China National Energy Strategy and Policy to 2020

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CHINA NATIONAL ENERGY STRATEGY AND POLICY TO 2020:

SCENARIO ANALYSIS ON ENERGY DEMAND

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Executive Summary[1]

1. Background

In November 2003, the Chinese Communist Party (CCP) held its 16th National Congress. It declared that, in the next two decades, China would concentrate on building a *xiaokang shehui*, or "well-off society."

To build a well-off society in an all-round way implies that more of the rural population will enter urban areas, accelerating urbanization. Expansion of urban areas will promote rapid development of services and transportation. Because of rising incomes, increasingly urban families will purchase cars and consume more energy. More rural households will consume commercial energy instead of traditional biomass fuels.

To achieve widespread industrialization by 2020 implies that manufacturing will continue to expand and to play the primary role in China's economic development. The share of industry (mining, manufacturing, and construction) in GDP is still expected to be approximately 50 percent by 2020. Since industry is expanding and much more energy-intensive than other sectors, its energy demand will still rise significantly in the next twenty years.

According to international research, future energy consumption in China may exceed 4 billion metric tons of coal equivalent (tce[2]) by 2020 as she strives for complete industrialization and a moderate standard of living.

Looking at the domestic resources available,[3] China's future energy development will face great challenges in meeting the huge long-term energy demand with domestic resources. Measures and policies adopted to improve energy efficiency, strengthen the competitive power of the national economy, solve domestic environmental problems resulting from energy use and global climate change issues will have significant impacts on China's achievement of sustainable development targets. These efforts will affect whether the objective of building a "well-off society" can be achieved.

In current international experience, no developing economy has been able to achieve a sustainable development path exhibiting low carbon emission rates while maintaining high economic growth. Per capita energy consumption and carbon

[1] We owe thanks to Dr. Jonathan Sinton for reviewing the English version of executive summary and the editing.

[2] One tce equals 29.31 GJ, or 0.70 tons of oil equivalent (toe).

[3] Crude oil production has nearly reached the upper limit of economically viable extraction; increased output in future will be difficult. At present, the natural gas yield is still low and on a per capita basis is far lower than the world average. Coal resources are abundant, but calculated on a per capita basis; coal availability is still lower than the world average.

emissions in developed countries have reached very high levels, up to ten times those in developing countries.

There is no existing development pattern with low carbon emission levels and high GDP growth rate for China to copy. On the other hand, China has great opportunities for future energy development. China's potential energy consumption pattern and energy demand trajectory as projected by research provide positive support for the Chinese government to implement relevant energy strategies, polices, and regulations.

2. Scenario Design

In 1999 the Energy Research Institute (ERI) initiated an in-depth and systematic study of China's sustainable energy development scenarios, named *China's Sustainable Energy Future Scenarios and Carbon Emission Analysis*, with financial support from the Packard Foundation, the Energy Foundation and the Shell Foundation. The following three scenarios were designed in that project:

Scenario 1: If economic development can promote improved energy efficiency, the investment in energy efficiency by enterprises may be restricted to some degree because of competitive market pressures. In addition, clean fuel technologies cannot be widely applied in the next 20 years because of high costs, limited resources, etc.

Scenario 2: Based on the 10th Five-Year Plan and the outlook for the following 10 years, it was assumed that the social and economic development goals would be easily achieved. This scenario can be considered a detailed interpretation of the sustainable economic and energy development for the 10th Five-Year Plan and the following 10 years.

Scenario 3: This Optimal scenario assumes that many appropriate policies and measures were undertaken to improve energy efficiency and to adjust the industrial structure and energy mix. Significant impacts can be achieved by (macro regulation) and sustainable development policies. In the meantime, the external environment will encourage China to make full use of its high quality energy resources in the international market. This will help adjust the energy mix, an essential step. Furthermore, China may introduce advanced technologies, equipment, and human resources so that by 2020 China's energy efficiency will be one of the best in the world).

That project was based on Mr. Deng Xiaoping's three-step strategy of economic development and related government development plans. Although the baseline scenario in that project for the social and economic development trend is quite similar to the goal for development proposed at the 16th National Congress, some scenario drivers still needed to be updated. In addition, in the earlier study, the scenario did not take into consideration that the sustainable development policy could not be implemented smoothly and still with the previous economy development pattern.

Therefore, it was necessary to carry out a detailed analysis of quadrupling the GDP by 2020 and of *Building a Well-off Society* based on the earlier study. To compare the different results under different policy implementation possibilities, three scenarios were designed to study China's energy demand to 2020.

Scenario A (without special policies): Quadrupling GDP by 2020, assumptions regarding social, economic, and energy based on Scenario 1 of the earlier study and Scenario B of this study.

Scenario B: Quadrupling GDP from 2000 to 2020; other factors similar to Scenario 2 of the earlier study.

Scenario C (also called policy strengthening scenario): Quadrupling GDP by 2020, emphasizing the influence of industry, energy, and environmental policies; other factors similar to Scenario 3 of the earlier study.

3. Scenario results[4]

3.1 End use energy demand and final energy mix

In 2020, final energy demand in the three scenarios is 2,480 million tce (Mtce), 2,250 Mtce, and 1,910 Mtce, respectively. The energy demand of Scenario C is the lowest because effective policies and measures were considered, including adjustments to the industrial infrastructure, technical improvements, and other similar measures.

The three scenarios show similar trends, with the rate of increase in high quality energy greater than that of total end use energy demand. The demand for natural gas, electricity, and oil will increase rapidly, while demand for coal will rise more slowly than the average for final energy consumption.

Industry will continue to be China's main energy consumer in the next 20 years. However, industrial energy demand will be quite different under different development strategies. Regardless of which path is chosen, the portion of final energy consumption by industry will decrease while that by the transportation and buildings (including both commercial and residential buildings) will increase quickly.

[4] The results in this paper do not include biomass energy, which total about 220 Mtce per year.

3.2 Primary energy demand and primary energy mix

Scenario C assumes that more non-fossil fuels, such as renewable energy, will be used in power generation while in Scenario A it is assumed that fossil fuels will continue to dominate power generation and non-fossil fuels will have no significant increase in their shares in power generation. In Scenario C, China's total energy consumption will reach 2,470 Mtce by 2020,while in Scenario A, it will reach 3,280 Mtce, 33 percent higher than in Scenario C.

The rate of electrification provides an important indicator in assessing a country's living standard. Experience from the developed countries shows that demand for electricity and heat in commercial and residential sectors will significantly increase when per capita GDP reaches middle-class standard of living. International experience shows that coal should be used mainly in transforming sectors in order to solve environmental issues. Considering the availability of various energy resources, even if non-fossil fuel sources are developed quickly, coal will still be the main energy source in China. However, in Scenario C, in which most industrial boilers will still use coal, and more coal will be used for power and heat generation, the commercial and residential sectors will consume less coal and more electricity, natural gas, and oil. Even so, in Scenario C, China's annual coal demand in 2020 will reach 210 million tons (Mt). In Scenario A, China's coal demand in 2020 will reach about 290 Mt, double the current rate.

Looking only at domestic oil supply capacity, Scenario C assumes energy-savings in transportation and stricter fuel efficiency standards. The result is that energy consumption (converted to primary energy) in transportation will drop from 373 Mtoe (533 Mtce) in Scenario A to 287 Mtoe (410 Mtce) in Scenario C. But in either case, total nationwide oil demand in 2020 will exceed 450 Mtoe (643 Mtce).

Compared to oil, the exploitation and utilization level of natural gas is very low. It is assumed that in all three scenarios the demand for clean energy in the commercial and residential sectors will be inevitable. In the meantime, more natural gas will be used in the chemical industry to improve energy efficiency. In the power sector, besides using natural gas to adjust the peak demand for electricity, CHP (combined heat and power) and CHCP (combined heating, cooling, and power) systems will primarily use natural gas. Based on the above, China's natural gas demand in 2020 will reach 16 billion cubic meters, five times the current level.

The portion of final energy consumption by the industry sector will drop gradually with the rapid increase in energy use in other sectors. In Scenario C, the portion of total energy consumption by industry will drop from 72.7 percent in 2000 to 56.7 percent in 2020, and in the other two scenarios it will drop to less than 60 percent. After achieving industrialization, energy demand from manufacturing will increase slowly, while demand from buildings and transportation will increase rapidly.

3.3 Electric power demand and power generation structure

As there are some differences among the three scenarios in technological improvements and energy efficiency polices, electricity demand in the three scenarios are also different. Power demand in Scenario C is 430 TWh lower than in Scenario A. The different assumptions concerned power generation structure, energy efficiency of generation, and transmission losses. In Scenario C, if primary power (hydro, nuclear, and wind) is developed quickly and the efficiency of power generation is improved by eliminating low-efficiency equipment, installed capacity will increase from 282 GW to 865 GW, at a rate of 29 GW annually. By contract, in Scenario A, annual additions to capacity must be 33 GW to meet the final electricity demand.

All three scenarios encourage significant exploitation of hydro resources. By 2020, the capacity of hydropower in Scenario A will be 190 GW and that in Scenario C will be 240 GW (including 40 GW of small hydro power). This means installing additional hydropower capacity of six to nine GW annually over the next 20 years. Optimistic assumptions were also made regarding the development of nuclear power in Scenario C, in which nuclear power rises from 2.1 GW in 2000 to 40 GW in 2020; an annual rate of increase of 16 percent.

Despite the changes in all the scenarios, fossil fuels, particularly coal, will still be the major source of future power generation. In Scenario C, coal used for power and heat generation reaches 1,070 Mtce in 2020, accounting for more than half of all coal use.

3.4 CO2 emissions

By 2020, carbon emissions in scenarios A, B, and C will reach 1,940 million metric tons of carbon (MtC), 1,716 MtC and 1,437 MtC respectively, representing a difference of 500 MtC between Scenario C and Scenario A.

Causes for such great disparity include the total amount of energy consumed and the energy supply mix. For instance, energy consumption in the three scenarios will be 3,170 Mtce, 2,780 Mtce, and 2,320 Mtce, respectively for Scenarios A, B and C, and the proportion of coal in the fossil fuel mix will be 65.3 percent, 64.3 percent, and 63.1 percent, respectively.

According to the scenario results, without implementation of strong policies, per-capita annual CO_2 emissions could reach 1.33 tC by 2020, more than twice that in 2000. However, if appropriate policies to improve power generation and end-use energy efficiency are implemented, per-capita CO_2 emissions will rise more slowly. In 2020, they could be less than 1 tC annually, just 33 percent of current per-capita CO_2 emission levels in OECD (Organization for Economic Cooperation and Development) countries.

As energy consumption in buildings and transportation increases rapidly, so will the portion of carbon emissions from these two sectors. In Scenario A, the annual carbon emissions from the commercial and residential sectors increase from 130 MtC in 2000 to 490 MtC in 2020, an annual rate of increase of 6.9 percent. The share of carbon emissions from these two sectors also increases from 16.1 percent in 2000 to 24.9 percent in 2020. But because Scenario C assumes that many energy efficiency policies are implemented, the amount of carbon emissions are reduced, and would only increase to 376 MtC in 2020, an annual rate of increase of 5.5 percent.

3.5 Influence of industrial infrastructure changes on energy demand

For a long time, an important role of industrial infrastructure changes has been to affect energy demand and carbon emissions. In the past 20 years, China's economy has allowed development to increase at a steady rate. As a result, there is high energy consumption and heavy pollution. With technological improvements, globalization and entrance into the WTO, China has the opportunity to realize rapid development with lower energy consumption rates. Hence, economic development strategy will have an important effect on China's future energy demand.

Scenario results show that if industrial infrastructure is improved and other conditions remain unchanged in scenario B, final energy demand will only rise to 2,327 Mtce, 2.3 percent lower than in Scenario B. The analysis of this new type of industrialization assumes that: (1) the structural patterns in industrial sectors are unchanged, based on the GDP structure of 2000; (2) there is improvement in the energy efficiency of energy-intensive industries, light industry, and manufacturing industry. Under these assumptions, energy demand in industry in 2020 will reach 1,260 Mtce, 7.7 percent (90 Mtce) higher than Scenario B.

3.6 Influence of energy mix adjustment on energy demand

China's energy mix depends primarily on coal (about 70 percent). Calculations show that if China's energy mix were the same as the average world level, its energy consumption would be cut about 200 Mtce.

Of the three scenarios, Scenario C presents the strongest case for energy structure optimization. Policies suggested in Scenario C include increasing the share of oil and natural gas in the energy mix and developing non-fossil fuels like hydropower, nuclear power, and alternative sources.

Two additional cases were designed in order to study the sensitivity of total energy demand to changes in the energy mix. In the first sensitivity case, the energy mix of 2000 is retained and other factors are the same as in Scenario B, resulting in energy demand of 2,980 Mtce in 2020, 86 Mtce (3.2 percent) higher than Scenario B. In the second case, the energy mix of 2000 is the same as in Scenario C and other factors are the same as in Scenario B. The resulting energy demand in 2020 decreases from 2,980 Mtce to 2,770 Mtce (4.3 percent change).

3.7 Influence of energy supply pattern on energy demand and carbon emissions

The energy supply pattern will affect not only the primary energy demand but also GHG emissions. To meet a given final energy demand, energy transformation will play a decisive role on GHG emissions.

Scenario C assumes that huge energy projects like West-east Power Project and West-East Gas Project can be implemented smoothly, domestic natural gas market and hydro resources will be well utilized, and that coal-based units will be improved. But in both Scenarios A and B, there are less optimistic assumptions about power generation infrastructure improvements. These different assumptions result in different carbon emissions projections.

Because final energy demand in the three scenarios differs, it is difficult to directly compare the influence of power generation structure on carbon emissions. Therefore, a sensitivity analysis of the power generation structure was conducted that assumed seeking the same electricity demand. The shares of non-fossil fuels in the first sensitivity case is 38 percent and in the second case is just 22 percent. The results show that carbon emissions in the first case would be 1,630 MtC, 129 MtC, or 7.3 percent less than in the second case.

In addition to economic development models and energy mix, energy efficiency policies and environmental policies have an important effect on the future energy demand and carbon emissions in China. The influence of these policies on energy demand includes: (1) changes in newly built production capacity and people's lifestyles, primarily the energy consumption of buildings, cars, and appliances; and (2) energy efficiency improvements to existing production capacity. Scenario results show that if energy efficiency policies can be implemented smoothly, the available energy savings potential will be fully realized and the objective of increasing products without increasing energy consumption may be realized by 2020 for some energy-intensive industries like iron and steel and building materials.

Environmental policies have important influences on energy technologies, energy policies, and industrial polices. This study considers primarily policies of regional environmental control and municipal air quality. Although the influence of international actions to reduce GHG has been considered, specific GHG indicators have not been considered in this study. Even so, results show that environmental policy has a great influence on carbon emissions.

4 Conclusions

Scenario results show the following:

- *Energy demand is related to many factors, including, among others, economic structure (industry and products), technological improvements, energy efficiency policies and their implementation, and energy mix. Different economic development models and different policies will result in* *markedly different energy demand. Future primary energy demand cannot be considered a firm number; it may range from 2,400 to 3,200 Mtce in 2020.*

- *Even under the same rate of economic development, energy demand may vary by up to 800 Mtce because of variability in energy supply mix, energy efficiency, and related factors.*
- *The energy demand that would result from Scenario C is an optimistic forecast based on smooth improvements in economic structure, well-implemented energy and environmental policies, etc. This scenario offers the lowest estimate of future energy demand and significant efforts should be made to realize that goal.*

The scenario results can be summarized as follows:

- *If the sustainable development strategy consisting of improving energy efficiency, improving the energy mix, and strengthening environmental policies can be fulfilled, China can realize the goal of doubling energy demand to support quadrupling GDP in the next 20 years.*
- *Choosing the path of sustainable development is a decisive and critical factor for future energy development.*
- *The rate of increase of energy demand from industry will be lower than that from other sectors, and some energy-intensive industries may realize increased production without increased energy consumption.*
- *Buildings and transportation will be the key sectors affecting the energy demand in the next 20 years. Therefore, significant attention should be paid to the energy efficiency in these sectors.*
- *Improving the energy supply mix may greatly reduce future energy demand. Therefore, China needs to promote the improvement of the energy mix, especially the final energy mix.*
- *Energy mix improvement is a long-term task. Therefore, it is important to regulate mid-term and long-term energy development strategy and energy supply schemes (including natural gas, oil, and hydro power) as soon as possible.*
- *Strengthening energy conservation and improving energy efficiency will have considerable influence on future energy demand.*

1. China's Energy Challenges of Building a Well-off Society in an all-round Way

1.1. Criteria for building a well-off society in an all-around way

1.1.1 Implication evolution of "Xiaokang Shehui" or "well-off society" terminology[5]

In the viewpoint of historic evolution, the concept of well-off society may include 3 stages: well-off idea proposed by our ancestor, well-off society designed by Mr. Deng Xiaoping and well-off society proposed by the 16th Congress of CCP. There are correlations and differences among these 3 concepts. In this paper, the later 2 concepts were compared and studied.

The word of "Xiaokang " or "the well-off" is derived from *the Book of Songs*, a poem completed in the 11th century B.C. to the 6th century B.C. in China. In the end of 1970's, Mr. Deng Xiaoping put forth a new meaning of well-off and well-off society. In 1979, he announced the development goal of 2000 was to live well-off. " Well-off was defined as China reaching USD $800 per-capita GDP".

The concepts of "four modernizations"[6] and "well-off society" indicated that great changes of China's modernization developing stratagem. In 1978, Mr. Deng Xiaoping proposed the developing goal of "fulfilling modernization by 3 steps": solving the basic living problem in the end of 1980's, reaching well-off level in the end of 1990's, and realizing modernization in the middle of 21st century.

After over 20 years' efforts, people's general living standard has reached well-off level and basically realized the former two steps of the 3-step strategy. According to the China's actual situation, the current well-off level is still low level, not all-round and unbalanced. [7]

In the 16th Congress Bulletin of CCP, it was announced that all efforts would be concentrated on "building a well-off society in an all around way" in the first 20 years of the 21st century and realize modernization in the middle of 21st century.

The planning of a well-off society in the 16th Congress has inherited and enriched Mr. Deng Xiaoping' ideology on well-off society.

1.1.2. Criteria for building a well-off society

In early 1990's, according to the international standards, a special group coming from 12 governmental agencies, including State Statistics Bureau, planning agency,

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[5] Resources: http://www.china.com.cn/chinese/zhuanti/ , http://www.macrochina.com.cn
[6] i.e., the modernization of agriculture, industry, national defense and technology.
[7] The so called low level means that the income just reached well-off level and just and is still middle and lower income country. The so called not all-round has two meaning, (1) the coverage and scope of the residents for well-off level is not all-round, (2) the present living standard in well-off society is not all-round. The so called unbalanced means there exists difference both between urban and rural and among different income estate.

financial agency, health and sanitation agency, education agency and so on, had confirmed the following 16 appraisal indicators in terms of 5 aspects including economic development level, living standard, population quality, inspirit living standard and living environment.

- **1 indicator of economic developing level:** per-capita GDP
- **8 indicators of substantial or physical living standard:** per-capita disposable income of urban resident, per-capita disposable income of rural resident, per-capita floor space of urban resident, per-capita living area of rural resident, per-capita protein absorption, per-capita area of paved roads of city residence, percentage of administrative village access to highway, Engle coefficient
- **3 indicators of population quality:** adult literate rate, per-capita life expectancy and infant death rate
- **2 indicators of spirit living standard:** percentage of household expenditure on education, culture and entertainment, coverage rate of TV sets.
- **2 indicators of living environment:** rate of access to forest, percentage of qualified counties on rural sanitary heath care

Building all-round well-off society has profuse implications. In fact, the above appraisal indicators can’t reflect all the contents including economic development, people’s living standards, technology and education, social activities, resource and environment, democratic and legal system, moral and so on. Hence, some researchers think that there is no need to establish all-round indicators and just need one comprehensive indicator of percentage of social insurance.

However, in term of macro control, it is required to stipulate typical appraisal indicators to inspect the developing process of well-off society, which may help the government to make in-time policy adjustment. In term of the influence of building all-round well-off society on the future energy demand, it is also necessary to quantify related indicators for rational research.

On the basis of the developing goal proposed at the 16th Congress and relative domestic and overseas studies, the related strategic goal that has close relations with energy development is described as following

- **Economic growth rate**: It is the fundamental chief task for establishing all-round well-off society to quadruple the GDP of the year 2000 by 2020. By 2020, by comparable price, China’s GDP will reach about 36000 billion Yuan, which may exceed 4000 billion US$ based on the current exchanging rate.
- **Population and urbanization rate:** At present, the growth rate of China’s population has dropped to below 10‰. According to “China’s population white book”, the nationwide population in 2010 will be controlled below 1.4 billion and that in 2020 will be within 1.5 billion.
- **Per-capita GDP:** On the basis of the current exchanging rate, per-capita GDP should exceed 3000 US$. While on the basis of PPP, per-capita GDP

may exceed 10000 US$, which ranks the average standard of mid income countries' level.

- **Average life span of expectancy**: Chinese people's average life expectancy will be 73 in 2010 and 74 in 2020, which is near the standard of high-income countries' level.
- **Residential conditions**: MOC has advanced the living standards of well-off society as following: one suit of house for one household, one room for one people, function matched facilities, rounded appliances. It is estimated that the per-capita living area of city residence may reach 23~30 m^2, and that of rural residence may exceed 30 m^2.
- **Per-capita electricity consumption for living:** It is an important indicator to describe the living standard level of a country or a district. It is estimated the per-capita electricity consumption for living may reach 712 kWh in 2020, the current mid income countries' level
- **Engle coefficient:** In the coming 20 years, the nationwide average Engle coefficient will drop from over 40% at present to about 30%. Engle coefficient of the rural residences will decrease to 38%, while that of the city residence will decrease to 25%.
- **Gap between the rich and the poor (Geordie coefficient):** On one hand, this indicator reflects the impartiality on the social income distribution; on the other hand, it has influence on energy fuel. At present, China's Geordie coefficient hasn't departed too much from the average value. Anyway, the welfare policy and revenue policy should be adjusted in order to establish all-round well-off society. In 2010, the Geordie coefficient may keep current level of 0.45, while in 2020, it should drop to about 0.4.
- **Living environment indicator**: By 2010, most regional environment quality will be improved and rate of access to forest may reach 20%, SO_2 and solid pollutant emission may decrease 10% based on current level, the disposal rate of polluted water may reach over 60%.

