient buildings: INDICATORS OF ENERGY EFFICIENCY IN COLD-CLIMATE BUILDINGS, Results from a BCS Expert Working Group, http://eetd.lbl.gov/EA/Buildings/ALAN/indicators99/index.html.
(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 °C; USA data is from “monthly state, regional, and national heating degree days weighed by population, National Climate Data Centre”, USA, 2006, based on 65 Fahrenheit; Japan data is sourced from “Handbook of Energy and Economic Statistics of Japan”, energy conservation centre, 2006, based on 14 °C; Other European countries are sourced from 2007 Earth Satellite Corporation (www.earthsat.com), based on 18.3 °C.
(3) Correction 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 of 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 folds of high-rise apartments in China (12 floors), and shape coefficient of most office buildings in Europe is over 1.5 folds of that in China. In addition, in recent years, indoor air quality of European buildings is strictly controlled by common application of mechanical ventilation, and the exhaust volume is mostly over 1 times per hour. Besides, the set temperature in European residences varies from 21 °C to 24°C, which shall consume approximately 15% more energy than that of 18°C.

And another important reason could be the 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 which are regarded as the most energy efficient currently. Consequently, although the envelope in China is worse insulated, yet the overall heating consumption appears lower, compared with developed countries.

2.3.3 Great individual differences in domestic buildings in China

It could be obviously 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 the buildings serve the same function in the same geographical region of China. Fig. 2-12 shows the surveyed annual electricity consumption of some residential buildings in Beijing, Shanghai and Chongqing, including all household electric end-uses such as AC, lighting, and household electric appliances, etc. 3~5 folds of individual differences would be easily found.

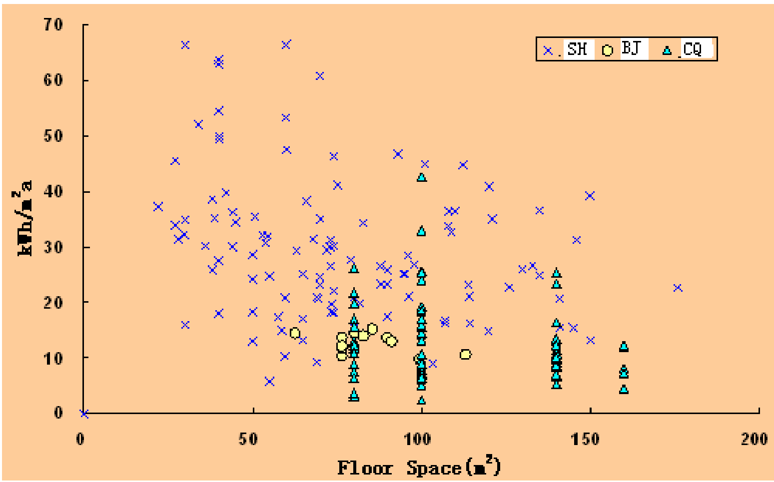

Fig. 2-12: Surveyed residential electricity consumption (Beijing, Shanghai and Chongqing)

Fig.2-13 offers the whole year AC electricity consumption of medium income families in a Beijing residential building, with 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 lives and use the same cooling device – split air conditioner. Further analysis suggests that the over ten times differences in Fig. 2-13 are not greatly concerned with the incomes of each family but with the ages of householder. The older person will have lower AC energy consumptions.

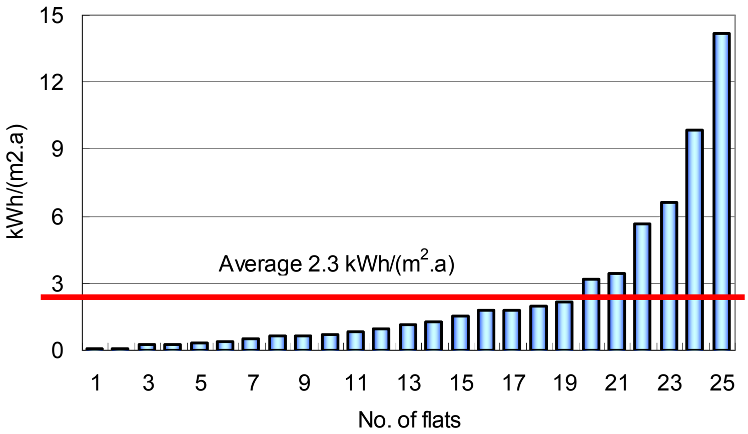

Fig. 2-13: Electricity consumption of split ACs in a Beijing residential building

2.3.4 Differences in commercial sector are also majorly determined by energy consuming modes

Impacts of energy consuming modes on residential energy consumption are as discussed in above paragraphs. And generally, the same conclusion could be well drawn in commercial sector. Folds of differences on energy consumption in commercial buildings can be, in major, attributing to how people use buildings rather than what technical solutions are equipped in buildings.

Fig. 2-14 is the comparison on annual electricity consumption of some office buildings in two famous campuses of Beijing (China) and Philadelphia (US). An office building, with its electricity consumption near to the average level of the whole campus, is selected for in-depth analysis on the energy consumptions of 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 are caused by lighting and appliances, cooling, and ventilation fans in a centralized AC system.

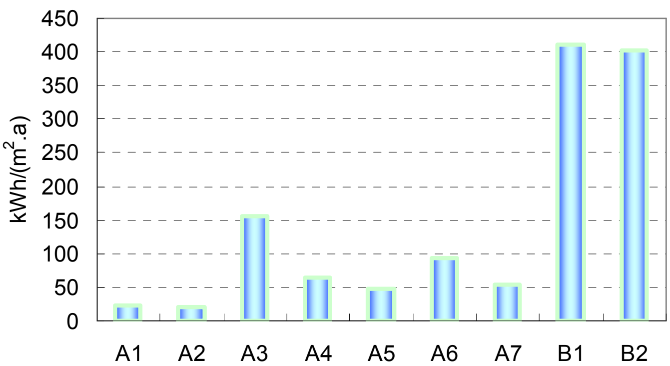

Fig. 2-14: Annual electricity consumption of campus office buildings in Philadelphia (B) and Beijing (A)

Fig. 2-15 illustrates the cooling consumptions of several Beijing government office buildings applying centralized AC systems. Individual floor area of these buildings is similar to this case, but there is an over 1 times gap 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 rate of all occupants.

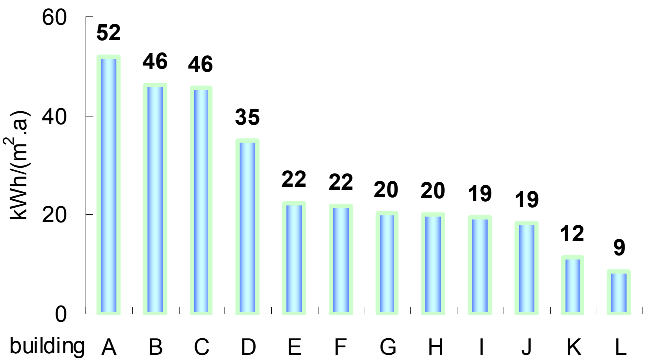

Fig. 2-15: AC electricity consumptions of some government office buildings, Beijing

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

Generalizing above discussions, there are now two different routines for good indoor environment: 1) mechanical one, which consumes great amount of energy, and 2) natural one, which is mainly in virtue of natural means, with complementation of 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. More, the industrial revolution with developing scientific technologies enables greatly the human being to maintain good indoor environment. The concept of "human will overwhelm natural forces" had gradually prevailed, which is un-appraisable consequence of unreasonable expansion of the energy conception in industrial sector to 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 and so on, so as to provide the optimal services for residents. However, it ignores the adaptability and regulation capacity of the human body, and their positive regulation upon the environment. Then two consequences emerge: 1) enormous amount of energy is consumed; if all people follow this living mode, it shall consume 130% of the produced energy in the present whole world; 2) the residents are not very satisfied for lacking free choices of individual control upon indoor environment, which is actually not coherent with human beings' requirements after millions of years' evolution, especially requirements for physical health. The energy consumptions can be reduced in a certain degree through various technical

breakthroughs, yet it is almost an infeasible dream to lower the proportion to 30%-40% from the 130% at present merely by technical solutions. Indeed, endowing the residents with abilities of regulation upon preferred environment conditions may be more psychologically appropriate, and shall be fulfilled by technical innovations. Yet completely relying on mechanical approach to maintain such environment may further increase the demands of energy resources.

Natural routine: in natural mode, various passive means and self regulations of the residents, such as opening window for ventilation and sunshade and so on, should be used for appropriate indoor environment. Also should it 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 environment requirements, it 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, and has no overflow destruction upon the global environment, and would be regarded as sustainable.