1.2. International comparisons of social/economic/energy status at the level of per-capita GDP over 10000 US$

In term of the developing process of the western industrialized countries, there existed apparent correlations between economic development and energy consumption. The historic review on the social/economic/energy situation of the developed countries when per-capita GDP reached 10000 US$ (so called mid-level developed countries) may help to learn and understand China's future economic and energy development when China enters such a stage.

In this paper, comparison and analysis on social, economic and energy conditions of developed countries when the per-capita GDP reached 1000 US$ were conducted on the basis of PPP value provided by World Bank. The selected indicators included economic development, industrial structure, urbanization rate, household vehicle own level and related energy consumption. The selected countries included industrialized OECD countries (such as USA, UK, etc.), recently rising industrialized countries (such as Korea, Singapore, etc.) and Japan who has the highest energy efficiency.

1.2.1. Per-capita GDP and economic development

The time for Western developed countries to realize per-capita GDP of 10000 US$ were quite different. Tab. 1-2-1 described the per-capita GDP of some developed countries and related time on the basis of PPP value provided by World Bank.

Tab. 1-2-1 Per-capita GDP of selected developed countries (regions) by PPP

USA	9946（1961）	11649（1965）	12963（1970）	13682（1975）	15440（1978）
UK	10133（1978）	10167（1980）	11237（1985）	13217（1990）	15073（1999）
Japan	9340（1978）	10072（1980）	11771（1985）	14331（1990）	15105（1992）
Hong Kong	9956（1983）	10599（1985）	13969（1988）	14849（1990）	15601（1991）
Singapore	9395（1987）	11710（1990）	13702（1993）	14855（1994）	15838（1995）
Korea	9165（1995）	9695（1996）	10131（1997）	9454（1998）	10451（1999）

Note: Per-capita GDP was based on 1985 US$ by PPP and the related time was in the bracket.
Resource: Website of World Bank.

Tab. 1-2-2 Economic rapid increasing period and per-capita GDP of selected developed countries or region

Countries (regions)	Rapid increasing period（Lasting period）	Per-capita GDP	Growth rate (%)
Japan	1961-1973（12years）	2200-14000	9.8
Germany	1951-1955（5 years）	2400-4300	9.1
Korea	1983-1994（11 years）	2870-8260	8.8
Singapore	1961-1994（33 years）	3572-19420	8.3
Malaysia	1987-1994（7 years）	3891－6478	8.2
Hong Kong	1961-1994（33 years）	3705-21650	8.1

Greece	1961-1973（12 years）		7.7

Source: “ World development report” of 1996 and other related years.
Note: Per-capita GDP was based on 1994 US$ by PPP.

In general, after the economics had developed to certain degree, there existed an accelerating period, or called rapid increasing stage, which might be seen from many countries’ experiences. In addition, this period usually happened under the condition that the per-capita GDP had reached 3000 US (influenced by such factors as exchanging rate, etc.) and this rapid developing period usually last for a long time.

The statistical data also showed that the countries that entered the rapid increasing period lately usually had a relative higher increasing speed. With the development of science and technologies and the existed advantage of “ later development” in developing countries, the lasted period when per-capita GDP kept at the level of 10000~15000 have become shorter and shorter.

1.2.2. Industrial structure

The general tendency of economic development shows that the focus of industrial structure changes from primary industry to secondary industry, then to tertiary industry.

According to the developing process of the industrial structure of USA and Japan (as shown in Tab 1-2-3), although their rapid increasing period when per-capita GDP based on PPP began to exceed 10000 US$ happened in 1960’s and early 1980’s respectively, but the same point is the evolutive tendency of industrial structure. During that period, percentage of tertiary industry in these two countries raised stably, while the secondary industry tended to decrease slowly and the primary industry dropped stably. In addition, the percentage of tertiary industry exceeded 50% in the whole industrial structure.

Tab 1-2-3 Comparison of industrial structure in selected countries and regions

	Year	Primary industry	Secondary industry	Tertiary industry	Period with per-capita GDP of 10000~15000 US$
USA	1960	9	31	63	1961－1978
	1970	4	30	66	
	1980	4	29	67	
Japan	1980	3.6	37.6	58.8	1978－1992
	1985	3.1	36.4	60.5	
	1992	2.5	35	62.5	
Hong Kong	1995	8	43	49	1995－
	1998	6	43	51	
	2000	5	44	51	

Note: (1) Materials of USA came from *Industrial construction and policy*, edited by Gong Yangjun.
(2) Materials of Japan came from *Japan’s economy*, edited by Feng Zhaokui.
(3) Materials of Hong Kong came from *Research of world economic statistics*, edited by China social & science academy.

As shown in Tab 1-2-4, most developed countries in the world are in the process of mid-late industrialization or have completed industrialization. In these countries, with the rapid development of advanced high-techs, the GDP percentage of the high added-value industries has exceeded that of the traditional industries. While in most developing countries, the GDP percentage of mining industry, light industries and heavy industries is still high.

Tab. 1-2-4 GDP mix of industrial sectors in developing & developed countries (%)

Industrial sector	World		Developed countries		Developing countries	
	1990	1998	1990	1998	1990	1998
Total industry	100.0	100.0	100.0	100.0	100.0	100.0
Mining	9.8	9.1	5.4	5.0	24.7	21.0
Coal mining	1.2	0.9	0.8	0.6	1.1	0.9
Oil and NG mining	6.6	6.3	3.2	3.2	20.0	16.8
Metal mining	1.0	0.9	0.6	0.5	2.2	1.8
Manufacturing industry	81.6	82.4	85.0	85.6	69.4	72.9
Food, drink	10.0	9.9	9.0	8.3	13	14.2
Textile	3.9	3.4	2.5	2.0	7.0	6.0
Clothing, leather	2.9	2.0	2.5	1.7	3.6	2.4
Wood	1.8	1.5	1.9	1.7	1.2	0.8
Paper-making, printing	6.3	5.7	7.9	7.3	3.0	2.9
Petrol-chemical, chemical	12.7	13.0	12.8	13.0	13.7	14.0
Nonmetal	3.5	3.2	3.2	2.7	4.0	4.3
Metal	4.9	4.4	4.8	4.2	4.7	4.7
Machinery	12.2	10.4	13.5	11.4	6.7	6.5
Office equipments	12.3	18.7	13.9	22.1	6.2	8.0
Transporting equipments	7.8	7.7	9.3	8.6	4.0	6.1
Power, heat, water supply	8.6	8.4	9.7	9.5	5.9	6.1

Note: Developed countries included North America (Canada, USA), Europe, Australia, Israel, Japan, New Zealand and South Africa and developing countries included Middle America and South America, Africa (except South Africa), Asia (except Israel and Japan), Oceania (except New Zealand and Australia).
Source: *World economic statistics 2000,* the same for the followings.

1.2.3. Urbanization

According to the experiences of the developed countries, during the early stage of industrialization process, urbanization rate increased slowly and may reach over 30%; during the expanding stage of industrialization process, urbanization rate entered an accelerating stage with the economic development, the annual growth rate of urbanization rate may reach 1.5~2.5 times of that at early stage and urbanization rate at this stage may reach 70%; when industrialization process has completed, the growth rate of urbanization rate will slow down.

Tab. 1-2-5 Urbanization rate in selected countries (%)

	1960	1965	1970	1980	1985	1990	1995	Period with per-capita GDP of 10000~15000 US$
Japan	62.5	67.0	71.2	76.2	76.7	77.4	78.1	1978－1992
Korea	40.2	45.1	54.2	56.9	57.6	58.4	59.1	1995-
USA	70.0	71.9	73.6	73.7	74.5	75.2	76.1	1961－1978
France	62.4	67.1	71.0	73.3	73.7	74.0	74.7	1973－1998

As shown in the above table, after per-capita GDP has reached 10000 US$, i.e. when the industrialization process has basically realized, the urbanization rate in these countries will keep at a high level. The urbanization rate of USA, Japan, etc. are keeping on the level of about 70%, and still are growing slowly. The peak period of urban developing growth rate happened before per-capita GDP had reached 10000 US$, such as this peak period in France and Japan happened in 1960's~1970's. In Korea, before economic rapid development and industrialization, urbanization rate was low and in 1960 just kept at the level of 40%. While with the development of industrialization, the annual growth rate of urbanization rate increased continuously which had resulted 1 percent increase of urbanization rate. When per-capita GDP has reached 10000 US$, the urbanization rate increased slowly, but it had reach a high level of 60% which was similar with the urbanization rate of the western developed countries at that time.

1.2.4. Living standard of the residents

When the living standard of the residents has reached certain level, the demand on clothes and food will transforms to habitation and traveling, which is reflected by the following: per-capita vehicle own level and living area increases continuously; percentage of the household appliances and luxury goods increases continuously and the living standard transforms from living type to comfortable type; per-capita social services increases continuously.

(1) Per-capita vehicle population

Higher income may result higher own level of household vehicle (as shown in Tab. 1-2-6). In the countries where the per-capita GDP has exceeded 10000 US$, the vehicle own level of 1000 households all exceeded 150, and in some traditional developed countries this level is much higher.

The evolution process of per-capita vehicle own level in Korea is quite typical. In early 1970's, the vehicle own level of 1000 people just was 4 (the same level of China in 1990's); when per-capita GDP reached 10000 US$, that level rapidly increased to 188.

Tab. 1-2-6 Motor vehicle populations per 1000 people

Country	1960	1965	1971	1973	1980	1985	1990	1995	1999
USA	**409**	458	544	587	686	722	756	761	770
UK					**308**	390	459	481	520
Japan					**324**	382	467	533	567
Hong Kong						**50**	66	78	80
Korea							79	**188**	238
Singapore						**139**	140	142	140

Source: Institute of Energy Economics, Japan, "2003 Handbook of Energy and Economic Statistics in Japan", 2003

Note: Data in bold also showed the time when per-capita GDP reached 10000 US$.

(2) Living space

As shown in Fig. 1-2-1, when per-capita GDP reached 10000 US$, the newly built building area reached the peak level, thereafter, the annual growth rate slowed down. In addition, long before per-capita GDP reached 10000 US$, the newly built building area also increased slowly. It means that in the period that per-capita GDP reached about 10000 US$ the demand of inhabitants on the living area are most strongest, hence the growth rate of the per-capita living area is rapidest in this stage.

In term of the absolute amount of living area, there exists great difference in different countries. Such as, per-capita living area in USA has reached 60 m^2, while that in Japan is just about 30 m^2. As can be seen, demand on living area has great correlation with many factors (such as the resource condition, culture background, environment and so on) in different countries.

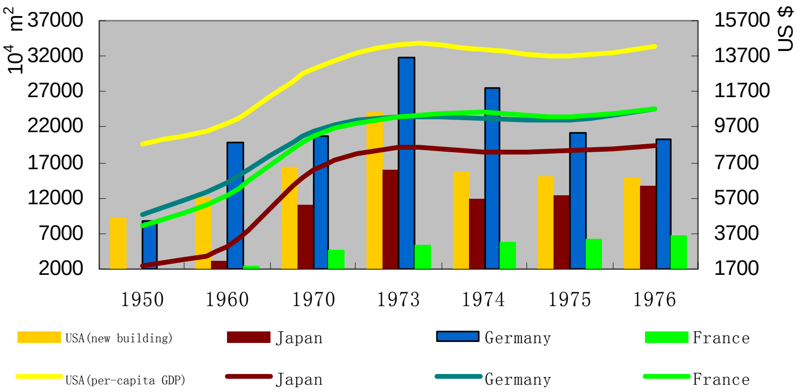


Fig. 1-2-1 Comparison of annual newly added living space & per-capita GDP

1.2.5. Energy consumption

(1) Per-capita energy consumption and per-capita GDP

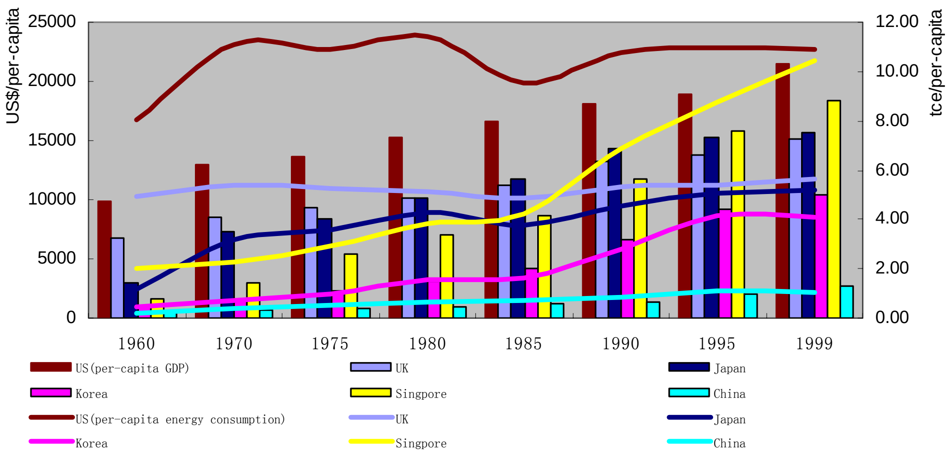


Fig. 1-2-2 Comparison of per capita energy consumption and GDP

In most developed countries, before completing industrialization process and per-capita GDP reaching 10000 US$, per-capita energy consumption increased rapidly, and thereafter, the growth rate began to slow down and kept a relative stable value (as shown in Fig. 1-2-2). This tendency was quite obvious either in the countries with high-energy efficiency (such as Japan) or in new developed countries (such as Korea). In Singapore, the per-capita energy consumption always kept rapid increase because quite a part of Singapore' GDP comes from Refinery Oil Industry. Although most oil exports to other countries, the related energy consumption was included in its own energy consumption. In addition, per-capita energy consumption of USA is much higher than that of the other countries. One reason is its "energy wasting" consuming pattern of USA, another reason is related with the time when USA completed industrialization. In 1960's, the per-capita GDP of USA had reached 10000 US$, and at that time, USA's industry products and living consumptions were based on abundant and cheap energy fuels, which had resulted in the rapid increase of per-capita energy consumption and this trend had continued to the early 1980's. With the economic entered into late industrialization process, the dependence on energy of USA has reduced. From 1990's, the per-capita energy consumption of USA kept relative stable at the level of about 11 Tce.

As may be seen by international comparison, in the stage that per-capita GDP reached 10000 US$ and industrialization process had been basically realized, the energy efficiency in Japan is highest and the related per-capita energy consumption was 4.25 Tce, while the per-capita energy consumption of UK (traditional industry country) at related stage was 5.1 Tce, and that of Korea (newly developed country) at related stage was 4.07 Tce. With the same per-capita GDP, the related per-capita energy consumption was quite different. Such as, the per-capita energy consumption was low in the countries with high-energy efficiency, and that was further lower in the newly developed countries that had taken advantages of information technologies and knowledge economic. Anyway, from the viewpoint of the world, in any case the per-capita energy consumption was on the level of over 4 Tce in the countries who had basically realized industrialization.

(2) Energy consumption mix

The difference of resource conditions and policy environment had resulted in different energy consuming structure in different countries at the same stage (as shown in Tab. 1-2-7). However, as can be seen, the tendency of energy mix optimization had certain rule in different countries when they entered the stage with 10000 US$ of per-capita GDP. In general, the percentage of coal in the primary energy mix at that stage had dropped to below 35%, while that of oil was over 40%, and percentage of natural gas and primary power existed difference in different countries.

Tab. 1-2-7: Energy consumption Mix (%)

	Year	Coal	Oil	Natural Gas	Primary power
USA	**1960**	**24.7**	**40.8**	**33.2**	**1.3**
	1970	20.8	40.7	37	1.5
	1980	20.7	44.4	26.3	8.6
	1990	24.9	39.2	25.9	10

	1999	24.96	37.64	26.41	10.98
UK	1970	50.7	42.6	5.4	1.3
	1980	**34.2**	**40.8**	**20**	**5**
	1990	29.5	37.6	24.3	8.6
	1999	16.49	33.34	39.21	11.96
Korea	1980	32.5	65	0	2.5
	1990	**29.79**	**49.43**	**3.62**	**17.15**
	1999	27.39	44	10.38	18.19
Japan	**1980**	**17.2**	**68**	**6.2**	**8.6**
	1990	20.3	51.7	12.2	15.8
	1999	21.3	44.7	14.34	21.31
China	1980	74.3	21.6	2.9	1.2
	1990	81.4	14.5	2.3	1.8
	1999	68	23.2	2.2	6.6

Note: The bold character also shows the time when per-capita GDP reached 10000 US$.

International experiences shows that energy mix optimization and industrialization process are correlated, energy mix optimization was pushed by industrialization, in verse, it also put forward the development of the industrialization process.

(3) Per-capita residential energy use

Per-capita energy consumption for living is closely related with both the living standard of the people and the residents' income level and per-capita GDP level. Japan has the highest energy efficiency in current developed countries, with great population and less land, which is certain similar with China. Therefore, by studying the evolution of the energy consumption for living during the period of rapid economic development in Japan, it is helpful for related Chinese governments to stipulate rational consuming policies.

The per-capita GDP of Japan in early 1960's was about 3000 US$ (on the basis of PPP provided by World bank), and that in 1965 was 4400 US$, and the level in 1980 had reached 10000 US$, in 1995 was 15000 US$ (as shown in Fig. 1-2-3). During the 15 years before GDP reached 10000 US$, the annual growth rate of per-capita energy consumption for living was 6% and that of per-capita GDP was 5.5%. When per-capita GDP reached 15000, the annual growth rate of per-capita energy consumption for living reduced to 3% and that of per-capita GDP also dropped to 2.8%. These results also proved that there existed a rapid increase period of energy consumption for living before per-capita GDP reached 10000 US$.

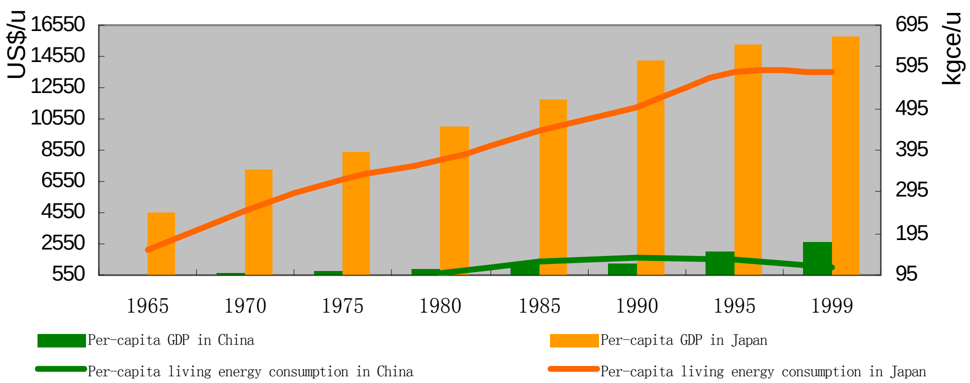


Fig. 1-2-3 Comparison of per-capita GDP and residential energy use between China and Japan

1.3. Regional comparison of social/economic/energy status

1.3.1. China's regional economy development profile

In China, there exist apparent unbalance on the economic development in terms of different regions, urban and rural. On the basis of the current exchange rate, in 2002, per-capita GDP in the southeast coastal area exceeded 1400 US$, while that in the western 9 provinces was less than 600 US$. In 2002, per-capita consumptive expenditure in cities was 6030 Yuan RMB, while that in rural was just 1834 Yuan.

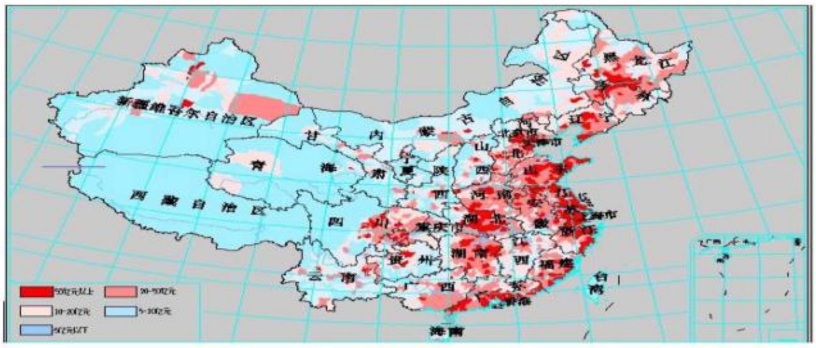


Fig. 1-3-1 GDP by county in 1999

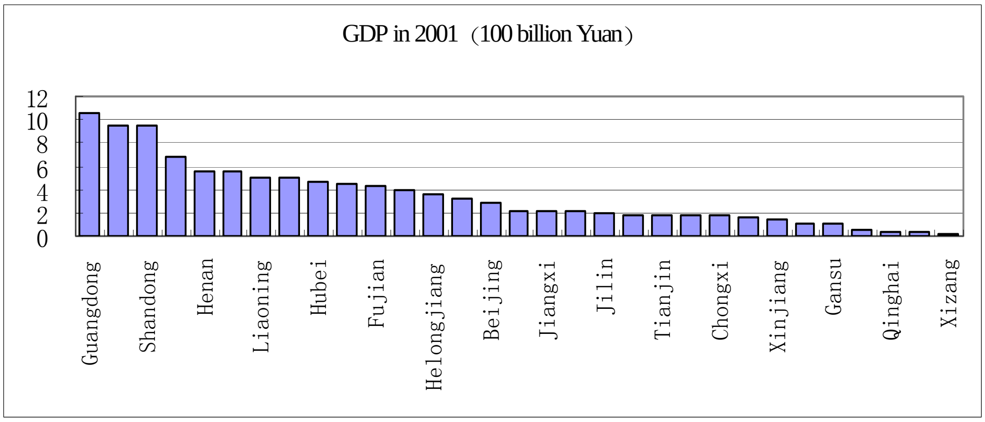


Fig. 1-3-2 GDP by province

On the whole, the economic developed areas mainly focus on the southeast regions, while the western regions are relative undeveloped (as shown in Fig. 1-3-1).