To sum up, it is the choice between these two routines that causes, in major, times and even ten times differences of building energy consumption.

2.4 Current Status of China Urban Transport and Energy Consumption

Rapid urbanization and motorization, especially the rapid growth of private cars, has brought great challenge to urban transport system. Figure 2-16 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 millions; 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 3-1, 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. They don’t include the 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.

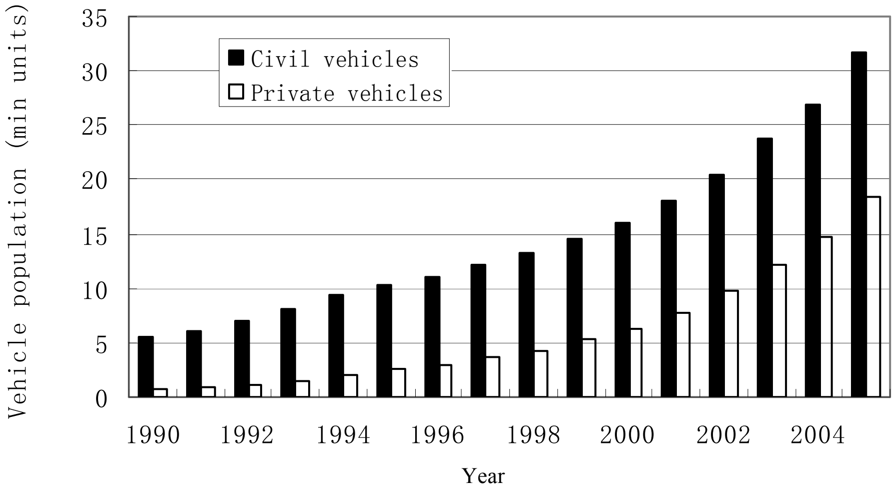

Figure 2-16 Growth of Registered Motor Vehicles in China

Motorization will continue rapidly in the next 10-20 years, yet the 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.

2.4.1 Overview of China Transport Development

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

（1） Initial Phase

Before the industrialization and motorization, urban population increased slowly, and people traveled by foot, animal or bicycle, etc. Most available transport modes were at a low speed, besides the travel distance was generally short. The conflict of transport was no evident in this phase. The travel time and distance are tolerable by most people.

（2） Startup Phase

Along with the development of urban economies, GDP and public living quality, the 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, the motor focus transport development plan is in a great need. Many cities started constructions for new broader vehicle lanes, express ways, separation bridges, and so on. The development of those infrastructures further accelerated the motorization process in cities. Congestions became worse. Lessons showed 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 transport, China cities began to implement series of policies and measures for the Smooth Project, and bring attention to public transport's priority. Ministry and other national government constituted relative regulations, and also raised a goal of establishing a public transport focused system by 2010. During the phase, the conflict between public and private transport became more evident, besides the supply-demand conflict. In that motorization process developed dramatically, and brought significant impact to the urban living condition, many cities added special items in to their urban transport 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 transport issues, but faces many challenges by far. More effort should be enhanced to strategic planning and land using to meet development objectives eventually.

（4） Maturation Phase

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

2.4.2 Demand of Resident Travel Keeps Increasing

Rapid urbanization and the improvement of citizens' standard of living will lead to increasing travel distances and time. Such situations may stimulate the use of motor vehicles and travels 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 will be gradually 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 2-17).

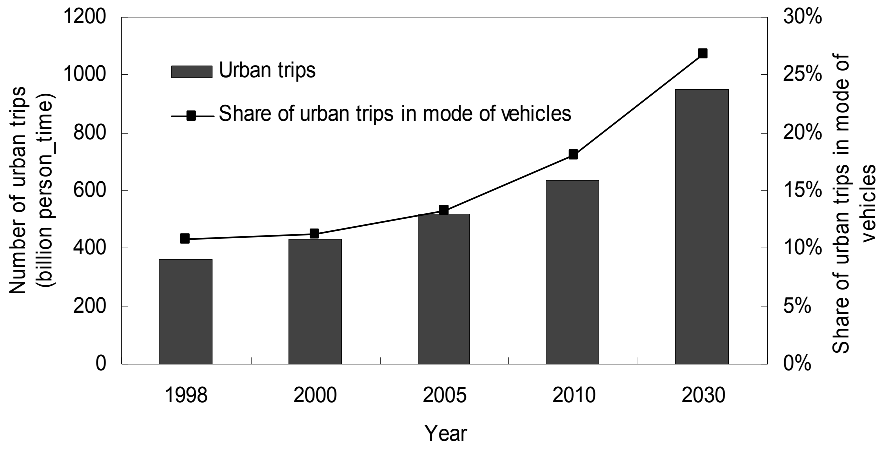

Figure 2-17 Future Personal Trips in China

2.4.3 Urban Passenger Transport Volume Increases Rapidly

The urban public transport 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 increases 7.4% per year, which is close to the rate of GDP increase (Figure 2-18). The urban passenger transport is a major petroleum consumer in China, while it consumes a relative less ration 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. Above 90% of petroleum was used for transport. Most of that was used for urban passenger transport, and small portions were taken by inter-city passenger transport and freight transport. As the study of China National Development and Reform Commission, Beijing's petroleum consumption was 0.9 million tons in 2000, and 2.1 million tons in 2005 respectively. Correspondingly, figures of Shanghai are 1.06 and 2 million tons. Small cars took 80% of the total petroleum consumption.

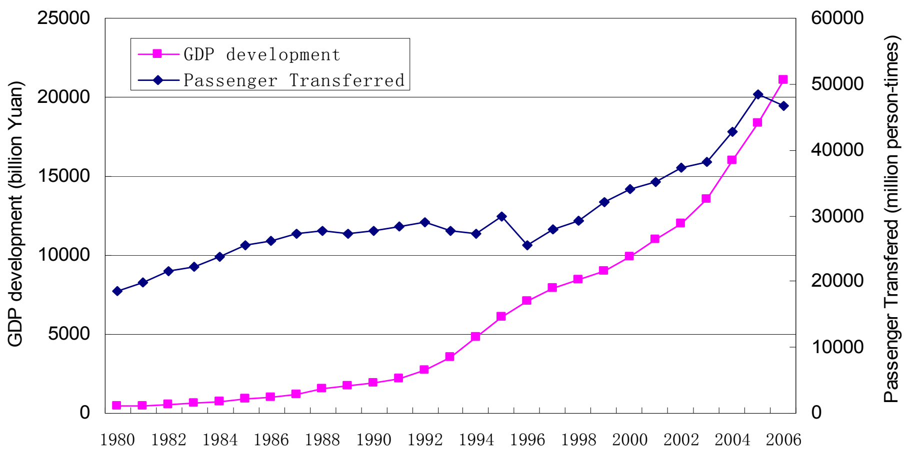

Figure 2-18 Passenger volume of public transport in China

2.4.4 China Transport Energy Consumption Increases Most Comparing with Other Sectors

The transport sector is significantly relied on recourses. The energy consumption for transport increases dramatically along with China's economic development. It becomes one of the most rapidly increasing industries in terms of energy consumption. Data reveals that the transport industry consumed 7.55% of total energy used by the nation. For oil related products, transport takes 31.45%. Two figures increased 10.75% and 12.16% respectively since 2000 (Figure 2-19). There is still evident gap between China and developed countries, regarding to unit energy consumption, utilization rate, equipment efficiency of the transport industry.

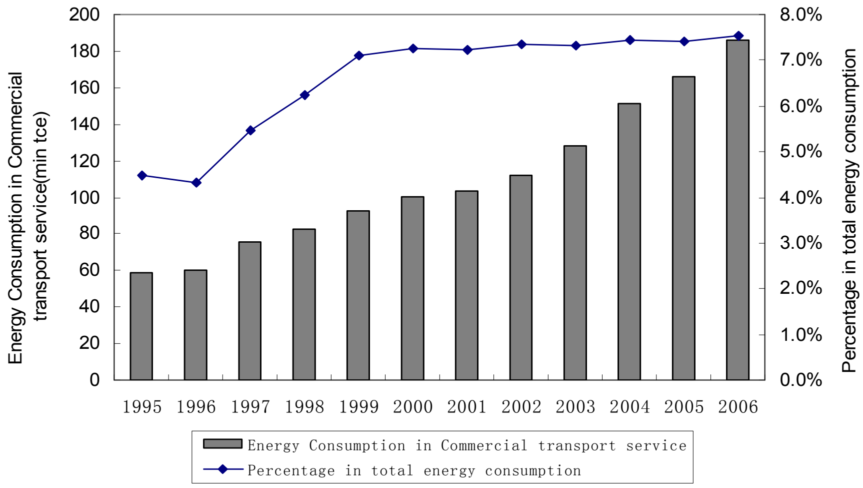

Figure 2-19 Transport energy consumption in 1995-2006

It should be noted that the data in China's statistics system only includes operational transport enterprises whose energy consumption is counted. The current data do not contain those 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 transport industry consumes almost all gasoline, 60% of diesel, and 80% of coal oil. China's petroleum is dependent on foreign import at a high rate of 40%, where the dependence is keep growing. In order to ensure the nation's energy security and reach the energy conservation goal for the Eleventh Five Plan of reducing 20% energy consumption per unit GDP, the transport industry must bring more effort on energy conservation.