Great gap exists in the GDP of each province (as shown in Fig. 1-3-2). Hence, it may exist big error to describe the nationwide level just by regional average indicators.

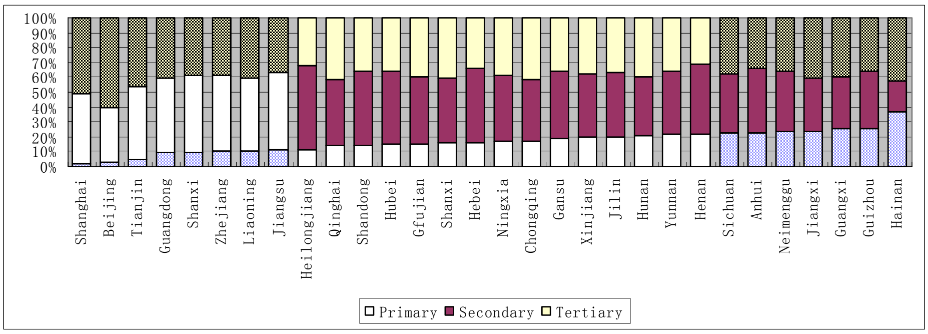


Fig. 1-3-3 Industrial structure of each province in 2001

In term of industrial structure, except Tibet and Hainan, percentage of the secondary industry in most provinces exceeded 50%, which had shown that China is still at the early and middle stage of industrialization process.

The difference of per-capita GDP among different provinces is also very large. In the nationwide scope, it may be divided into 3 big regions on the basis of per-capita GDP: developed regions represented by Beijing and Shanghai, developing regions represented by Hunan and Hubei, poor regions represented by Gansu and Guizhou. The level of per-capita GDP is the decisive factor of both the energy consumption and other economic activities in each region. Many indicators have close relationship with per-capita GDP, such as residents' living consumption, owned vehicle, living area, industrial structure, technology improvement etc.

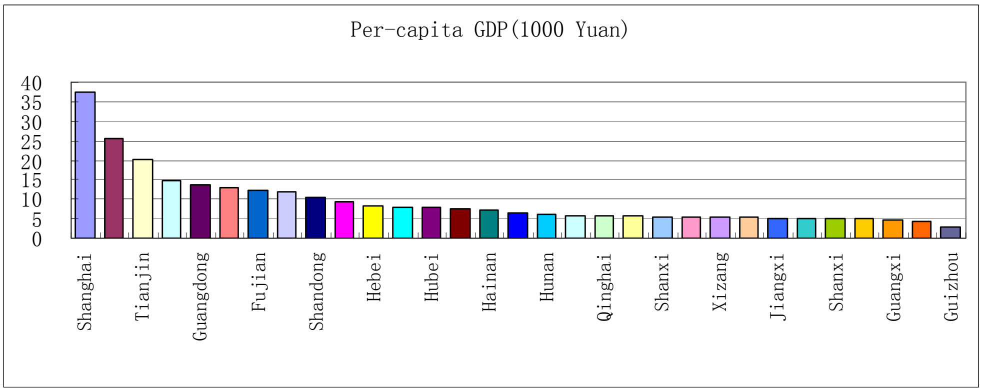


Fig. 1-3-4 Comparison of per-capita GDP by province

1.3.2. Characteristics of social & economic development in those regions achieving well-off level

In 2002, per-capita GDP in Beijing, Shanghai, Shenzhen, etc. has reached or exceeded 3000 US$. According to the developing goal proposed at the 16th Congress, theses regions have lead to enter well-off society. The social & economic developing characteristics in these regions are as the following

(1) Experiencing a rapid economic developing stage.

Before per-capita GDP reached 3000 US$, Shenzhen, Shanghai and Guangzhou all had experienced a rapid economic developing stage. After the economic accumulation at this stage, compared with the year of 1990, the total GDP of these 3 cities have increased 3.44 times, 4.15 times and 4.53 times, respectively (as shown in Tab 1-3-1).

Tab. 1-3-1 GDP and growth rate of Shenzhen, Shanghai and Guangzhou

Unit: 10^8 Yuan RMB, %

Year	GDP（Shanghai）		GDP（Guangzhou）		GDP（Shenzhen）	
	Amount	Growth rate	Amount	Growth rate	Amount	Growth rate
1990	756.45	3.5	319.60	11.3	171.67	32.5
1991	893.77	7.1	386.67	16.3	236.66	36.0
1992	1114.32	14.8	510.70	23.3	317.32	33.2
1993	1511.61	14.9	740.84	26.4	449.29	30.0

1994	1971.92	14.3	976.18	18.8	615.19	30.1
1995	2462.57	14.1	1243.07	16.4	795.70	23.0
1996	2902.20	13.0	1444.94	12.4	950.04	16.4
1997	3360.21	12.7	1646.26	13.4	1130.01	16.0
1998	3688.20	10.1	1841.61	13.1	1289.02	14.5
1999	4034.96	10.4	2056.74	13.2	1436.03	14.1
2000	4551.15	10.8	2375.91	13.4	1665.47	14.2
2001	4950.8	10.2	2684.83	12.7	1954.65	

Note: GDP was based on current year price and growth rate was based on comparable price.

(2) Updating and optimization of economic structure

Industrial structure trends to be dominated by tertiary industry.

From 1990's, in term of the industrial structure evolution of Shenzhen, Shanghai and Guangzhou, it appeared that the percentage of primary industry dropped quickly, the percentage of secondary industry kept relative stable and the percentage of tertiary industry increased continuously. For instance, the percentage of primary industry in these 3 cities have increased from 2.5%, 5.2%, 1.6% in 1990 to current 1.7%, 3.6%, 1.0%; the percentage of secondary industry always kept within 45%~50%. At present, the percentage of tertiary industry in Shanghai and Guangzhou has exceeded 50% and that of Shenzhen is 46.5%. These indicators have shown that the industrial structures of these 3 cities have basically entered the stage of matured industrialization and tertiary industry has become the dominating industry.

Improvement of industrialization level

In term of the industry inner structure of Shenzhen, Shanghai and Guangzhou when per-capita GDP reached 3000 US$, there existed two main characteristics. First, the percentage of light industry reduced while that of heavy industry increased. Second, it was quite evident of the dominance of heavy industry and the function of high-tech industries was more and more prominent, which showed that the industrialization of these 3 cities was transforming from expanding stage to mature stage.

Improvement of the residents' consumptive structure

Tab. 1-3-2 Consumption Mix comparison Among Beijing, Shanghai, Guangzhou & Shenzhen

	Beijing	Shanghai		Guangzhou		Shenzhen	
	2001	1997	2001	1997	2001	1996	2001
Per-capita income	11577.8	8438.9	1283.5	10290	14416	16968.45	22672.6
Per-capita consumptive expenditure	8922.7	6819.9	9336.1	8707.0	11137	14172.2	18006.1
Structure（%）	100	100	100	100	100	100	100
1.Food	36.2	51.5	43.1	48.7	40.1	34.8	27.6
2.Clothes	9.2	8.1	6.2	6.1	5.0	9.2	5.3
3.Household appliances	9.5	8.7	6.9	7.2	7.5	10.1	9.9
4.Medical	7.6	2.9	6.0	3.9	4.8	3.6	4.5
5.Transp. & communic.	8.6	5.6	9.4	4.7	9.2	6.6	16.1
6.Entertainment and education	16.0	11.5	14.6	12.5	12.4	12.4	12.2
In which：Education	8.4	4.5	7.8	5.2	6.5	5.2	
7.Residence	6.6	7.9	7.8	10.7	13.9	16.8	18.8
8.Other goods	6.3	3.9	6.1	6.1	6.9	6.5	5.6
Debt and credit	2106.5	1745.0	3950.4	3014.2	5745.0	3450.4	

When per-capita GDP reached 3000 US$, the developing trends of consumptive structure in Beijing, Shanghai, Guangzhou and Shenzhen are almost the same. First, Engles coefficient of all cities dropped prominently. Second, the expenditures on traffic, communication, medical, entertainment, education, etc increased continuously. Of them, the expenditure percentage of traffic & communication increased most sharply, and that of residence & housing also increase remarkably.

According to the trend of the rural residence in the above mentioned cities, although the expenditure percentage on foods & clothes has dropped prominently, that on household equipments are still rising, which shows that their expenditure on household equipments is still at developing stage and the consumptive characteristics of well-off society is quite prominent.

In terms of the household endurable equipments, household appliances such as color TV, refrigerator, washing machine, camera, telephone and so on have quite high permeation and basically are saturate. In addition, air-conditioner, computer and mobile phone also are quite popular at present, just household cars are in initial stage and have low permeation. These facts show that after the “1000 Yuan-level” consumption of the “new 3 appliances” (color TV, refrigerator, washing machine) in 1980’s, “10000 Yuan-level” consumption on multi-hotspots, multi-level appliances has become popular. In the meantime, the consumers have increasingly expanding their consumptive scope from goods based on life safe demand to the consumptions on entertainment, culture, education, traveling, healthy and so on.

Tab. 1-3-3: The endurable appliances owned per 100 Beijing households in 2001

	Color TV	Refriger ator	Washing machine	Came ra	Motor car	Car	Telephon e	Air-co ndition er	Computer	Mobile phone
Urban	148.9	123.5	102.2	100.7	5.0	4.7	93.5	89.7	45.3	62.4
Rural	112.0	68.0	91.0	29.0	35.0	2.6	90.0	27.0	12.0	30.0

1.3.3. Energy consumption status of those regions in China living a well-off life

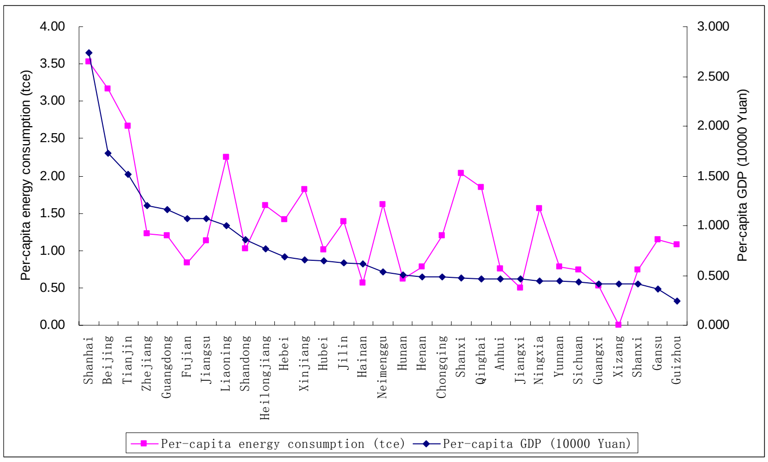


Fig. 1-3-5 per-capita energy consumption and per-capita GDP by region (1999)

Resource: Based on “ China energy statistics yearbook” and “ China Statistical Yearbook”.

Shanghai, Beijing and Tianjin are the 3 direct administrative cities with highest per-capita GDP, correspondingly per-capita energy consumption of these 3 cities are also highest, and reached 3.5, 3.2 and 2.7 Tce respectively in 1999, which is 2 times higher than the nationwide averaged level and has exceeded the average level in the world.

By studying the situation of Shanghai, we may find that energy demand of China faces great pressure to establish all-round well-off society and basically realize industrialization by 2020. As the developed city with rapid urbanization and industrial structure optimization, the per-capita GDP of Shanghai has exceeded 4000 US$ in 2002, or exceeded 10000 US$ on the basis of PPP. In term of economic developing stage, Shanghai has basically realized industrialization and the percentage of tertiary industry has exceeded 50%. The urban rate has exceeded 80%, which shows that its urbanization process has basically completed. Public facilities are relative perfect, public transport is still the dominant way for passenger transport, and the indoor environment is relative comfortable. Under these conditions, the per-capita energy consumption of Shanghai was 4.2 Tce in 2002. Compared with the developed countries such as USA, UK and so on, Shanghai entered well-off society with relative lower energy consumption.

In terms of the relationship of economic development and energy consumption in Shanghai, ample energy supply is still the substantial foundation to guarantee the economic development. Higher income level means higher demand on energy consumption. As shown in Tab. 1-3-4, the energy structure of Shanghai was prominently improved. The share of coal in residential energy consuming mix has dropped from 72.7% in 1980 to the current level of 18.3%, while the electricity percentage has increased continuously. Different from the other regions that the residential energy consumption experienced a stage of “reducing firstly increasing afterward” with energy mix improvement, this trend didn’t happen in Shanghai because economic level in Shanghai is relative high and energy mix optimization has little influence on the total energy consumption.

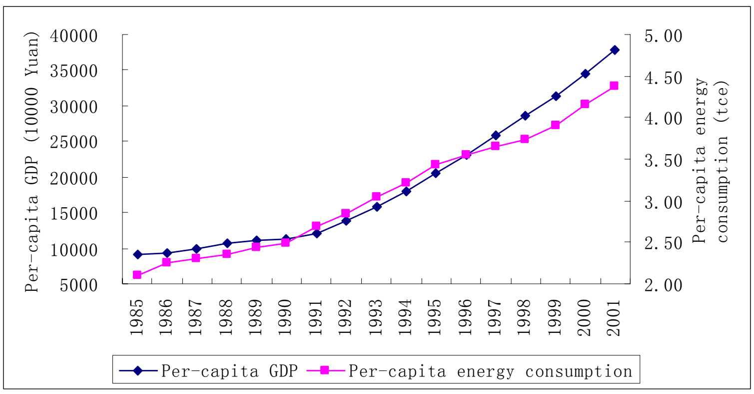


Fig. 1-3-6 Relationship of economic growth & energy consumption in Shanghai

Note: Based on the data in “Shanghai statistics almanac”, the same with the following.

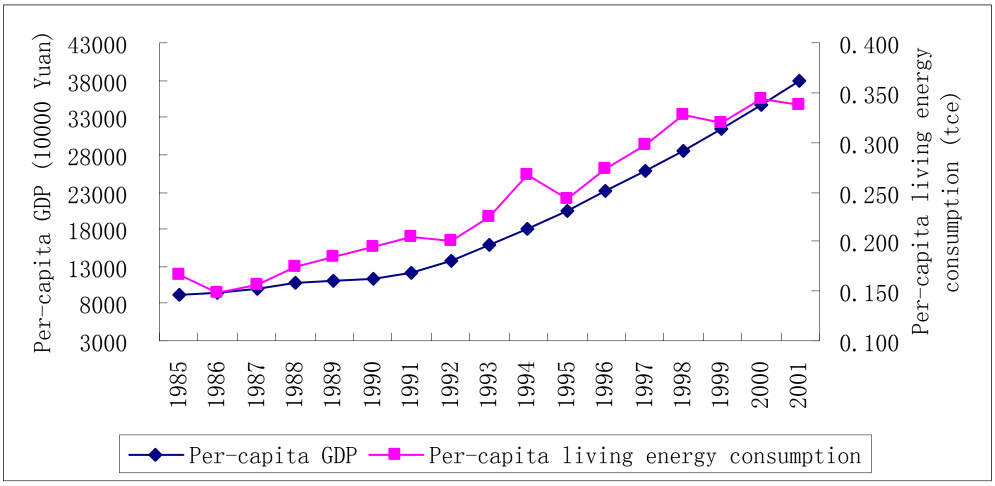


Fig. 1-3-7 Relationship of economic growth and per-capita residential energy use in Shanghai（1985~2001）

Tab. 1-3-4 Per-capita residential energy consumption in Shanghai（1980~2001）

	1980	1990	2000	2001
Per-capita residential energy use (kgce)	**150.74**	**191.53**	**342.75**	**338.39**
Coal (kg)	153.41	143.04	105.54	89.20
Kerosene (kg)		0.65	0.05	0.01
LPG (kg)	0.61	3.34	16.00	15.33
Coal gas (cubic meter)	28.61	45.08	121.14	90.34
Electricity (kWh)	54.59	112.51	402.53	429

1.4. Challenges facing China's energy development under the background of building a well-off society in an all-round way

In the long-term viewpoint, the key factor to determinate the future energy demand will still be the social & economic continuously development at high speed. The 16th Congress has proposed the developing goals that "building a well-off society of a higher standard in an all-round way to the benefit of well over one billion people", "on the basis of optimized structure and better economic returns, efforts will be made to quadruple the GDP of the year 2000 by 2020" and "in the main achieving industrialization by 2020". All the above goals will be based on ample energy supply. Correspondingly, high demand has been advanced to the future energy development.

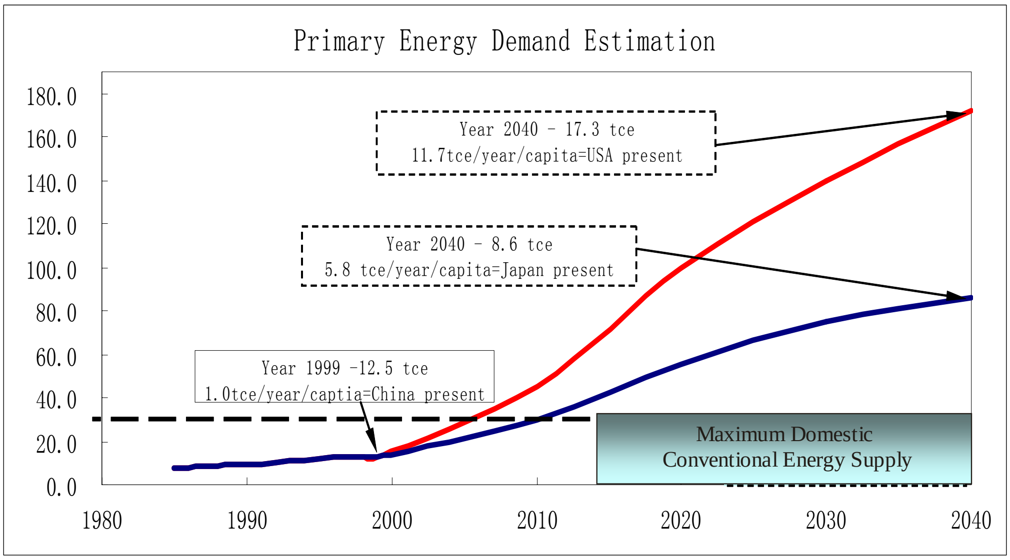


Fig. 1-4-1 China's future outlook on energy demand

In the viewpoint of China's developing status, industrialization has been achieved, there are still 900 million people are living in the rural areas, and there is a long way to follow up for industrialization process and urbanization progress. According to the above international comparisons, in order to achieve the goal of "building a well-off society in all-round way", if we follow the consumptive level of USA, per-capita energy consumption may reach 11 Tce; if we follow the average level of OECD countries, per-capita energy consumption may reach 5.2 Tce; even if we follow the consumptive level of Japan who has the highest energy efficiency, per-capita energy consumption may reach over 4 Tce.

Although China may explore a new type industrialization road by technical improvement and high added-value industries, the status of Shanghai and Beijing shows that even if China can enter all-round well-off society with per-capita energy consumption of 3 Tce in the future, China's energy demand by 2020 will still reach the high level of more than 4000 Mtce. As can be seen that China's future energy development, especially the future energy demand, will face quite austere challenge.

2. China's Energy Consumption Status and Potential Energy Efficiency Improvement

2.1. Historical review and status story of energy consumption

2.1.1. Coal consumption rebounded, electricity kept balanced on the whole and trended to be deficient, oil and gas continuously kept steadily increase, which indicated that China's energy demand will enter a new increasing stage (as shown in Fig. 2-1-1).

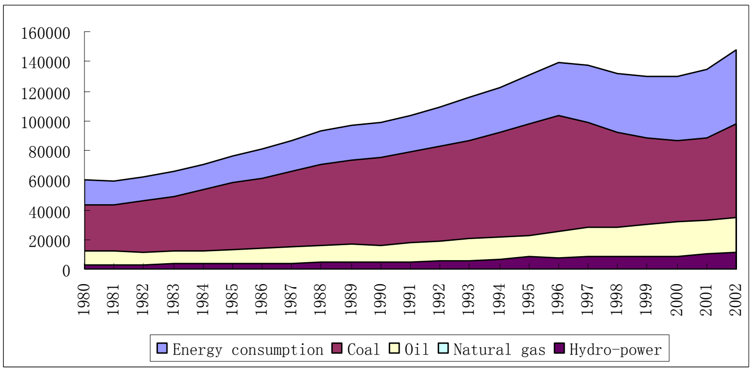


Fig. 2-1-1: The fuel structure of primary energy consumption between 1980 and 2002

Source: "China statistical yearbook", "China energy statistical yearbook", the same with the following.

2.1.2. Percentage of coal in energy mix dropped continuously, that of oil and gas went up, which indicated that energy mix optimization process will be strengthened and advance the high quality energy security problem in the future (as shown in Fig. 2-1-2 and Fig. 2-1-3).

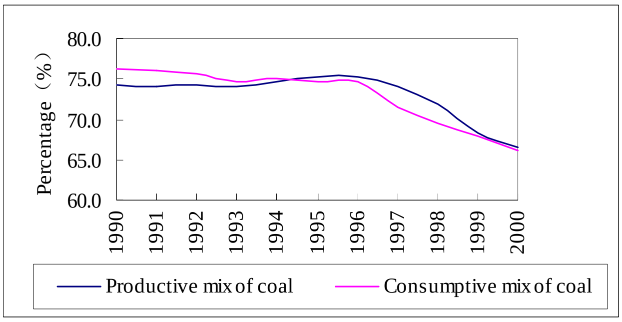


Fig. 2-1-2 China's coal production and consumption Mix （1990~2002）

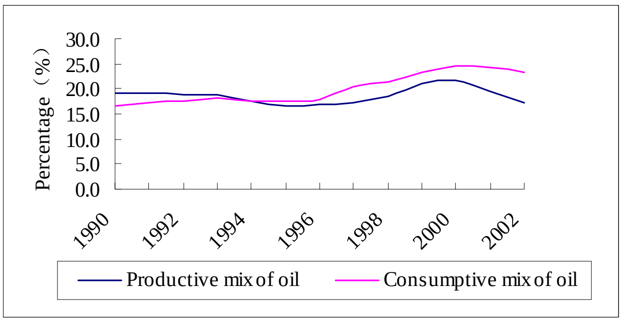


Fig. 2-1-3 China's oil production and consumption Mix（1990~2002）

Tab. 2-1-1 China's oil consumption status (1993~2002)

	1993	1995	1996	1997	1998	1999	2000	2001	2002
Consumption (10^4 ton)	14721.3	16064.9	17436.2	19691.7	19817.8	21072.9	22439	22949	24242
Import (10^4 ton)	3615.7	3673.2	4536.9	6787	5738.7	6483.3	9748.5	8170	8976
Export (10^4 ton)	2506.5	2454.5	2696	2815.2	2326.5	1643.5	2172	1679	1792
Net import (10^4 ton)	1109.2	1218.7	1840.9	3971.8	3412.2	4839.8	7576.5	6491	7184
Importing dependency %	7.53	7.59	10.56	20.17	17.22	22.97	33.76	28.29	29.64

Sources: "China energy statistics yearbook", "International oil economics" (vol.3, 2003)

2.1.3. In the final energy consumption structure, clean and high efficiency energy fuel including oil, gas, electricity and heat increased rapidly, which advanced new demand and challenge on energy supply (as shown in Tab. 2-1-2).

Tab. 2-1-2 China's final energy consumption by fuel（1980~2000）

	Unit	1980	1990	1995	1997	1999	2000
Coal	10^4 ton	38804.2	60205.9	66156.1	61792.0	51572.2	46086.8
Coke	10^4 ton	4294.7	6846.3	10648.0	10848.9	10302.7	10297.1
Oil	10^4 ton	6311.0	9304.7	13676.3	17051.9	18664.7	19893.5
Gasoline	10^4 ton	998.6	1899.5	2909.6	3311.1	3379.6	3503.7
Kerosene	10^4 ton	365.9	350.9	512.1	681.7	824.2	869.6
Diesel	10^4 ton	1590.9	2564.8	4070.0	4549.2	6016.2	6546.6
Natural gas	10^8 m^3	126.0	137.2	165.2	168.0	187.0	208.9
Electricity	10^8 kWh	2763.4	5795.8	9278.9	10486.0	11443.3	12534.7

Resource: "China statistics yearbook", "China statistics brief"

2.1.4. In terms of energy consumption by sectors, industry still was the biggest energy consumption sector, the energy consumption changes in recent year were all related with industry sector, and the energy consumption of industry sector will still influence China's future energy demand and supply in the long-term future (as shown in Tab. 2-1-3, Tab. 2-1-4, Tab. 2-1-5 and Fig. 2-1-4).

Tab. 2-1-3 China's energy consumption by sector (1995~2000)

Unit: %

	1985	1990	1995	1997	1998	1999	2000
Total energy share	100	100	100	100	100	100	100
Sub-sector：							
Agriculture	5.3	4.6	4.2	4.3	4.4	4.5	4.4
Industry	66.6	68.5	73.3	72.4	71.4	69.8	68.8
Construction	1.7	1.2	1.0	0.9	1.2	1.1	1.1
Transp.& Comm.	4.8	4.6	4.5	5.5	6.2	7.1	7.6
Commercial	1.0	1.3	1.5	1.7	1.9	2.2	2.2
Others	3.2	3.5	3.4	3.4	3.9	4.2	4.4

Residential	17.4	16	12.0	11.9	10.9	11.2	11.4
Sub-industry:							
Primary	5.3	4.6	4.2	4.3	4.4	4.5	4.4
Secondary	68.3	69.7	74.3	73.2	72.6	70.8	69.9
Tertiary	9.1	9.4	9.5	10.6	12.1	13.5	14.2
Residential	17.4	16.0	12.0	11.9	10.9	11.2	11.4

Resource: "China statistical yearbook", China statistical bureau

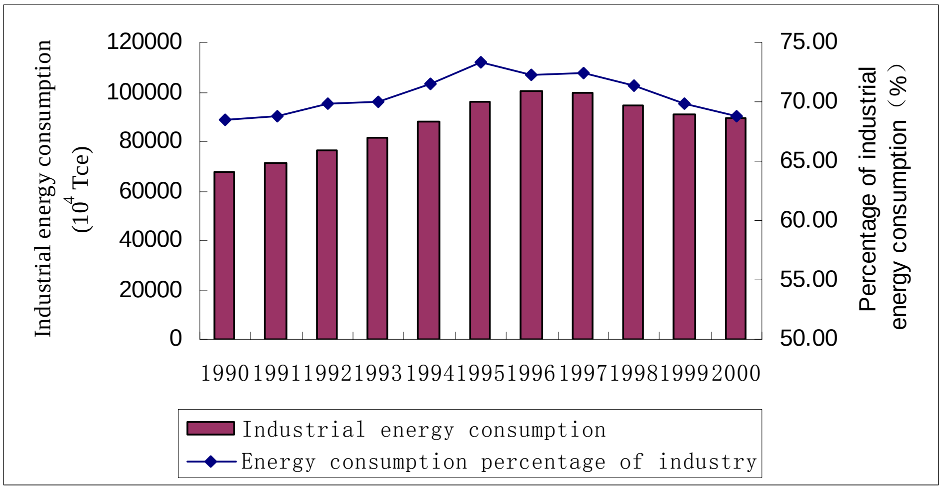


Fig. 2-1-4 Industrial energy consumption in 1990's

Tab. 2-1-4 Energy intensity of main sectors (1980~2000)

Unit: Tce/10^4 Yuan

	1980	1985	1990	1995	1997	1998	1999	2000
Agriculture	1.11	0.61	0.50	0.45	0.43	0.40	0.40	0.39
Industry	6.28	5.68	5.35	3.78	3.20	2.87	2.56	2.30
Construction	1.58	1.21	0.77	0.34	0.25	0.31	0.25	0.24
Trans. & comm.	4.59	3.53	2.15	1.88	2.06	2.01	2.07	1.85
Commercial	0.78	0.33	0.47	0.40	0.40	0.39	0.40	0.39
Others	0.70	0.74	0.63	0.44	0.37	0.37	0.35	0.33
Average	4.29	3.28	2.89	2.18	1.92	1.71	1.57	1.46

Note: On the basis of 2000 year comparable price
Sources: "China statistical yearbook", "China energy statistical yearbook"

Tab. 2-1-5 China's GDP breakdown（1980~2002）

Unit: %

	1980	1985	1990	1995	1997	2000	2001	2002
Agriculture	30.1	28.4	27.1	20.5	19.1	16.4	15.8	14.5
Industry	44.2	38.5	37.0	42.3	43.5	43.6	43.5	44.9
Construction	4.3	4.6	4.6	6.5	6.5	6.6	6.6	6.9
Trans.& comm.	4.5	4.5	6.2	5.2	5.1	6.0	6.1	5.4
Commercial	4.7	9.8	7.7	8.4	8.3	8.2	8.1	8.0
Others	12.2	14.2	17.4	17.1	17.5	19.2	19.9	20.3
Sum	100	100	100	100	100	100	100	100

Resources: "China statistical yearbook", "China statistics brief"

2.1.5. Compared with the average level in the world, China's per-capita energy consumption level is still very low, but the per-capita energy consumption in the regions leading to enter the well-off society has exceeded the average level in the world (as shown in Fig. 2-1-5).

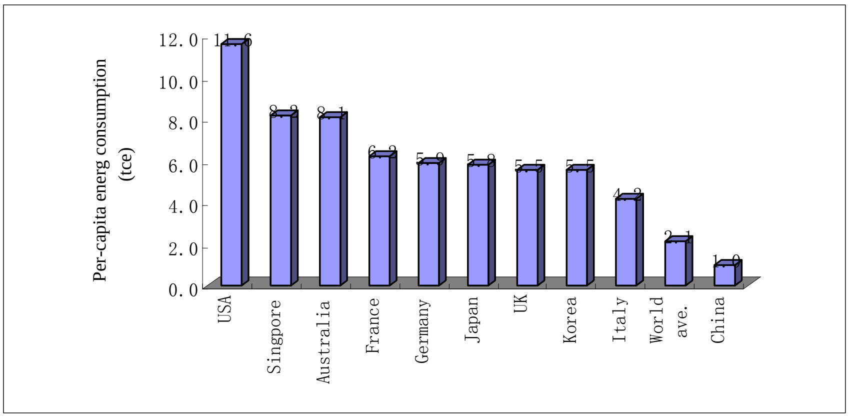


Fig. 2-1-5 International comparison of per-capita energy consumption（1999）

Source: "2003 Handbook of Energy and Economic Statistics in Japan " (2000)

2.2. Review of China's energy development in the past decades

2.2.1. Achievements obtained

In the past 20 years since opening and reform, great achievements on energy fields have been obtained in China.

Steadily and continuous development of economic was supported by relative lower energy input (as shown in Tab. 2-2-1 and Fig. 2-2-1).

Tab. 2-2-1 Relationship of economic growth and energy use at different stages in China

Period	1980~1985	1986~1990	1991~1995	1996~2000	2002/2000
Economic growth rate	10.7%	7.9%	12.0%	8.3%	7.7%
Energy consumption growth rate	4.9%	5.2%	5.9%	-0.1%	6.6%
Energy consumption elasticity	0.46	0.66	0.49	-0.02	0.85

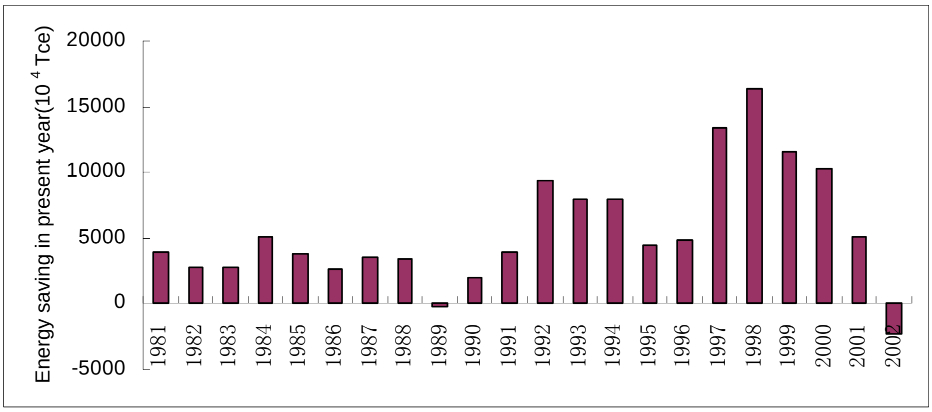


Fig. 2-2-1 China's energy-savings during the period of 1981 and 2002

Note: Based on "China statistical yearbook".

Economic energy density dropped continuously and energy efficiency was improved prominently; the difference of product energy density between China and international advanced level was reduced continuously.

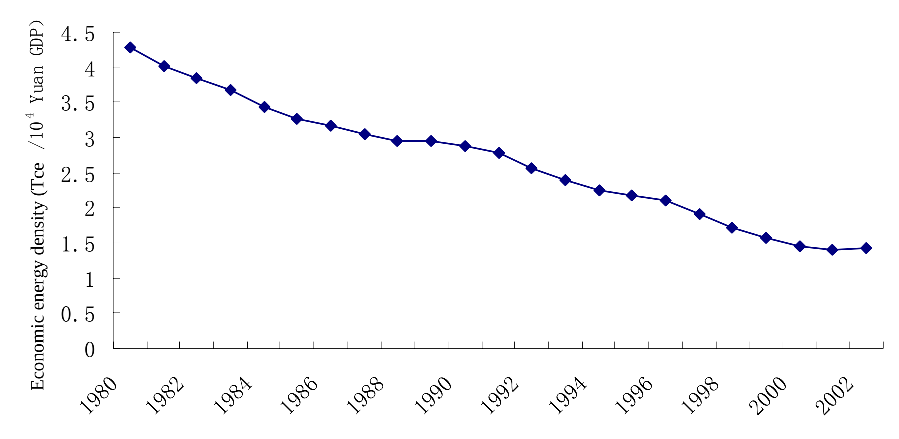


Fig. 2-2-2 China's energy intensity in 1980~2001

Note: Based on 2000-year comparable price.
Resources: "China statistics brief of 2003"

Tab. 2-2-2 Energy intensity of selected energy-intensive products (1980~1999)

ITEM	UNIT	1980	1985	1990	1996	1998	1999	2000
Fully energy consumption for steel production	Tce/t	2.039	1.746	1.611	1.392	1.29	1.24	1.21
Fully energy consumption for aluminum production （9 aluminum plants）	Tce/t	11.48	10.35	11.53	10.88	10.11	9.843	9.561
DC consumption of electrolyse aluminum	KWh/t	15432	15047	14916	14487	14122		
Fully energy consumption for synthetic ammonia								
In which：large-scale	Tce/t	1.431	1.368	1.343	1.292	1.372	1.215	
middle-scale	Tce/t	2.439	2.27	2.176	2.062	1.981	1.959	
small-scale	Tce/t	3.021	2.358	2.263	2.03	1.984	1.83	
Fully energy consumption for alkali (main enterprises)	Tce/t	1.87	1.75	1.66	1.608	1.58	1.572	
Coal consumption for power supply	Kgce/kWh	448	431	427	410	404	401	398
Fully energy consumption for cement (large and middle scale)	Tce/t	0.207	0.201	0.185	0.173	0.17		
Fully energy consumption for glasses	Kgce/box	32.32	37.05	34.79	29.4	29.21		
Fully energy consumption for paper-making	Tce/t	1.88	1.7	1.55	1.57	1.56		
Oil consumption for internal combustion engine	Kg/ 10^4 ton. kilometer	35	28.8	24.4	24.6			
Electricity consumption for power-driven engine	KWh/ 10^4 ton. kilometer	129.8	121.5	111	109.9			
Oil consumption for trucks	Litter/ 10^2 ton. kilometer	8.7	7.7	7.1	7.55			

Note: Coal consumption for power supply was based on the plants over 6 MW.

Sources: " China energy statistical yearbook" (1991, 1996), " proceedings of international comparison on energy intensive products.

Making contributions to the environment improvement, GHG emission reduction and the implementation of sustainable economic developing strategy.

2.2.2. Main measures adopted and experiences

The reason that China has supported rapid and steadily economic development with lower energy consumption elasticity and effectively reduced GHG is related with the social/economic/energy/environment developing strategy and the corresponding policy measures Chinese government has stipulated.

In early 1980's, according to the status of economic development and energy consumption at that time, Chinese government had stipulated the guideline of "resource exploitation and conservation, and put conservation the priority position in the near future". In addition, energy conservation was included into the national economic and social development planning, including compiling resource saving and comprehensive utilization planning, stipulating energy conservation policies and regulations, building the nationwide energy conservation administrative system, gathering energy conservation finance, promoting energy conservation technologies and products, conducting energy auditing and energy conservation dissemination, supporting R&D of energy conservation technologies and projects.

In 1990's, in order to meet the demand of sustainable development, Chinese government also considered improving the environment and improving the living standards of poor regions' residents as another goal. A series of activities were conducted to improve the environment, increase energy efficiency and reduce GHG emission, including " Green lighting program", "clean production pilot planning", " clean vehicle activity", "building energy efficiency" and so on. With the development of mechanism reform on the basis of market economy, Chinese government was also exploring the innovate mechanism adapting to socialism market economy and had inducted many new mechanisms such as " IRP", "DSM", "ESCO" and so on.

The achievements China has obtained in energy field may be summarized as following

(1) Industrial policy and structure regulation (government's macro control)

(2) Economic mechanism reform (market)

(3) Energy price mechanism reform (market)

(4) Optimization of the energy consumption structure (combining the macro control with the role of market)

2.3. Gap and potential

2.3.1. International comparison of energy efficiency

Tab. 2-3-1 Energy efficiency of selected countries in 1970's

Region	Italy	Japan	Western Europe	Eastern Europe	USA	India	West Germany
Year	1978	1975	1972	1972	1972	1972	1972
Energy efficiency（%）	42.50	36.40	32.06	33.23	47.49	32.5	37.20

Note: The indicator of energy efficiency was defined here as the product of the energy efficiency in transformation and that of end-use.
Sources: " China's long-term and mid-term energy developing strategy".

In early 1970's, many countries in the world had conducted researches and analysis on energy efficiency, and in the main adopted the method by sectors according to the energy utilizing process (as shown in Tab. 2-3-1). According to the domestic researching results, the current energy efficiency of China is just about 34.1%, which is about 8% lower than the developed countries.

In 1990's, economic energy density and product energy consumption were usually used to evaluate the energy efficiency. And the difficulty to conduct international comparison with economic energy density is the conversion of the different currencies each country used.

In Tab. 2-3-2 and Fig. 2-3-1, the energy efficiency indicators of some countries in 1990's were listed. In Fig. 2-3-1, the energy efficiency indicators of some countries in 2000 were compared, which showed that the gap between China and the developed countries had reduced.

Tab. 2-3-2 Comparison of the energy intensity in selected countries

Unit: Toe/10^4 US$, 1987 constant price

	China	USA	Japan	France	UK	Korea	Italy	OECD	World
1980	33.33	4.76	1.82	2.44	3.57	2.08	5.56	3.45	4.35
1994	14.29	3.85	1.16	2.27	2.86	2.22	5.56	2.94	4.17
Annual energy saving rate（%）	5.87	1.51	0.85	0.50	1.58	-0.46	0.00	1.13	0.30

Source: the same with the above.

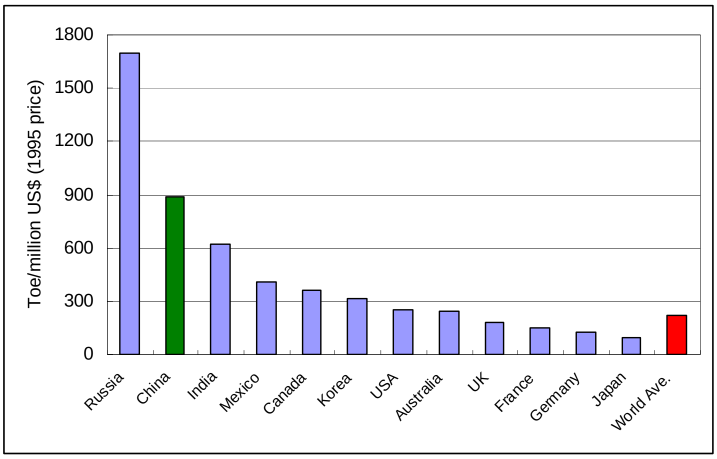


Fig. 2-3-1 Energy Intensity Comparison of selected countries in 2000 (based on the exchange rate of 1995)

Tab. 2-3-3 International comparison of energy-use per captia output in selected countries

Item	Unit	1980			2000		
		Domestic average level	International advanced level	Gap（%）	Domestic average level	International advanced level	Gap（%）
Coal consumption for power supply	Kgce/kWh	448	338	+32.5	392	317	+23.7
Fully energy consumption for steel production	kgce/t	1201	705	+70.4	781	629	+24.2
Fully energy consumption for cement	kgce/t	203.8	135.7	+50.2	181.3	124.6	+45.5
Energy consumption for ethylene	kgce/t	2013	1100	+83	1210	870	+39.1
Oil consumption for trucks	Litter/ 10^2 ton. kilometer	8.7	3.4	+155.9	7.6	3.4	+123.5

Sources: " China energy development report (2001)", Research report of ERI
Note: Power supply was based on the plants over 6MW, Steel data came from 75 large and middle scale enterprises, Cement data were based on the large and middle scale rotary kilns.

When conducting comparison analysis on energy efficiency, most countries have adopted the indicator of product energy efficiency. In Tab. 2-3-3, the main energy intensive products' energy efficiency was compared with that of the international advanced levels. In the past 20 years, the gap between the main energy intensive products' energy efficiency of China and the international advanced levels has been reduced prominently, while most energy intensive products' energy efficiency is still higher 30% than that of the international advanced level.

2.3.2. Potential analysis

The reason that big gap of energy efficiency still exists between China and the international advanced level may include the following factors.

(1) The poor technical equipments are the fundamental reason that has resulted in the lower energy efficiency of China.

(2) Smaller scale of the equipments is also the important factor constraining the energy efficiency improvement.

In Tab. 2-3-4, some energy intensive enterprises and equipments were compared with the international level.

Tab. 2-3-4 Comparison of selected energy intensive enterprises and equipments

	China	International level
Power plants （1996）	Average unit capacity was 49.8 MW for the units over 6MW	Average capacity for gas turbine unit was 600~1000 MW
Blast furnace （1995）	There were 3228 units, the average capacity was 853 m^3.	There were 42 units in Japan, the average capacity was 2500 m^3.
Synthetic ammonia （1997）	55% units were small with capacity below 50000 tons.	Large-scale units were used in developed countries with the capacity over 300000 tons.
Cement（1997）	There were 7410 enterprises, the average capacity was 853 with enterprise capacity below 90000 tons and unit capacity below 50000 tons.	Most foreign enterprises produced over 2.5~5 million tons each year.

(3) The difference of material and technical level is the main reason that has resulted in the big gap of energy efficiency between China and the developed countries.

In Tab. 2-3-5, the material mix of synthetic ammonia and paper pulp was compared.

Tab. 2-3-5 Comparison on the material use for synthetic ammonia and paper pulp sector

	China	Other countries	Influence on energy consumption
Synthetic ammonia	Coal and coke shared 62%, NG and coal gas shared 21%	NG shared 98% in USA	70% higher of energy consumption, and 2 times of investment
Paper pulp	Timber pulp shared 14%	Timber pulp shared over 90%	Bark and dark liquid may be used to generate electricity

In addition, the higher product energy consumption is related with the enterprise energy management and the optimal design on industrial processing energy utilization. Because of the problem of technical design, it is quite popular that higher capacity with lower load. Therefore, even if the energy efficiency of the equipments is high, the actual operating energy efficiency may be much lower because of the unreasonable management and operation. For instance, the design efficiency of boilers in China is about 80%, which is similar with the international level, but the actual operating energy efficiency is only about 65% because of the unreasonable management and operation.