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 2-7 shows that cars consume most energy per passenger-kilometer. The energy consumption per passenger-kilometer of light rail, subway and tramcar is only 6% that of cars and the buses (single bus) is 10% of the cars. And cars produce the largest CO2 emission per passenger-kilometer among the six modes of transport, and 7 times the buses. Thus, from views of both of environment benefit and transport efficiency, promotion of mass public

transfer tool such as light rail, subway or tramcar is one the measures to established an energy-effective urban transport system in the future.

Table 2-7 Comparison of Energy Consumption among Various Transport Modes (energy intensity per person-km 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		

2.4.6 Transport Energy Consumption Per Capita is less than Developed Countries, but increasing rapidly

The fuel consumption per capita in China had been increasing steadily from 1990 to 2005(Figure 2-20), where Beijing consumes most fuel as much as 3 times of the nation's average level which is still less than Japan and Korea. Figure 3-5 shows that Tokyo's fuel consumption per capita was less than the national average until 1999. One of reasons to that is the change of preferences of car buyers in Tokyo. It is common for families in Japan having two vehicles. Most of them would like to buy bigger cars at first, so the fuel consumption kept increasing. When families purchase their second car, they become to prefer small or economy-model ones regarding to tax costs and environmental issues. Hence, Tokyo's car population increased continuously, but its fuel consumption per capita stayed at a relative steady rate.

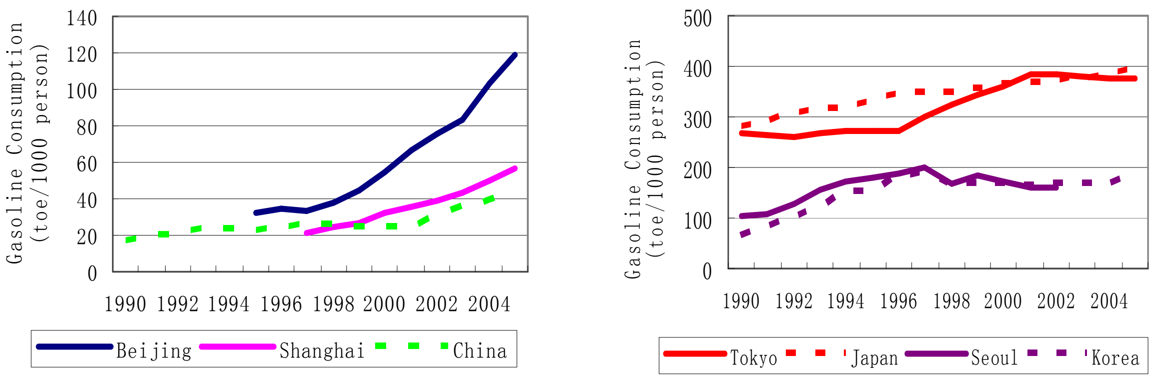

Figure 2-20 Urban passenger transport energy consumption of China, Japan and Korea

2.4.7 Cars Take Largest Portion of Urban Passenger Transport Energy Consumption

It's reported that China urban passenger transport consumed 7.9 million tons of oil in 2000, and the increasing rate from 2000 to 2030 is 5.9%. 45.3 million tons of oil will be consumed in 2030, as 6 times as the amount of 2000, and small cars take 80% of the total urban transport energy consumption, which is undoubted the largest consumer of energy (Fig.2-21).