In general, the future energy saving potential of China may be composed by two parts: the first part is indirect energy saving which may be realized by structure adjustments and management, another part is direct energy saving which may be realized by technical improvement. Compared with the western developed countries, there exists big gap of the economic energy density in China. Even if analyzing on the basis of PPP, China's economic energy density is still 1~3 times higher than that of the developed countries. However, it doesn't mean that China may make full use all the potentials in the future, because of: (1) Different-developing stage for China and other countries. At present, China is in the middle stage of industrialization process. At the 16th Congress, the goal was proposed to in the main realize industrialization by 2020, which means higher economic energy density. (2) Barriers on the energy mix transformation from coal based to oil and gas based. Different energy fuels may result in different energy efficiency, and China; situation constrains this transformation process to reduce the gap of energy efficiency.

According to related domestic researches, if the product energy efficiency may reach the international advanced level, the near-term energy saving potential is about 300 Mtce, even if it may reach the domestic advanced level, the near-term energy saving potential is about 150~200 Mtce.

3. Methodology

Many domestic and international agencies have conducted outlook on China's future energy demand (as can be seen in Tab. 3-0-1). These results show that the method they adopted exist shortages to analyze the future uncertainties influencing on the future energy demand.

Tab. 3-1-1 (a) China's future energy outlook by related agencies

Agency		Base year	Predicting method	Results on energy demand (10^8 tce)			
	Year	Year		2000	2010	2020	2050
IEA	2002	2000		12.14	18.6		30.47(2030)
ERI	1996	1990	Sectoral analysis	15.0	20.5	25.5	
Qtsinghua University	1994	1990	Sectoral analysis Residential consumptive flow analysis	14.4-15.3 13.9-17.1		23.8-26.8 22.0-27.8	34.8-44.0 33.0-42.0
Former department of energy	1994	1990	Sectoral analysis	14.4-15.3		23.8-26.8	34.8-44.1
China engineering academy	1996	1990	Sectoral analysis	16.6-17.0	22.7-24.0	29.0-31.5	35.7-41.3
IEA	1993	1993		13.9-14.0	20.5-20.9		
EIA		1990		12.49	16.96		
EDMC		1991		16.21	26.37		

Sources: " China's mid-term and long-term energy strategy", 1999; "China's energy outlook 2002" (IEA).

In this study, efforts will be made to overcome the above shortages. Scenario analysis method was selected and bottom-up method was used to annotate the goal of well-off society and study the energy demand and supply. Under the premise that most main factors' influences on the future energy demand, different energy scenarios were designed. In addition, by using LEAP model and combining quantitative analysis and qualitative analysis to study the influences of different policies on China's future energy demand in order to meet the given developing goal.

3.1. Basic considerations for the selection of scenario analysis method

In the latest decade, more and more international agencies adopted scenario analysis method to study the future energy issues.

The difference between scenario analysis and prediction is that prediction is used to study the developing trends that will happen most possibly, while scenario analysis is used to study the possible results under certain assumptions. Another application of scenario analysis is study the premise conditions in order to realize the given goal.

Tab. 3-1-1 Differences between scenario and forecast

	Forecast	Scenario analysis
Definition	Study the developing trends that will happen most possibly	Study the possible results under certain assumptions
Condition	Definite	Indefinite or may not certainly happen
Application scope	Multi-objective	Mainly used to study the influence of related policies

There may exist many uncertainties about the industrial structure and energy development for China in the coming 20~30 years, which will have much influence on China's future energy demand. If just using the traditional predicting method, it is quite difficult to master the evolution of China's future energy development because of the limitation of the researchers' knowledge.

3.2. Steps for scenario analysis

There are two main steps for this scenario analysis including scenario design and scenario computation. And scenario design is the necessary premise to quantify the variables and conduct scenario analysis. In this paper, variables and parameters to quantify include macro economic parameters with important influences on energy consumption (such as population, urbanization rate, GDP, GDP distribution in each sector, activity level of each sub-sector, etc.), the energy consuming system structure and the energy efficiency level of related technologies.

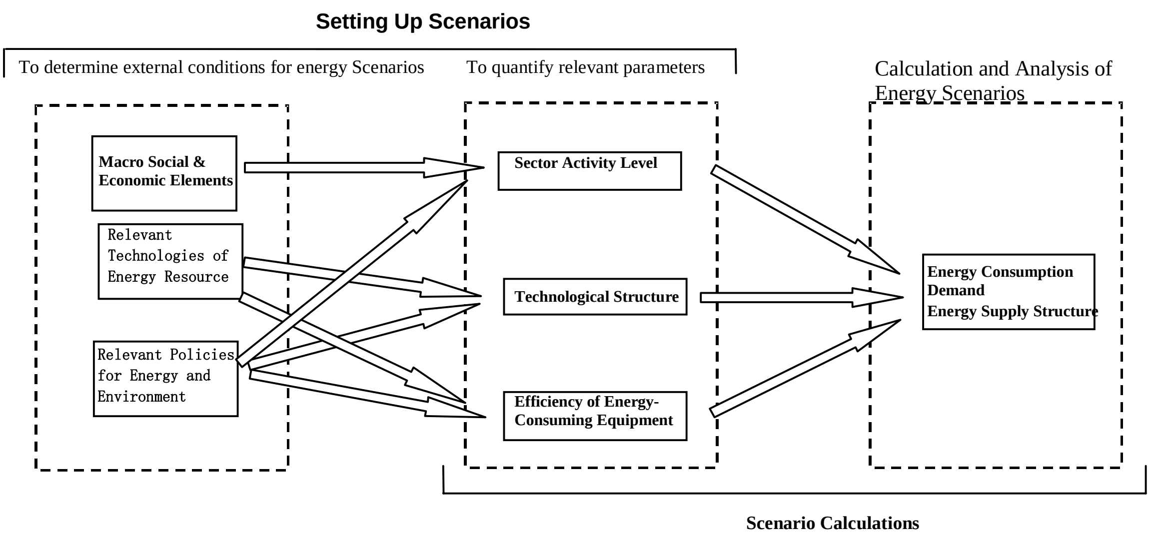


Fig. 3-2-1 Process of scenario analysis

Internationally, general equilibrium models are usually used to simulate and restrain quantitative relations between macro economic growth and activities of different sectors. Quantity and quality of the economic growth in our country have been significantly influenced by variations in systematic factors due to quick changes of the economic structures, and it is difficult for calculations in the general equilibrium models to be applied to these systematic changes. It is also hard to handle those non-market economic factors and specific technological development with such equilibrium models.

Therefore, when conceiving the scenario of the social and economic development under well-off society, we made scenario design on the basis of the domestic researching achievements and related experts' estimation. In addition, the related governmental planning were also considered as important resource to identify related economic development and activity level for each sector. The relationship among different sectors was judged by the experts in related fields.

Fig. 3-2-1 has schematically shown the process of scenario analysis in this paper.

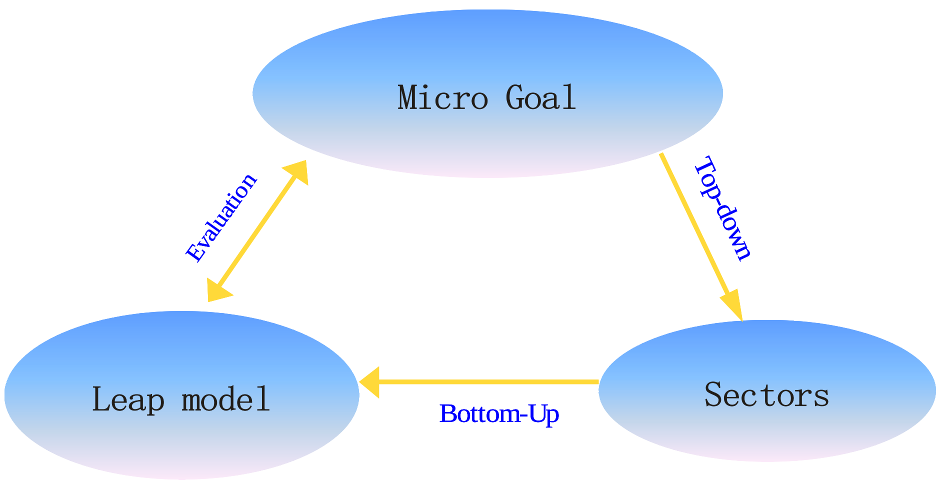


Fig.3-2-2 Schematic diagram for this study on scenarios analysis

3.3. Consideration in model selection

Some kind of model tools should be employed in order to completely and systematically study the energy demand difference by different sectoral technical improvement and different policies, especially for the case that there are many policy selections should be considered. For this project, LEAP2000 is select as the analyzing tools for scenario analysis.

LEAP2000 is a bottom-up project analysis model developed by Stockholm environment association and SEI-Boston in 1997, which can make scenario analysis on future energy demand and environment development by designing different schemes.

The most advantage of LEAP 2000 model is that the users can easily regulate the model structure and data framework according the project's demand and the future tendency by using the way of "what if" . Compared with the original version of LEAP model, LEAP2000 can run under Windows environment and tree structure of input data is adopted, two kinds of output types including table and figure can describe the model results and the output data can be easily selected according to the users' demand. In LEAP2000 model, the database of energy technology and environment are expanded, lots of emission factors of IPCC and other countries are included. Some other functions are added so that LEAP2000 model can be used more easily and conveniently.

There are also some shortcomings for LEAP2000. It can not automatically describe the influence and reactions among each sectors so that the user should have profound knowledge on China's social, economic, energy and environment.

3.4. Sector structure and model framework

Nowadays, classification of sectors in China's energy statistics system is not fully identical to the internationally accepted way of classifying energy-consuming sectors. Generally, to categorize sectors into primary, secondary and tertiary industries plus industry for civil use is the commonly adopted way in China's statistics system (see figure 3-4-1). Statistics of industrial sector is relatively systematic and specific while that of other sectors is comparatively rough. Statistics of energy in industrial sectors may sometimes include the GDP value and energy consumption of the non-production sectors that are affiliated with enterprises (or institutions) in addition to the GDP value and energy consumption of the production sectors and auxiliary sectors.

In order to further reflect the specialty of different usage of energy in the scenario analysis and in consideration of the availability of the relevant technical parameters of energy consumption, we have made necessary adjustment to the energy-consuming sectors on the basis of the classification of sectors by the *State Statistic Yearbook*, especially for transportation and commercial/residential sectors (shown in figure 3-4-2).

Tab. 3-4-1 listed the corresponding relationship of sectoral structure between this study and the state statistical agencies.

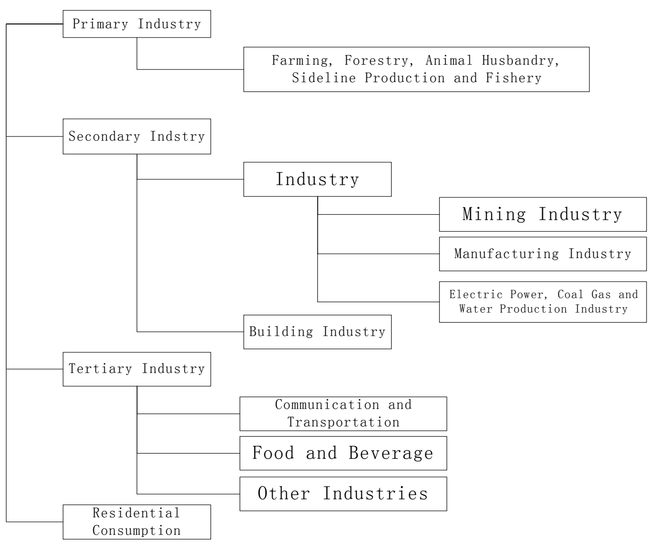


Fig. 3-4-1 Sectoral structure in Chinese statistical system

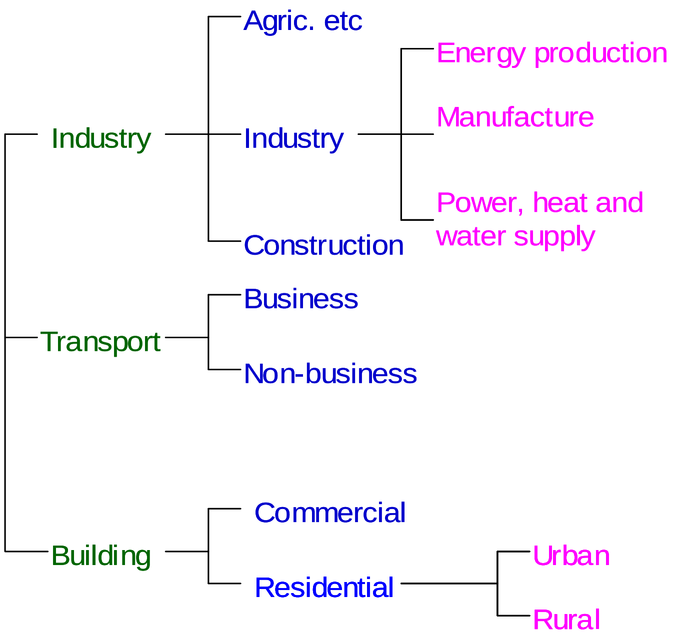


Fig. 3-4-2: The adjusted sectoral structure

The energy demand analysis process was schematically shown in the following figure.

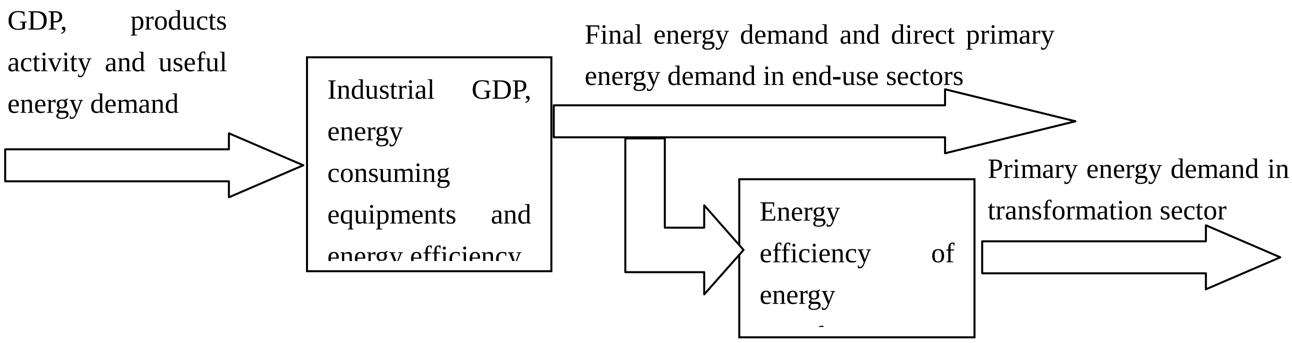


Fig. 3-4-3 Schematic energy demand computation process

Tab. 3-4-1 Corresponding relationship of sectoral structure between this paper and the state statistical yearbook

<table>
<tr><th colspan="3">Sector Division in State Statistical Yearbook</th><th colspan="5">Adjustment on sector division in this study</th></tr>
<tr><td colspan="3">Farming, forestry, animal husbandry, fishery & water conservancy</td><td rowspan="26">INDUSTRIAL SECTOR</td><td colspan="4">Farming, forestry, animal husbandry, fishery & water conservancy</td></tr>
<tr><td rowspan="25">INDUSTRY</td><td rowspan="7">Mining & Quarrying</td><td>1. Coal mining and dressing</td><td rowspan="25">INDUSTRY</td><td rowspan="15">Energy-intensive-industry</td><td rowspan="2">Energy production</td><td>1</td></tr>
<tr><td>2. Petroleum mining & dressing</td><td>2</td></tr>
<tr><td>3. Ferrous metal mining and dressing</td><td rowspan="2">Steel & iron</td><td>3</td></tr>
<tr><td>4. Nor-ferrous metal mining and dressing</td><td>27</td></tr>
<tr><td>5. Nonmetal minerals mining and dressing</td><td rowspan="2">Building materials</td><td>5</td></tr>
<tr><td>6. Other minerals mining and dressing</td><td>26</td></tr>
<tr><td>7. Logging and transport of wood and bamboo</td><td rowspan="2">Nonferrous</td><td>4</td></tr>
<tr><td rowspan="18">Manufacturing</td><td>8. Food processing</td><td>28</td></tr>
<tr><td>9. Food production</td><td rowspan="2">Chemical</td><td>6</td></tr>
<tr><td>10. Beverage production</td><td>21</td></tr>
<tr><td>11. Tobacco processing</td><td>Papermaking</td><td>17</td></tr>
<tr><td>12. Textile industry</td><td>Oil refinery</td><td>20</td></tr>
<tr><td>13. Garments and other fiber products</td><td rowspan="3">Power</td><td>37</td></tr>
<tr><td>14. Leather, furs, down and related products</td><td>38</td></tr>
<tr><td>15. Timer processing, bamboo, cane, palm & straw products</td><td>39</td></tr>
<tr><td>16. Furniture manufacturing</td><td rowspan="10">Light industry</td><td colspan="2">7</td></tr>
<tr><td>17. Papermaking and paper products</td><td colspan="2">8</td></tr>
<tr><td>18. Printing and record medium reproduction</td><td colspan="2">9</td></tr>
<tr><td>19. Culture, educational and sports articles</td><td colspan="2">10</td></tr>
<tr><td>20. Petroleum processing</td><td colspan="2">11</td></tr>
<tr><td>21. Raw chemical materials and chemical products</td><td colspan="2">12</td></tr>
<tr><td>22. Medical and pharmaceutical products</td><td colspan="2">13</td></tr>
<tr><td>23. Chemical fiber</td><td colspan="2">14</td></tr>
<tr><td>24. Rubber products</td><td colspan="2">15</td></tr>
<tr><td>25. Plastic products</td><td colspan="2">16</td></tr>
</table>

<table>
<tr><td rowspan="14"></td><td rowspan="11"></td><td>26. Nonmetal mineral products</td><td rowspan="15"></td><td rowspan="14"></td><td rowspan="6"></td><td>17</td></tr>
<tr><td>27. Smelting & pressing of ferrous metals</td><td>18</td></tr>
<tr><td>28. Smelting and pressing of nonferrous metals</td><td>19</td></tr>
<tr><td>29. Metal products</td><td>22</td></tr>
<tr><td>30. Ordinary machinery</td><td>23</td></tr>
<tr><td>31. Equipment for specials</td><td>24</td></tr>
<tr><td>32. Transportation equipment</td><td rowspan="8">Manufacturing industry</td><td>29</td></tr>
<tr><td>33. Electric equip. & machinery</td><td>30</td></tr>
<tr><td>34. Electric & telecom.equip.</td><td>31</td></tr>
<tr><td>35. Instrument, meters cultural and office machinery</td><td>32</td></tr>
<tr><td>36. Other manufacturing industry</td><td>33</td></tr>
<tr><td rowspan="3">Electric power, etc.</td><td>37. Electric power, steam and hot water production and supply</td><td>34</td></tr>
<tr><td>38. Coal gas production & supply</td><td>35</td></tr>
<tr><td>39. Tap water production & supply</td><td>36</td></tr>
<tr><td colspan="3">Construction</td><td colspan="3">Construction</td></tr>
<tr><td colspan="3">Transport, storage, postal & telecommunications services</td><td>Trans .</td><td colspan="3">Transport, storage, postal & telecommunications services</td></tr>
<tr><td colspan="3">Wholesale, retail trade and catering services</td><td rowspan="3">Builg</td><td colspan="2">Commercial</td><td>Wholesale, retail trade and catering services + Others</td></tr>
<tr><td colspan="3">Others</td><td colspan="2" rowspan="2">Residential</td><td>Urban</td></tr>
<tr><td colspan="3">Residential consumption</td><td>City</td></tr>
</table>

3.5. Calibration of model parameters

All the variations of economic developments and energy technologies are based on the existed conditions and foundations. Hence, it is important to calibrate the current parameters and related data.

In order to analyze the influence of related energy activities and technical improvements on the future energy demand, the analysis system on sectoral structure, activity level, energy technology and energy fuel in this paper was much more detailed than that of the current statistical system. Because some energy activities haven't been described in the current statistical system, experts' investigation and estimation were employed in this paper. Hence, there existed certain differences for some sectors between the analysis system in this paper and the current statistical system, especially for the base year of 2000. For example, the activity level of building material industry (GDP, products, etc.) were similar between the statistical data from the industrial association and state statistics bureau, but the energy consumption of the industrial association was near 100 Mtce higher than that of state statistics bureau. In addition, for petro-chemical industry, coal consumption of the industrial association was 40~50 Mtce lower than that of state statistics bureau.

For the energy data adjustment in the base year of 2000, two main aspects were considered. First, avoiding the possible errors on relative economic activities, especially to avoid the repeat or omit consideration for related sectors. Second, adjusting the energy system structure and energy efficiency level on the basis of actual technical economic investigation and the energy balance table. However, there still existed certain differences between the adjusted energy data and the energy balance table, especially the calibrated coal consumption in 2000 were much higher than that of the energy balance table.

For the continuous reduction of energy production and energy consumption during 1997 to 2000, there are many opinions. Most experts think that the statistical data may be lower than the actual level because of various reasons. Especially in some non state-owned middle or small enterprises, many uncertainties may exist. In this paper, the related data mainly were based on the results from related industrial associations because these data are more credible, which has resulted in the higher energy consumption than the governmental statistical data in 2000. However, this way may bring more reasonable and actual results on activity level and related energy data for each sector.

4. Main Driving Forces of China's Future Energy Demand Trajectories

The energy demand will be influenced by many factors in the coming decades from demographic to social and economic developments, such as the population condition, urbanization pattern or process, economic growth rate & economy activities expanding pattern, technology innovation or improvement, the availability of high-quality energy like oil and gas, environment policies and so on. The followings are the analysis and summery of the key factors that influence China's future energy demand.

4.1 Population and Aging Society

According to the white book of population development issued by the government in 2000, and the study results conducted by the domestic institutions, it is expected that the population will increase at lower speed and the growth rate will slow down in the coming two decades.

The low growth rate and the decrease of death rate will cause china enter an aging8 society. After entering the aging society, big changes will be taken place in the consumption structure and society development mode.

4.2 Urbanization

Presently, the urbanization rate in China is relatively low, which is only 36% in 2002. According to the research result of domestic institutes, urbanization will still be a main driver for China's rapid economic growth in the long term. The increase of urbanization level means the expansion of city scale and the construction of groups of new cities, which will lead to a huge demand in city infrastructure construction and investment to residential houses. Accordingly, energy-intensive industries, such as building material, iron and steel industry, will continue their high growth rate. Consequently, China's future energy demand will be influenced.

The speedup of urbanization progress will lead to an increase of commercial energy demand for civil use. At the same time, the construction of small towns will provide a requirement for the development of renewable energy. The speedup of urbanization progress will change future's energy consumption mix to a great extend. Energy for residential purpose will be developed toward higher quality, cleaner, diversified and sustainable.

4.3 Economic Growth Pattern and Industrial Structure Adjustment

The economic structure change in China in the last 20 years could be divided into two stages: before 1990, the adjustment of three key sectors played an activate role in energy conservation. After 1990, industry structure reconstruction provided much

[8] Note: internationally, the aging is related to the proportion of the people above 65 years old

contribution to energy conservation. The energy conservation contribution degree of different industries in the 9th five-year period was analyzed in the research, and the result had shown that industry sector played an important role in recent year's energy conservation.

As an unbalanced economic development country, the relatively well developed areas, such as in the south-east coastal area, has entered the medium stage of industrialization. In the coming 10 years, the industry structure adjustment tendency in these areas is towards high-tech fields. However, in the wide middle-east areas, they have just entered the preliminary stage of industrialization, and the construction of infrastructures has not been finished. With the speedup of "Great West Development", the economic structure adjustment will go in the direction of "231" mode. In general, the total energy demand of China will grow, but that does not necessarily mean the energy intensity of China will increase, too.

4.4 International Trade and WTO

International trade had played more and more important role in China's economic growth, and it has influenced China's energy consumption and energy efficiency level since the 1990s as well. It is believed in the long term, the impact brought by international trade will be even stronger.

4.5 Technology Advancement

In future's energy development, technology advancement will play more important role. In energy supply fields, such as energy production, processing and conversion, technology advancement will increase the availability of high quality energy.

In energy consumption fields, the development of science and technology will increase the efficiency in industrial sector. On one hand, the efficiency of devices can be improved, resulting to the reduction of unit product energy consumption. On the other hand, the rapid development of information industry, electronic business, communication devices etc. had shortened the trading process and lowered cost of the transaction. This will result to the decrease of energy intensity and energy consumption, too.

Though China's energy demand will keep growing, the development of new energy technology can lower the impact brought by energy consumption to the global climate change and field environment. It is foreseeable that new energy technology will exert a prominent influence to the CO2 emission reduction in the future.

Besides the great impact brought by technology advancement in energy field, the technology development in other fields will provide long and deep influence to China's economic growth and energy consumption, too.

4.6 Energy Mix Optimization

Energy mix optimization is one of the reasons that caused low growth rate in China's energy consumption during the 1990s.

If sustainable energy development is discussed, energy optimization is an inevitable topic. Seen from the long-term, China's oil demand will keep growing, and the gap of domestic supply and demand will be bigger and bigger. The distance between natural gas production fields and consumption area is long, and long-distance pipeline is needed. Therefore, the uncertainty of natural gas massive utilization has increased.

There are many forecasts about China's future energy supply gap for high quality energy in the next 20 years. One representative forecast result is shown in Table 4-1.

Table 4-1 Forecast on supply and demand of China's Future Oil & Gas

	2010	2020
Crude Oil Demand（Mt）	296	380
Gap of oil supply and demand（Mt）	96~116	180
Natural Gas Demand（$10^8 m^3$）	1100	1500~2200
Net Import（$10^8 m^3$）	300~400	500~1000

How to import oil and natural gas massively with guaranteed energy safety is one of the main challenges that China's energy strategy may face in the 21 century. How to guarantee the availability of oil and gas resources, and consequently adjust China's energy mix, is one of the main uncertainties in constructing future China's energy demand scenario.

4.7 Environment Policy

In the history of all countries' economy development, environmental problems brought stronger impact to energy supply technology and energy strategy. With the raise of living standard, people focus more and more on the quality of environment. The internalization of the environmental problems has made the cost of energy consumption grow. And the relative price of different energy type has been changed, too. In many cases, the environmental concern became more influential than energy resource conditions.

Environmental factor may influence energy supply/demand through two methods. One is the development of stricter environment emission standard, which will raise the cost of dirty energy's usage. Thus, energy shift can be promoted through market adjustment. The other is compelling energy change, which is enforced by government, to alter the energy type.

The influence of global environment problem is becoming stronger in the energy mix issue and energy efficiency issue in all countries. As a country that approved Kyoto Protocol, if China's future economic growth mode follows the road of current developed country, i.e. building the society on energy-intensive basis, taking no effective energy conservation measures to reduce energy consumption, not improving the energy consumption mix which is based on coal to reduce or mitigate CO2 emission growth rate, it will not be affordable. China should take the international responsibility of protecting global environment. This will provide active influence on energy efficiency improvement.

5. An Overview of China's Energy Demand Scenarios to 2020

5.1 Basic Concerns on Scenarios Design

- In the project of China's Sustainable Development Energy and Carbon Emission Scenario Analysis (abbreviated as Energy and Carbon Emission Project), three scenarios were developed to analyze China's medium-and-long term energy demand under sustainable development. Sustainable energy development objective were considered in all 3 scenarios, but different policy implementation strength, different energy technologies were selected. Thus, energy supply and demand was different. Scenario1 It is assumed that economic development will improve energy efficiency, but the devotion to energy efficiency improvement will be constrained by market competition pressure to some degree. Due to the constraint of some factors such as cost or resource, clean fuel technology can not be widely promoted and utilized.

- Scenario 2 Based on the "10^{th} five-ear plan" and its proceeding 10 year's project of China in different sectors, it is assumed the main social and economical objective, which was put forwarded by government, may achieve smoothly. It can be seen that scenario 2 is the explanation of China's sustainable economic development and sustainable energy development scene by sectional experts according to government's "10^{th} five-year plan" and proceeding 10 year plan.

- Scenario 3 This is a relatively ideal scenario, which requires strong measures in energy efficiency improvement, economic and energy structure adjustment, environment protection and technology advancement. The policy influence of macro adjustment and sustainable development promotion is assumed to be strong. Moreover, the external environment is relatively ideal, and China can fully use international energy market to obtain high-quality energy resource, which will result to an essential progress in energy mix shift. China may introduce advanced technology, devices and capable experts etc., too. In year 2020, China's energy efficiency level will reach somewhat leading status.

In the Chinese Communist Party's 16th congress in November, 2002, the objective of "building a well-off society in an all round way" was put forward, which requires "efforts will be made to quadruple the GDP of the year 2000 by 2020", "in the main achieve industrialization", and "the capability of sustainable development will be steadily enhanced". These development strategy and objective enriched and developed the 3-step development strategy raised by Mr. Deng Xiaoping. It is an all-round plan for the fore-stage (year 2000~2020) of achieving the 3rd strategic objective.

The scenario design of Energy and Carbon Emission Project was done before year 2001. At that time, macro scenario setup was mainly based on the economic development strategy raised by Mr. Deng as "using 3 steps to achieve modernization". The detailed social economical development objective in the period of 2000 to 2020 is referred to government's "10th five-year plan", other long-and-medium development strategy and plans, and some research result of domestic institutes. Though the social economic development tendency of the Energy and Carbon Emission Project is almost the same as the objectives raised by 16th CPC congress, e.g. the GDP growth rate will be kept at about 7% etc., some detailed development indexes was not reflected in the scenario design of that research. In addition, 3 scenarios in that research mainly focus on China's energy demand tendency under sustainable development. The situation of China's energy demand under the condition of frozen economic growth mode with unsuccessful sustainable development was not analyzed.

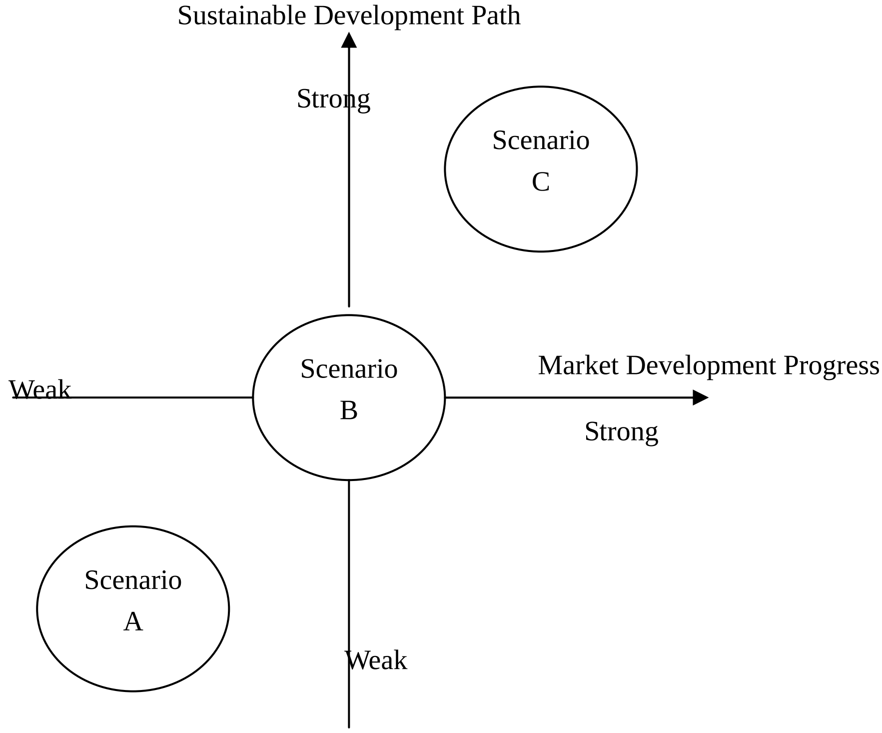
In general, based on the research of Energy and Carbon Emission Project, it is found to be necessary to analyze the energy development road under the condition of quadrupled GDP. In order to compare different future energy demand brought by different policy implementation strength, 3 energy demand scenarios under the condition of quadrupled GDP was designed[9]:

- Scenario A (taking no special policy measures, similar to BAU): GDP quadrupled, the setup of social/economic/ energy scenario was referred to Scenario 1 in Energy and Carbon Emission Project and Scenario B in this project;
- Scenario B: GDP quadrupled, the assumption of social / economic / energy scenario is similar to Scenario 2 in Energy and Carbon Emission Project;
- Scenario C (Policy strengthened scenario): GDP quadrupled, the influence of industry / energy / environment was emphasized, main social/economic/energy scenario assumption is similar to scenario 3 in Energy and Carbon Emission Project;

In order to show the similarity and difference of above 3 scenarios, the strength of sustainable policy implementation and the strength of market transition progress, which describes the openness of the market and China's adaptability toward WTO and globalization progress, were selected as the main driving force: Scenario B corresponding to a relatively success in policy implementation. Comparing with Scenario B, Scenario C is even more ideal, not only in the implementation of sustainable development policy, but also in market construction and its adaptability to globalization. Scenario A is worse than Scenario B whether in market construction or openness. The relative position in sustainable development and market transition progress is illustrated in Figure 5-1-1.

[9] In defining the name of the scenario, a problem was raised during the research done by World Energy Council and Inter-government Panel for Climate Change: it is difficult to use a few characters or a few words to describe the content of each scenario. Therefore, same solution is used in this research, i.e. to use A, B and C to represent the long name of each scenario.

Figure 5-1-1 Conceptual design of 3 scenarios



5.2 Key Assumptions of Scenarios

5.2.1. Assumptions on social and economic development

（1）population and urbanization rate prospects

Based on domestic research results, population growth and urbanization rate in China in the coming 20 years were assumed, shown in Table 5-2-1.

Table 5-2-1 Assumptions on population and urbanization rate among three scenarios

Scenario Name	Content	2000	2005	2010	2020
Scenario C	Population (billions)	1.267	1.321	1.368	1.445
	Urbanization rate (%)	36.22	40.45	45.32	58.29
Scenario B	Population (billions)	1.267	1.321	1.378	1.47
	Urbanization rate (%)	36.22	39.86	44.01	55.78
Scenario A	Population (billions)	1.267	1.327	1.385	1.485
	Urbanization rate (%)	36.22	38.89	42.94	52.86

（2）Economic Development

The domestic and International agencies have made some projections on China's future economic development (See Table 5-2-2). As above-mentioned, the research is to explore China's energy path under the anticipated economic development target, i.e., to keep the averaged annual economic growth rate by 7.2% in the next 20 years from 2000 to 2020. In this study, the growth rate was assumed to vary in different development phase, the details were shown in Figure 5-2-1 and Table 5-2-3.

Table 5-2-2 Forecasts Provided By International Agencies for China's GDP growth

Researcher	2000 -2010	2010 -2020
Chinese Academy of Science	8.0 -8.7%	7% -7.8%
Social Science Academy of China	6.4%	4.0%
Dev. Research Center of State Department	7.9%	6.6%
World Bank	6.9%	5.6%
Land Company	3% -4.9%	2.1% -5.3% （2010 -2015）

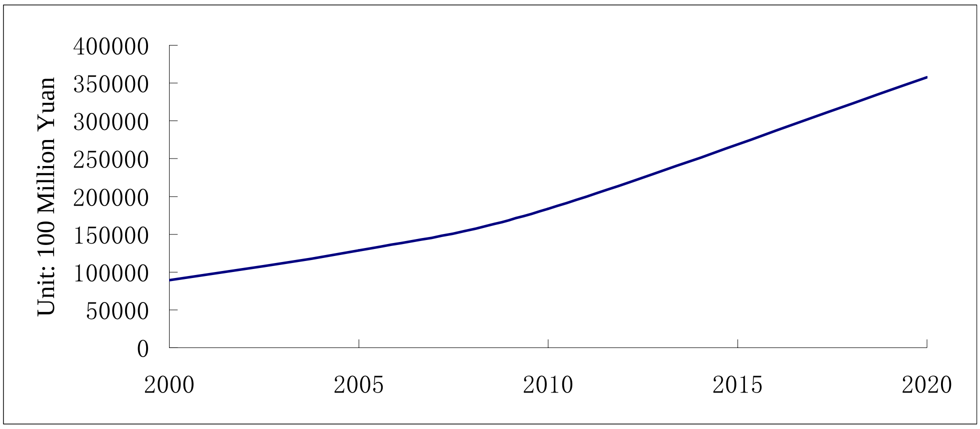


Figure 5-2-1 China's Future Economic Development Trend among three scenarios

In year 2020, the GDP per capita will be about 3000 $ (See Figure 5-2-4). According to the standard given by World Bank in year 1999, China will approach the lowest level of upper-middle income countries of current level[10].

Table 5-2-3 GDP and growth rate in the 3 scenarios

	Unit	2000	2005	2010	2020
GDP	billions RMB yuan	89468.1	128742	183540	357875
		2000~2005	2005~2010	2010~2020	
Average Annual Growth Rate	%	7.55	7.35	6.9	

Note: based on 2000 constant price

Table 5-2-4 per Capita GDP of the 3 Scenarios

Unit: RMB Yuan（price of year 2000）

	2000	2005	2010	2020
Scenario C	7061	9746	13417	24766
Scenario B	7061	9746	13319	24345

[10] If calculated as World Bank's PPP standard, China will enter the row of developed country

Scenario A	7061	9702	13252	24099

（3） Industrial Structure

The roadmap of China's future industrial structure change is assumed among three scenarios as shown in Figure 5-2-2 and Figure 5-2-B.

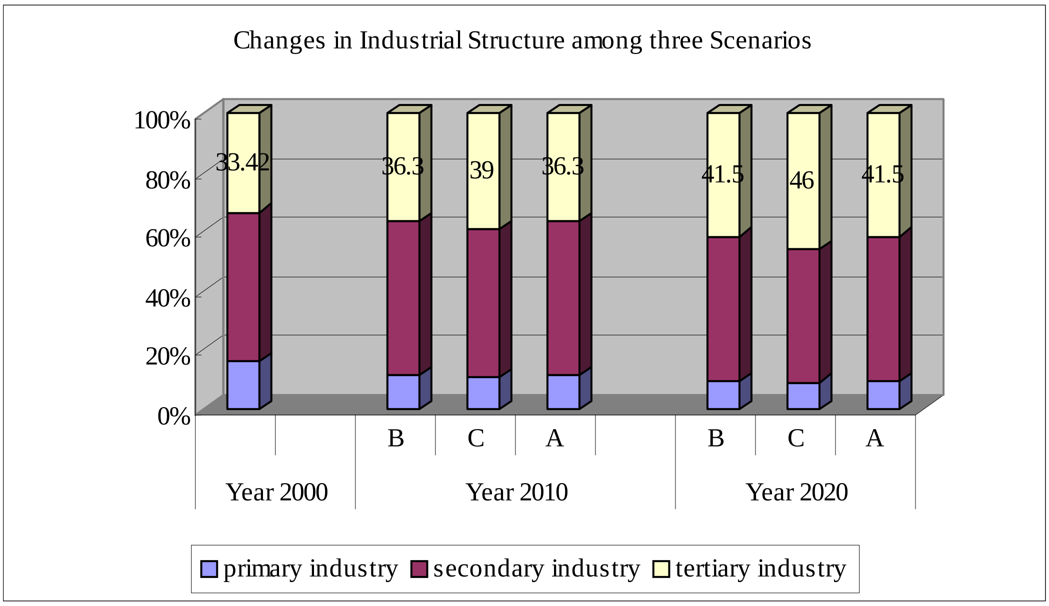


Figure 5-2-2 Perspective on China's future Industrial Structure among three scenarios

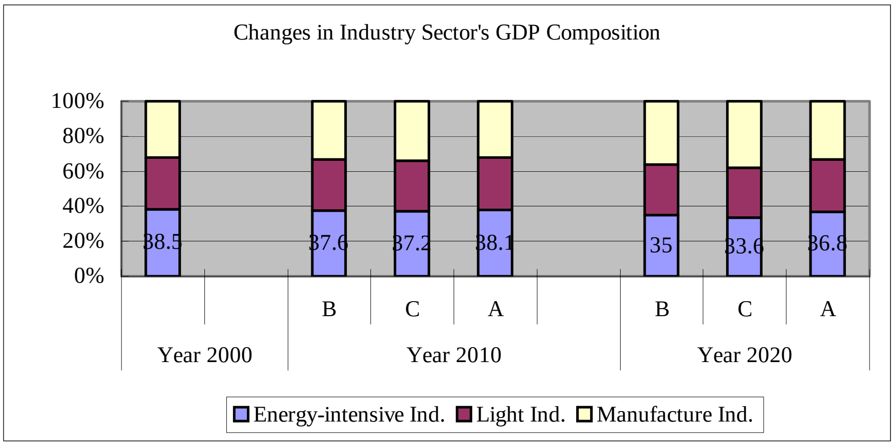


Figure 5-2-2B Change of industry sector's composition

5.2.2. Assumptions on sector development

（1）Output of energy-intensive products

When per capita GDP reaches 10, 000 $ or industrialization is basically achieved, the accumulated energy-intensive product consumption per capita in the developed countries will reach a certain level (see Figure 5-2-3).

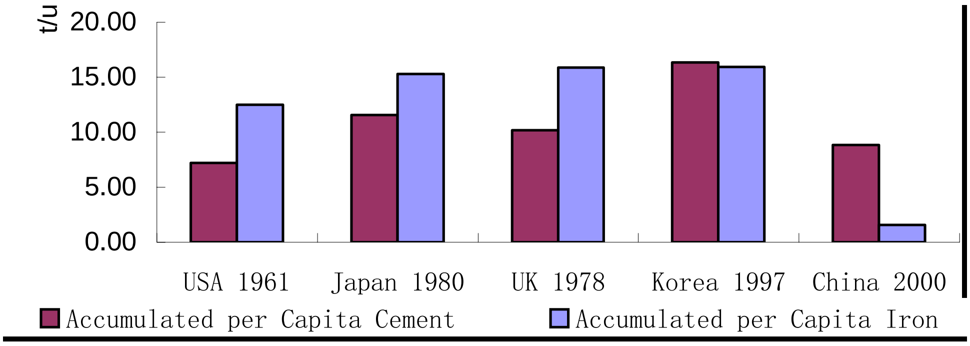


Figure 5-2-3 Accumulated per capita consumption of some energy-intensive products in selected countries

Table 5-2-5 Assumptions on main energy-intensive products to 2020

	2000	2005	2010	2020	Annual growth rate （%）
Iron & Steel (10,000tons)	12850	25000	30000	28000	3.97
Cement (10,000tons)	59700	68000	79066	107000	2.96
Synthetic Ammonia (10,000tons)	3346	3600	3800	4400	1.38
Ethylene (10,000tons)	450	790	1200	2000	7.7
Paper (10,000tons)	2487	4000	5000	7500	5.7

It is assumed that, technology advancement and the change of energy-intensive production utilization extent can help China to accomplish industrialization by year 2020, and the demand of energy-intensive product per capita could be less than other countries. However, the room for the growth of energy-intensive product is still large. The assumed output of energy-intensive products is listed in Figure 5-2-5.

（2）Per capita living space

Presently, per capita GDP in China has reached 1,000 $, but the construction area of residential housing per capita in cities and towns is only 20.3 m2. The Engel coefficient for the residents in cities and towns has decreased below 0.4, but the proportion for the consumption of housing is less than 10%, which is 5~10 percents lower than international average level. These two factors showed that the consumptions related to housing in China, or i.e., the real estate market, is expected to enter a rapid growing period.