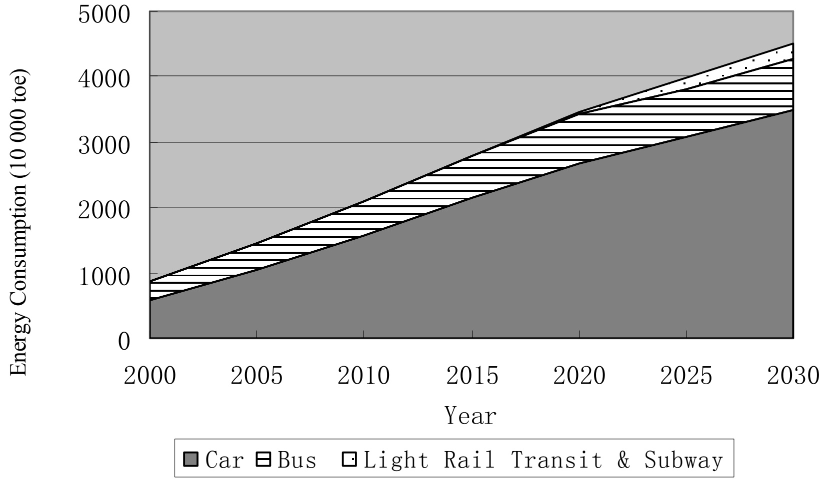

Fig. 2-21 Energy consumption of China urban passenger transport in 2000-2030

Part III: Conclusions

Currently, the proportion of both building and transportation energy consumption in social site energy consumption is as much as about 33%. Following the experiences from developed countries, the proportion would stably increase with the development of economy and the adjustments of industrial structure. For example, the proportions in OECD countries and EU member countries have 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 the whole world nowadays. Currently the urban building's scale continuously increases at the speed of 5%-8% in China and more than 1 billion m^2 of new buildings are built every year. This will not only lead to the double floor area of urban buildings and continuous increase of building operating energy consumption in the next 15 years, but also indirectly promote the fast development of energy-intensive building material (cement, steel, glass, etc.) industries. 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 Hongkong and is close to the average of Japan and Singapore (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, 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 operation 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 control the urban building floor area per capita to be less than 35 m^2 and the new buildings constructed every year to be less than 0.7 billion m^2. This should be the important part of the construction of resource-saving society, and is the basic guarantee to realize the sustainable development of urban construction according to the scientific development view.

Up to now, the building operating energy consumption per capita in China is 1/12 of that in USA 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 USA and 1/3.5 of that in west and north Europe;

the operating energy consumption per unit floor area for urban buildings in China is 1/3 of that in USA; the operating energy consumption per unit floor area for residential buildings in China is 1/3 of that in USA and 1/2 of that in Europe. However, recently, with the growth of the economic and the improvement of the life level and also the influence of the ideas of "joint track with international standard" and "30 years of no backwardness", 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, declaims 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 most of the time in a 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 200~300 kWh/m^2•a, which has already reached the level of developed countries such as the USA, Japan and Europe. The commercial buildings in China like those accounts for less than 5% of the total building floor area, while accounts 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 USA, then the 30 billion urban buildings in China will consume 3 trillion kWh electricity annually in 2020, which is 1.5 times of the current total amount of electricity generation in China; If it reaches the legal building energy efficiency level in German (60 kWh/m^2•a), 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 whole year.

Moreover, rapid urbanization and the improvement of citizens' standard of living will lead to increasing travel distances and time. Such situations may stimulate the use of motor vehicles and travels 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 will be gradually 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 from 2001 on. The improving livings of citizens due to great economic achievements of China inherently increase requirements of daily consumables such as dwellings, cars, domestic appliances and so on. Generally, motivation for industry development is transferring to updating structure of consuming sector of China economy. This necessitates the researches on: 1) impacts of living,

work, leisure entertainment and individual transportation on urban building and transport energy consumption; 2) categorization and distribution of different consuming patterns and their inherent social impacts; 3) objective policies and social guidance for energy conservative society of China; 4) possible consuming pattern in term of energy and resource conservation in future society; 5) proper energy consuming modes in building and transport sectors. These would 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 that, energy consumption moderation / decrease can be achieved as well by more efficient technologies to satisfy one's needs, and by more efficient organization, life-styles and consumption pattern. Moderation / reduction in the energy consumption in consumption sector, especially for building sector and transport sector, can be achieved through technological improvements, but also from moderation in the needs for energy services or from better organisation and management along with improved economic conditions in the sector ("non technical factors"). Moderating / decreasing energy consumption is first of all a matter of individual behaviour 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 individual energy consumption without decreasing individual welfare. At the other hand, it seems that the urban design has influnces on the energy consumption in transportation sector and household space heating.

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

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

This report was provided by Task Force.