Existing analysis and forecast, which was done by international and domestic institutes, of residential area of China's urban and rural residents is shown in Figure 5-2-4.

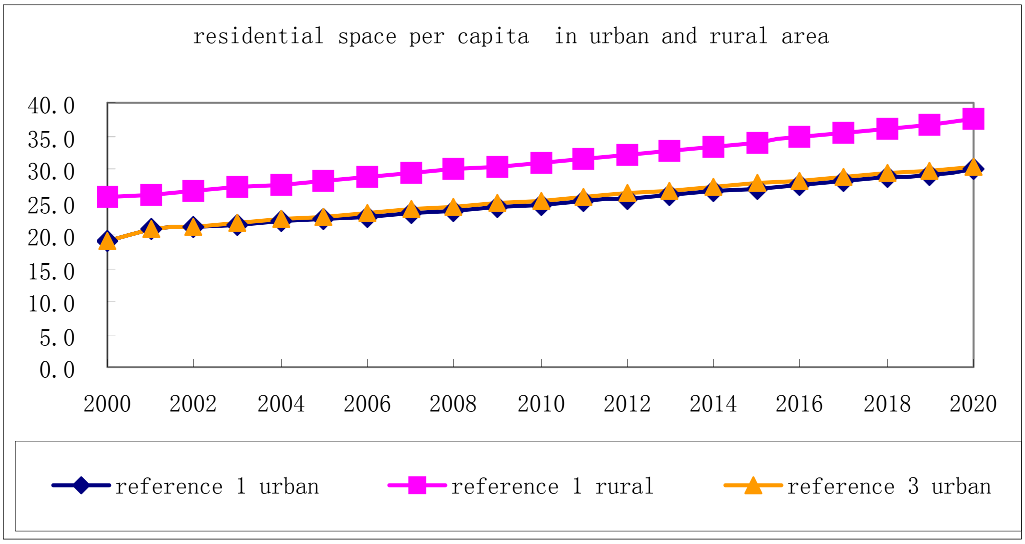


Figure 5-2-4 Selected forecast results on living space of Chinese urban and rural residents in future

Source
Reference 1: "main economic index of year 2020's well-off society", China macro economy network
Reference3: "Foreseeing the well-off society from qualitative and quantitative aspect- leanings from the 16th CPC congress report (A)"

Table 5-2-6 residential area (construction area) for urban and rural residents

	2000	2010	2020
Residential construction area per capita in urban area (m^2)	20.3	23	30
Residential living space per capita in rural area (m^2)	24.8	28	33

In order to compare the impact brought by different policies to the residential/commercial energy use in the 3 scenarios, same residential living space per capita in 3 scenarios was assumed, shown in Table 5-2-6.

（3）per Capita Automobile Possession

Generally, direct factors that may influence Chinese family's automobile possession include: resident's consumption level, consumption preference, automobile's price and type, national consumption policy etc.

It is estimated that during the "10th five-year plan" period, the annual growth rate of automobile demand in China will be 20~ 25% and the annual growth rate for the demand of private car will be about 33%. At that time, the proportion of car demand in total automobile demand will increase from 22% in year 2000 to 60% in year 2005. To summarize the forecast result of domestic and international research institutes, the tendency of China's automobile possession rate is listed in Table 5-2-7.

Table 5-2-7: Forecast on motor vehicle and private car population in use in China

	Unit	2000	2005	2010	2020

Motor Vehicle population	Million-set	16.1	38	58	110
Private car population	Million-set	3.7	13	32	72
Total population	Billion-person	1.266	1.321	1.378	1.47
Cars per 100 households	%	0.3	1.0	2.3	4.9

（4）Source of power generation

The sustainable development of power generation sector depends on the availability of reliable and affordable power generation and environment protection.

For the concern of energy resources, great potential exists in the development of hydropower, wind power or solar power.

In the 3 scenarios, different power generation structures are assumed (see table 5-2-8).

Table 5-2-8: Assumption of Power Generation Source

		Power Generation Capacity			
		2000	2005	2010	2020
Scenario C	Coal	72.2%	68.4%	62.3%	58.9%
	Oil	3.4%	2.2%	0.6%	0.1%
	Gas	0.4%	1.2%	4.6%	5.0%
	Hydro	23.1%	26.9%	28.3%	27.8%
	Nuclear	0.8%	1.1%	2.8%	4.7%
	Renewable	0.0%	0.3%	1.4%	3.5%
Scenario B	Coal	72.2%	68.9%	65.6%	65.5%
	Oil	3.4%	2.3%	0.8%	0.3%
	Gas	0.4%	0.8%	4.7%	4.5%
	Hydro	23.1%	26.7%	26.5%	24.3%
	Nuclear	0.8%	1.0%	1.9%	3.9%
	Renewable	0.0%	0.2%	0.6%	1.5%
Scenario A	Coal	72.2%	70.7%	68.7%	69.9%
	Oil	3.4%	2.4%	0.8%	0.6%
	Gas	0.4%	0.8%	4.9%	4.8%
	Hydro	23.1%	25.0%	23.5%	20.2%
	Nuclear	0.8%	1.0%	1.6%	3.3%
	Renewable	0.0%	0.2%	0.5%	1.2%

The improvement of power generation efficiency in Scenario C is listed in table 5-2-9.

Table 5-2-9: Improvements in power generation efficiency in Scenario C

	2000	2005	2010	2020
Coal	31.4%	33.8%	35.2%	38.5%
Oil	33.4%	36.1%	38.2%	40.0%
Gas	36%	41.8%	46.5%	51.5%

In power transmission and distribution, the loss will decrease from 7% in year 2000 to

5.8% in year 2020. The assumption is the same in 3 scenarios.

5.2.3. Other Assumptions

Besides macro-economic concerns, many factors, such as technology advancement level, availability of high-quality energy, environment policy, energy policy etc., will influence future energy demand strongly. A few examples of the mass scenario assumptions are given below:

The energy intensity of unit product for coal-based large synthetic ammonia production is shown in Figure 5-2-6 (Scenario A).

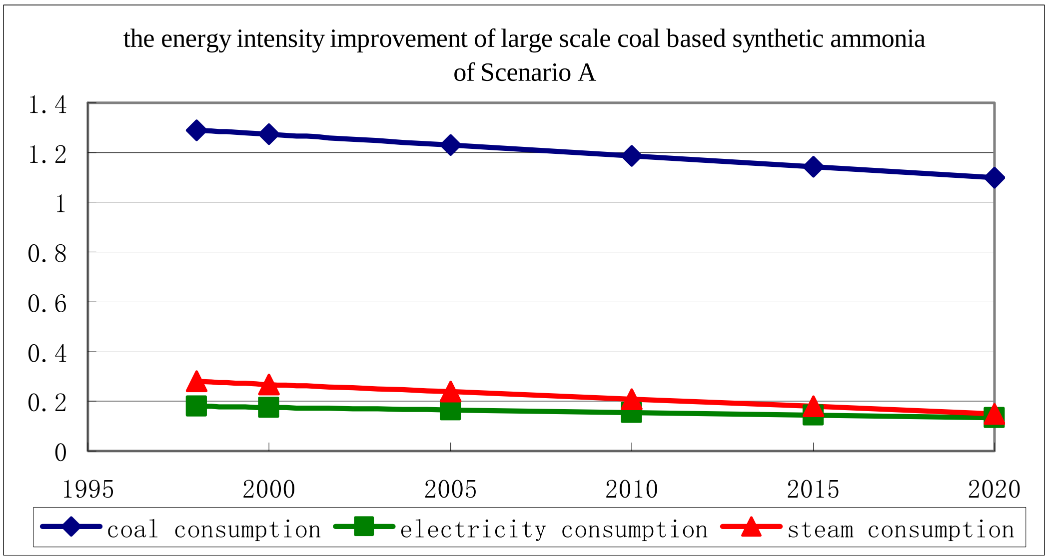


Figure 5-2-6: Energy efficiency improvement of large scale coal based synthetic ammonia of Scenario A

The increase of transportation load in Scenario B is shown in Figure 5-2-7.

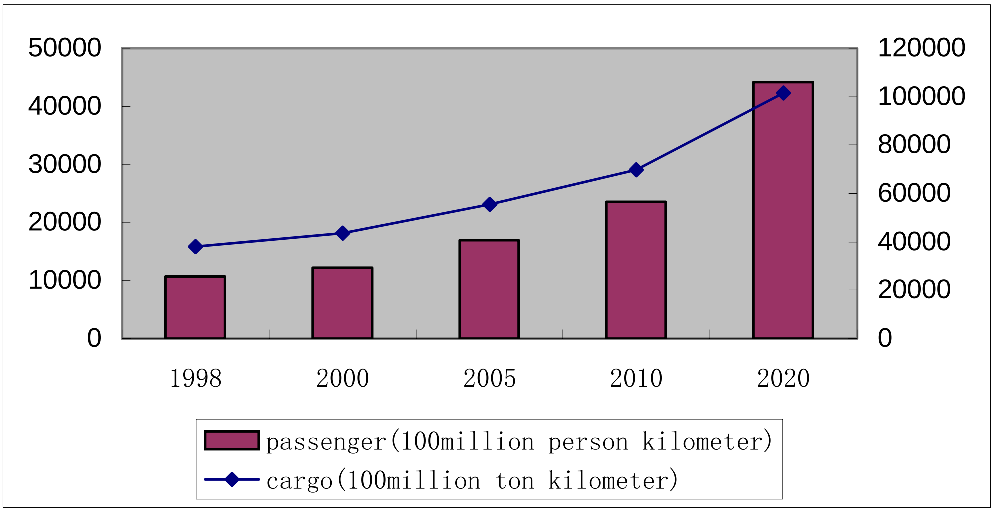


Figure 5-2-7: Assumptions on activities of transportation sector in future China

The improvement of air-conditioning load for public buildings in Scenario B is shown in Figure 5-2-8.

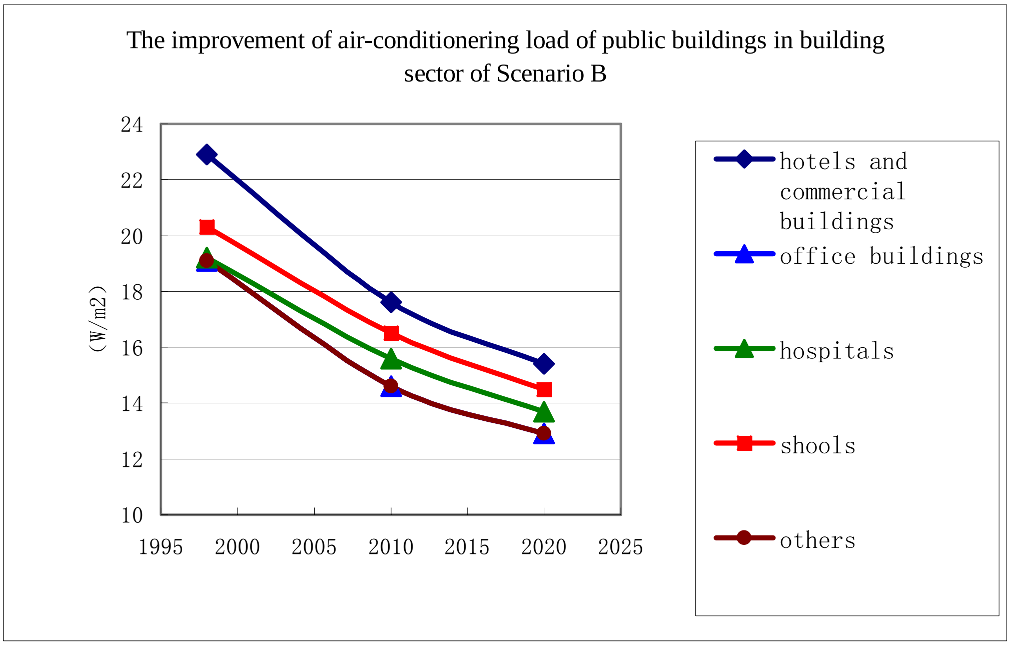


Figure 5-2-8: The improvement of air-conditioning load of public buildings in Scenario B

Though the setup of product energy intensity seems to be the consequence of technology advancement, actually, environment constrains and energy policies are concerned during the setup, i.e. different energy policies or environment policies will cause different technology advancement level and different speed for energy efficiency improvement, Besides, different policy enforcement strength will influence the setup of production output, processing technique and change of people's lifestyle.

Main policy measures assumed to be taken by government in scenario C is listed in Table 5-2-11. In Scenario B and Scenario A, different strength of policy enforcement is assumed.

Table 5-2-11 Assumed Key Policy Measures that China will take in Scenario Analysis

Transportation	Buildings	Industry	Energy conversion sector
● Fuel oil tax ● Public transportation development mode. Intelligent transportation System (ITS) will be used in big and middle cities. ● The development of measures to promote clean fuel vehicle ● The development of policies to encourage the introduction of energy efficient and environment friendly automobile from abroad ● Development of fuel efficiency standard ● etc.	● Development of building energy conservation standard, and implementation of heat price reform ● Development and implementation of lowest efficiency standard and labeling for household electric facilities ● Promotion of new energy conservation wall ● Demonstration and promotion of large projects, such as Green Lights ● etc.	● Demonstration and promotion of Voluntary Agreement ● revision of industrial energy conservation design code ● Establishment of product labeling and energy consumption rating system ● Development of relative laws and regulations for Energy Conservation Law, and corresponding demonstrations and promotions ● etc.	● Continuing electricity market reform ● Fully washout units below 100MW ● Installation of desulfur units for new built coal-fired power plant ● Development of low carbon or zero carbon energy, such as hydropower ● Encourage the research and application of technologies such as fuel cell and photovoltaic cell ● etc.

5.3 Scenario Results[11]

Looking from China's current development trend since 2000, China has entered into the stage of so-called "chemical and heavy industry" stage. The growth of energy-intensive industries is fast, and the speed of urbanization is speeding up. The residents' consumption structure is updating, more energy expense is appeared in living and traveling. In year 2003, the energy consumption of China increased 10.1%, and the GDP growth rate had reached 9.1%. According to current development status, the energy demand of China will strongly exceed the energy demand under the planned development objective. Under the fixed condition of GDP quadrupled in year 2020 to year 2000, the influence of different policy options to future energy demand will be discussed in this work.

5.3.1. End-use energy demand and final energy mix

Final energy demand and its composition by fuel of the 3 scenarios are shown in Table 5-3-1 and Figure 5-3-1.

Same tendency is reflected in the 3 scenarios, i.e., the growth rate of high-quality energy is higher than the growth rate of total energy in futures end-use sectors.

Table 5-3-1: Final Energy Demand and its Structure

Scenario	Type	End-use Energy Demand （Mtce）			Annual growth rate	Composition(%)		
		2000	2010	2020	2000~2020	2000	2010	2020
Scenario A	Coal	466	658	836	3.0%	47.3%	40.6%	33.7%
	Oil	289	503	827	5.4%	29.3%	31.0%	33.3%
	NG	28	72	157	9.0%	2.8%	4.5%	6.3%
	Elec.	154	287	487	5.9%	15.6%	17.7%	19.6%
	Heat	49	100	177	6.6%	5.0%	6.2%	7.1%
	total	985	1621	2484	4.7%	100.0%	100.0%	100.0%
Scenario B	Coal	466	640	758	2.5%	47.3%	40.5%	33.7%
	Oil	289	491	754	4.9%	29.3%	31.1%	33.5%
	NG	28	71	140	8.4%	2.8%	4.5%	6.2%
	Elec.	154	280	441	5.4%	15.6%	17.7%	19.6%
	Heat	49	98	158	6.0%	5.0%	6.2%	7.0%
	total	985	1580	2252	4.2%	100.0%	100.0%	100.0%
Scenario C	Coal	466	545	559	0.9%	47.3%	38.3%	29.3%
	Oil	289	431	605	3.8%	29.3%	30.3%	31.7%
	NG	28	79	159	9.1%	2.8%	5.6%	8.4%
	Elec.	154	275	434	5.3%	15.6%	19.3%	22.8%
	Heat	49	93	148	5.7%	5.0%	6.5%	7.8%
	total	985	1424	1905	3.4%	100.0%	100.0%	100.0%

Note: electricity is calculated according to its heat value

[11] Energy, which is mentioned here, does not include traditional biomass energy

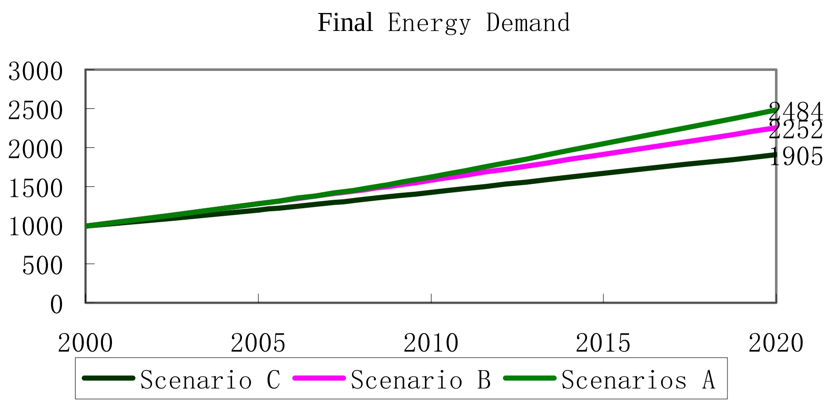


Figure 5-3-1 Final energy demand

For the demand of different energy type, natural gas, electricity and oil will grow fast in end-use field. However, the growth rate of coal is lower than the average level. International development history have shown that coal is more likely to be used in energy conversion sector, such as power generation, and the consumption of coal in end-use sector will continuously decreasing. The energy consumption by type in the 3 scenarios is shown in Figure 5-3-2 to Figure 5-3-4.

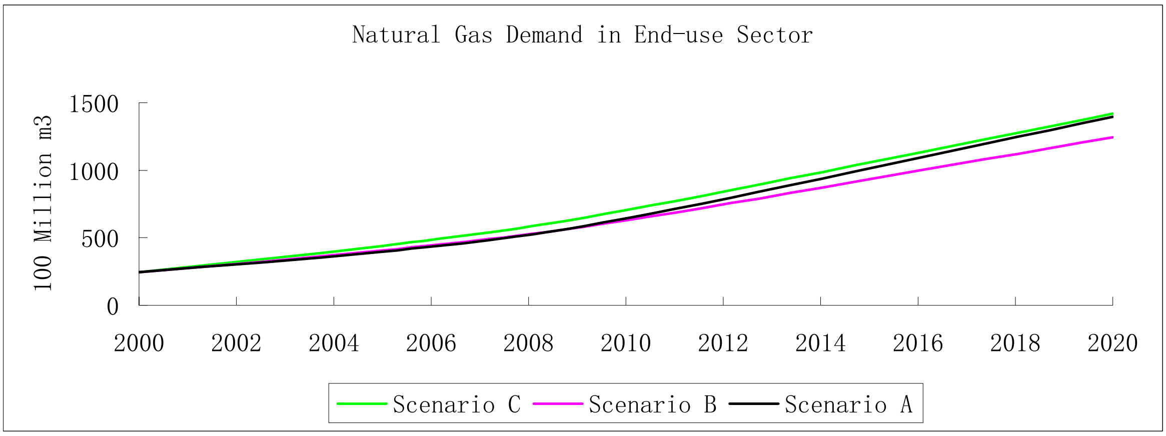


Figure 5-3-2 Natural Gas Demand in End-use Sector

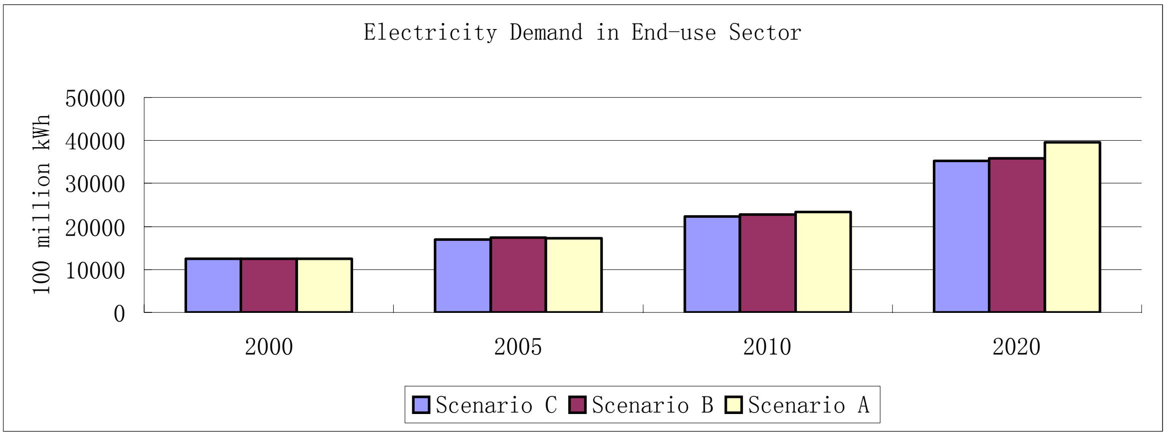


Figure 5-3-3 Electricity Demand in End-use Sector

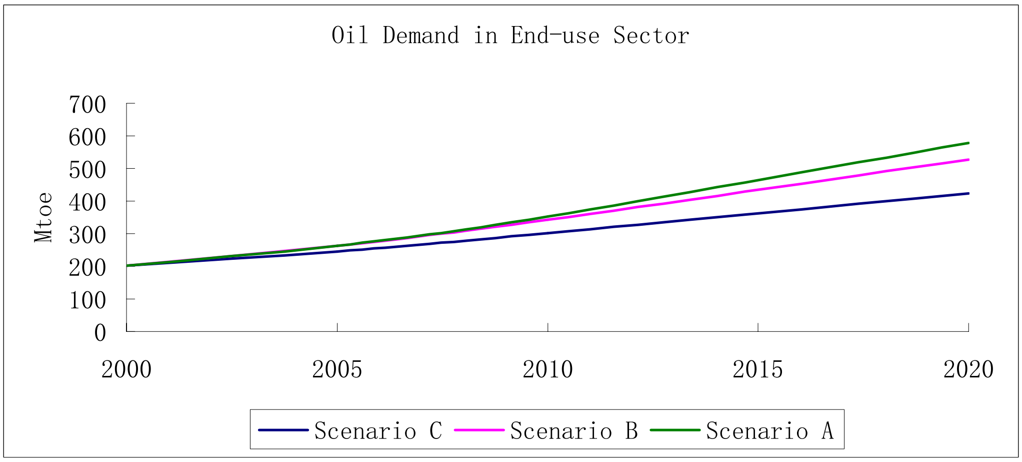


Figure 5-3-4 Oil Demand in End-use Sector

The final energy consumption by sector is listed in Table 5-3-2.

Table 5-3-2: Final energy use by sector

		End-use Energy Consumption （Mtce）			Average Growth Rate	Composition		
		2000	2010	2020	2000~2020	2000	2010	2020
Scenario C	Agriculture	39	42	59	2.18%	4.0%	2.9%	3.1%
	Industry	662	880	976	1.96%	67.2%	61.8%	51.2%
	Building	8	12	22	5.21%	0.8%	0.8%	1.2%
	Transportation	133	229	385	5.47%	13.5%	16.1%	20.2%
	Commercial	40	75	142	6.49%	4.1%	5.3%	7.5%
	Residential	104	186	321	5.82%	10.6%	13.1%	16.9%
	Total	985	1424	1905	3.35%	100.0%	100.0%	100.0%
Scenario B	Agriculture	39	49	69	2.96%	4.0%	3.1%	3.1%
	Industry	662	978	1169	2.89%	67.2%	61.9%	51.9%
	Building	8	14	27	6.27%	0.8%	0.9%	1.2%
	Transportation	133	255	465	6.47%	13.5%	16.1%	20.6%

	Commercial	40	80	153	6.89%	4.1%	5.1%	6.8%
	Residential	104	204	368	6.54%	10.6%	12.9%	16.3%
	Total	985	1580	2252	4.22%	100.0%	100.0%	100.0%
Scenario A	Agriculture	39	50	80	3.68%	4.0%	3.1%	3.2%
	Industry	662	1001	1316	3.50%	67.2%	61.8%	53.0%
	Building	8	16	29	6.65%	0.8%	1.0%	1.2%
	Transportation	133	262	503	6.89%	13.5%	16.2%	20.2%
	Commercial	40	79	156	7.00%	4.1%	4.9%	6.3%
	Residential	104	212	399	6.97%	10.6%	13.1%	16.1%
	Total	985	1621	2484	4.73%	100.0%	100.0%	100.0%

End-use energy consumption structure inside industry sector is shown in Table 5-3-3.

Table 5-3-3 Final energy use within industry sector

		End-use Energy Consumption （Mtce）			Annual Growth Gate	Composition		
		2000	2010	2020	2000~2020	2000	2010	2020
Scenario C	Energy intensive industry	557	740	797	1.80%	84.1%	84.1%	81.7%
	Light ind.	67	85	111	2.56%	10.1%	9.7%	11.4%
	Manufacture ind.	37	56	68	3.03%	5.6%	6.4%	7.0%
	Total	662	880	976	1.96%	100.0%	100.0%	100.0%
Scenario B	Energy intensive ind.	557	812	959	2.75%	84.1%	83.0%	82.0%
	Light ind.	67	107	135	3.56%	10.1%	10.9%	11.5%
	Manufacture ind.	37	59	76	3.64%	5.6%	6.0%	6.5%
	Total	662	978	1169	2.89%	100.0%	100.0%	100.0%
Scenario A	Energy intensive ind.	557	838	1090	3.41%	84.1%	83.7%	82.8%
	Light ind.	67	106	150	4.10%	10.1%	10.6%	11.4%
	Manufacture ind.	37	57	77	3.68%	5.6%	5.7%	5.9%
	Total	662	1001	1316	3.50%	100.0%	100.0%	100.0%

For transportation energy consumption (including freight, passenger and city transportation), freight transportation remains to be the biggest energy consumer in transportation sector (see figure 5-3-5).

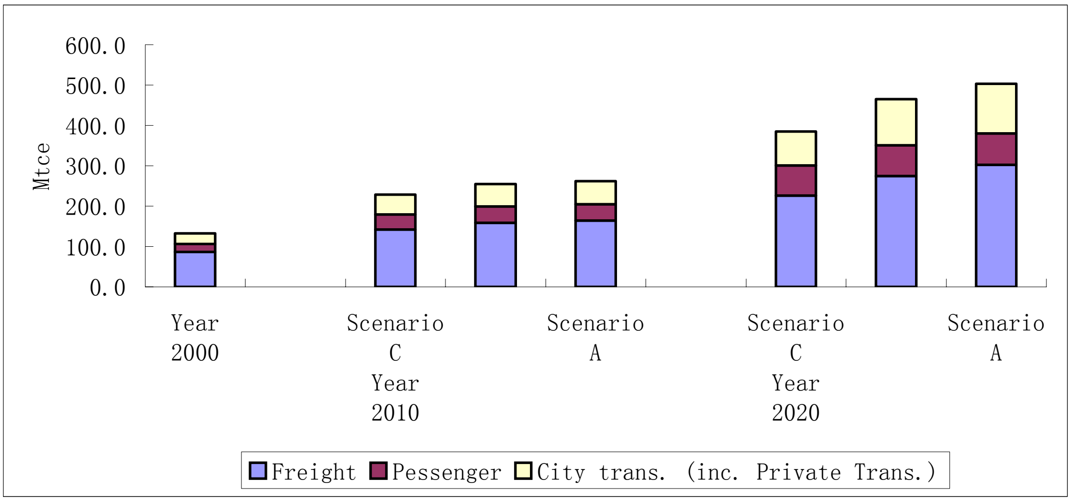


Figure 5-3-5: Transportation energy consumption by mode

Energy demand for freight transportation in the 3 scenarios is listed in Figure 5-3-6. It could be seen that if low energy intensive transportation methods, such as waterway or railway, are used, total energy demand will decrease correspondingly.

Table 5-3-4: Energy Consumption of Freight Transportation

		Final energy mix			Average Annual Growth Rate
		2000	2010	2020	2000~2020
Scenario C	Final Energy Demand（Mtce）	86.32	141.74	226.36	5.0%
	Highway	50.2%	45.3%	42.3%	
	Railway	22.9%	17.5%	15.0%	
	Railway transportation	22.1%	18.1%	16.1%	
	Aerial	3.9%	18.2%	25.8%	
	Pipeline	0.8%	0.7%	0.8%	
Scenario B	Final Energy Demand（Mtce）	86.3	158.6	274.4	6.0%
	Highway	50.2%	46.7%	44.4%	
	Railway	22.9%	15.6%	12.6%	
	Railway transportation	22.1%	17.7%	15.7%	
	Aerial	3.9%	19.3%	26.6%	
	Pipeline	0.8%	0.7%	0.7%	
Scenario A	Final Energy Demand（Mtce）	86.3	164.6	302.1	6.5%
	Highway	50.2%	45.9%	45.0%	
	Railway	22.9%	16.1%	12.6%	
	Railway transportation	22.1%	17.9%	15.6%	
	Aerial n	3.9%	19.5%	26.2%	
	Pipeline	0.8%	0.7%	0.7%	

Seen from energy type, oil product will be the main consumed type in China's future transportation sector. This could be found out not only in Scenario C, but also in

Scenario B and Scenario A. In Scenario A, the consumption of gasoline, kerosene and diesel will be more than 90% of total energy consumption in transportation sector. In year 2020, the ratio is as high as 97.8%. The demand of aerial kerosene will increase dramatically, and in year 2020, the demand of jet kerosene in the 3 scenarios will be between 40~50 million tons.

5.3.2. Primary Energy Demand and its composition

Primary energy demand in the 3 scenarios and its composition is listed in Table 5-3-5 and Figure 5-3-6.

Table 5-3-5 Primary Energy Demand and primary energy mix

Scenario	Type	Total Energy Demand（Mtce）			Average Annual Growth Rate	Composition(%)		
		2000	2010	2020	2000~2020	2000	2010	2020
Scenario A	Coal	907	1425	2074	4.22%	69.9%	66.7%	63.2%
	Oil	324	538	877	5.10%	25.0%	25.2%	26.7%
	N.G	36	112	220	9.44%	2.8%	5.2%	6.7%
	P.E	29	63	109	6.77%	2.3%	2.9%	3.3%
	Total	1297	2137	3280	4.75%	100.0%	100.0%	100.0%
Scenario B	Coal	907	1365	1788	3.45%	69.9%	66.0%	61.7%
	Oil	324	524	795	4.58%	25.0%	25.3%	27.5%
	N.G	36	108	193	8.74%	2.8%	5.2%	6.7%
	P.E	29	70	120	7.28%	2.3%	3.4%	4.1%
	Total	1297	2068	2896	4.10%	100%	100%	100%
Scenario C	Coal	907	1205	1466	2.43%	69.9%	64.8%	59.4%
	Oil	324	460	638	3.44%	25.0%	24.7%	25.9%
	N.G	36	115	219	9.41%	2.8%	6.2%	8.9%
	P.E	29	79	144	8.26%	2.3%	4.3%	5.8%
	Total	1297	1859	2466	3.26%	100%	100%	100%

Note: electricity is calculated according to its heat value

P. E is the abbreviation of primary electricity

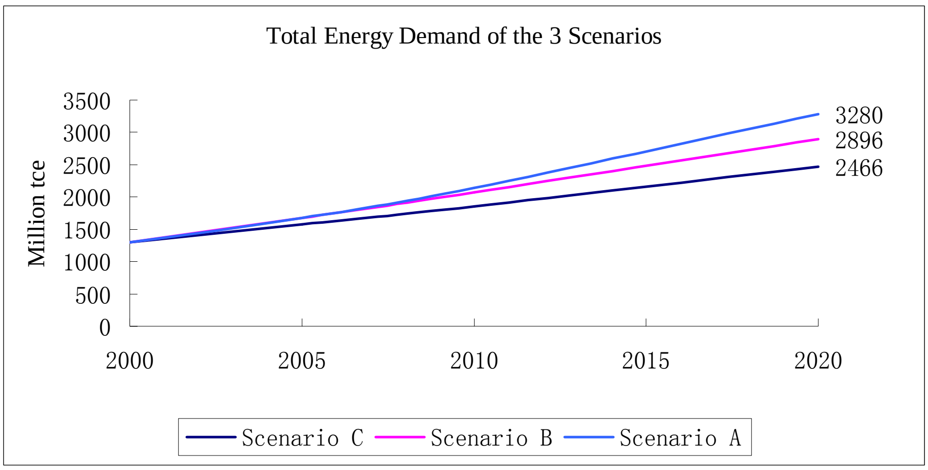


Figure 5-3-6 Primary Energy Demand

Total energy demand of coal, oil and natural gas is shown in Figure 5-3-7~5-3-9.

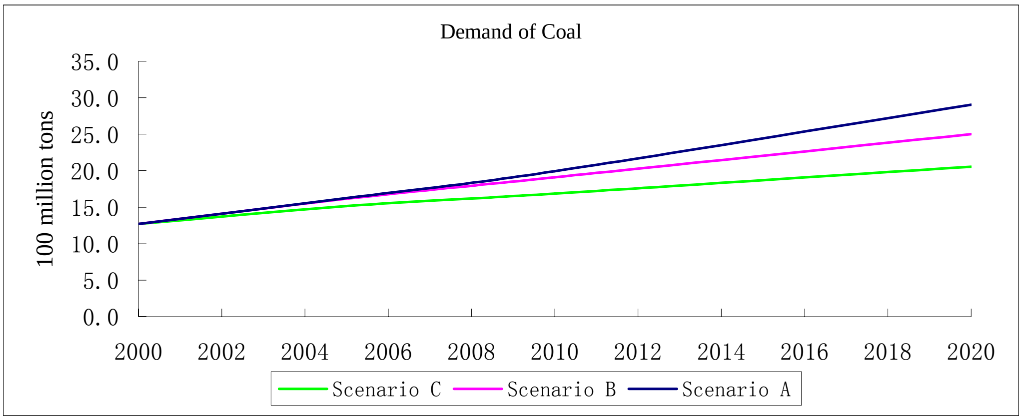


Figure 5-3-7 Total Coal Demand

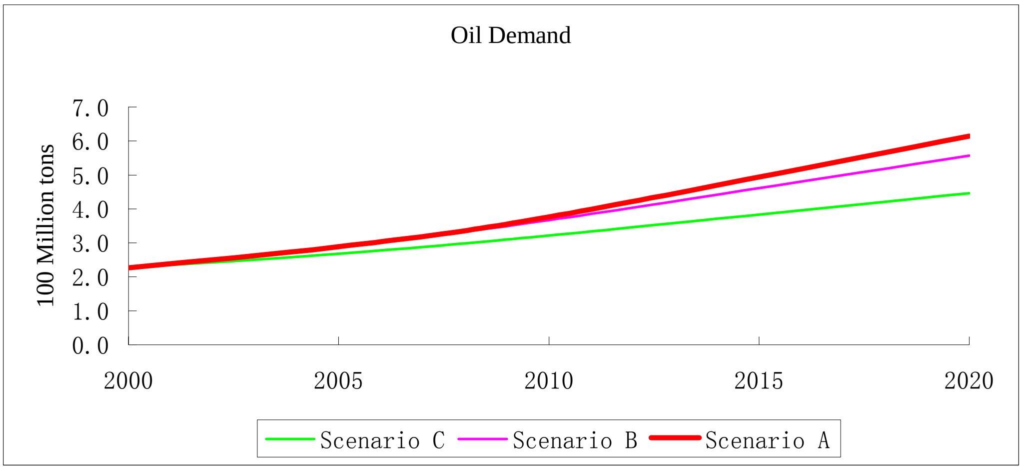


Figure 5-3-8 Total Oil Demand

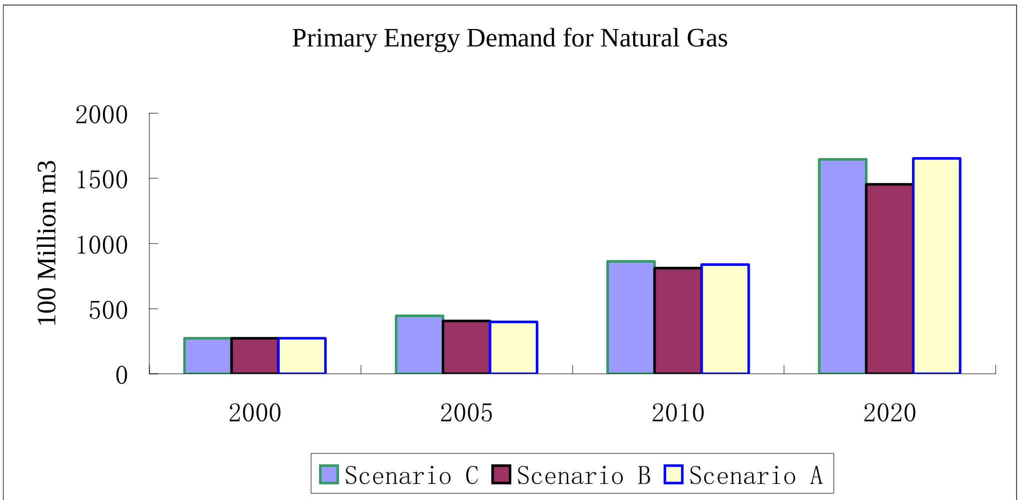


Figure 5-3-9 Total Natural Gas Demand

Total primary energy demand and its composition by sector are shown in Table 5-3-6 and Figure 5-3-10.

Table 5-3-6 Primary Energy Demand by Sector

		Total Energy Demand（Mtce）			Average Growth Rate
		2000	2010	2020	2000~2020
Scenario C	Industry Sector	943	1239	1398	2.0%
	Transportation	145	246	409	5.3%
	Commercial/Residential	210	374	659	5.9%
	Total	1297	1859	2466	3.3%
Scenario B	Industry Sector	943	1384	1664	2.9%
	Transportation	145	275	494	6.3%
	Commercial/Residential	210	409	738	6.5%
	Total	1297	2068	2896	4.1%
Scenario A	Industry Sector	943	1429	1924	3.6%
	Transportation	145	282	535	6.8%
	Commercial/Residential	210	426	821	7.1%
	Total	1297	2137	3280	4.7%

Note: calculated from end-use energy demand in the 3 sectors

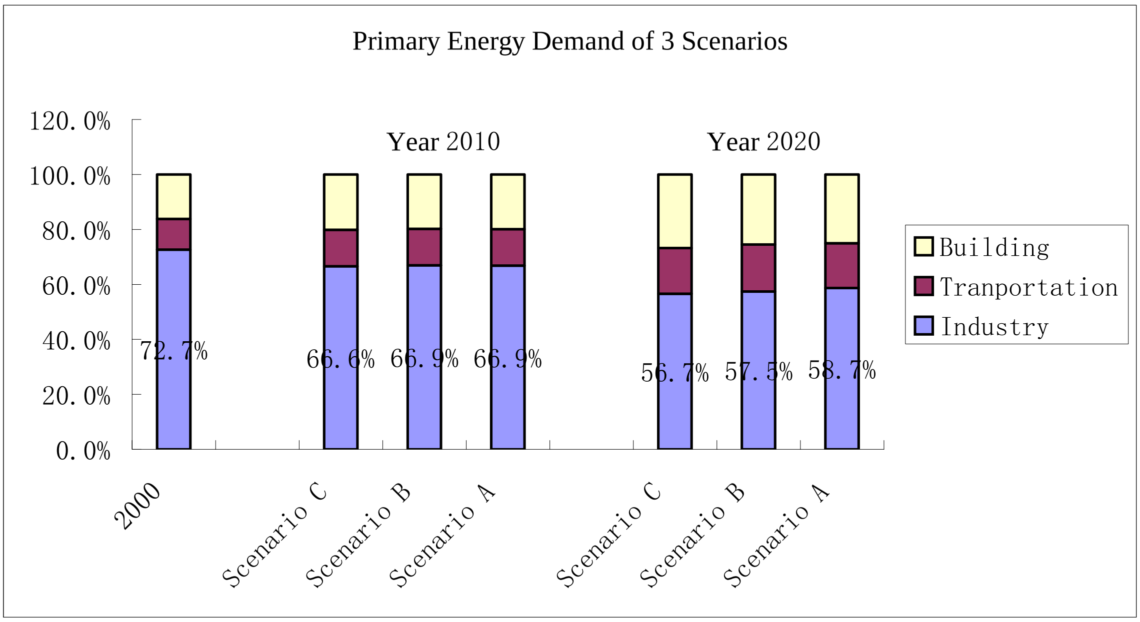


Figure 5-3-10 Primary Energy Mix by Sector

5.3.3. Electricity Demand and power generation structure

Different technology options and energy conservation policy implementation strength were assumed in the 3 scenarios, and consequently, the electricity and heat load of these scenarios are different. The end-use electricity demand of Scenario C is 430 billion kWh lower than Scenario A, which is 12% of the total electricity demand of Scenario C.

Table 5-3-7 Power Generation Installed- Capacity

		Installed Capacity（GW）			
		2000	2005	2010	2020
Scenario C	Total Capacity	282	398	543	865
	Coal-fired	204	272	338	509
	Oil-fired	10	9	3	1
	Gas-fired	1	5	25	43
	Hydropower	65	107	154	240
	Nuclear Power	2	4	15	40
	Renewable Energy	0	1	7	30
Scenario B	Total Capacity	282	407	551	867
	Coal-fired	204	281	361	568
	Oil-fired	10	10	4	3
	Gas-fired	1	3	26	39
	Hydropower	65	108	146	211
	Nuclear Power	2	5	10	34
	Renewable Energy	0	1	3	13
Scenario A	Total Capacity	282	402	559	947
	Coal-fired	204	285	384	661
	Oil-fired	10	10	4	6
	Gas-fired	1	3	28	46
	Hydropower	65	100	132	191
	Nuclear Power	2	4	9	31
	Renewable Energy	0	1	3	11

Different assumptions of future power generation composition, power generation efficiency, loss of transformation and distribution were assumed. The power generation installation capacity in China's next 20 years in the 3 scenarios is shown in Table 5-3-7. According to the assumptions in Scenario C, if power generation structure is optimized, primary electricity such as hydropower and nuclear development is promoted, and the measures to improve power supply efficiency like inefficient steam turbine washout can be successfully implemented, 290 GW's annual capacity should be newly increased in the next 20 years to make the electricity installation grow from 280 GW to 865 GW in year 2020.

Table 5-3-8 Comparison of power generation Source among 3 scenarios

		Power Generation（TWh）			Structure		
		2000	2010	2020	2000	2010	2020
Scenario C	Total Generation	1347	2392	3755	100.0%	100.0%	100.0%
	Coal-fired	1058	1622	2394	78.6%	67.8%	63.8%
	Oil-fired	46	14	5	3.4%	0.6%	0.1%
	Gas-fired	5	110	186	0.4%	4.6%	5.0%
	Hydropower	221	522	817	16.4%	21.8%	21.8%
	Nuclear Power	17	102	262	1.2%	4.3%	7.0%
	Renewable	0	22	90	0.0%	0.9%	2.4%
Scenario B	Total Generation	1347	2440	3822	100.0%	100.0%	100.0%
	Coal-fired	1058	1734	2668	78.6%	71.1%	69.8%
	Oil-fired	46	19	11	3.4%	0.8%	0.3%
	Gas-fired	5	114	168	0.4%	4.7%	4.4%
	Hydropower	221	496	717	16.4%	20.3%	18.8%
	Nuclear Power	17	68	219	1.2%	2.8%	5.7%
	Renewable	0	10	38	0.0%	0.4%	1.0%
Scenario A	Total Generation	1347	2497	4218	100.0%	100.0%	100.0%
	Coal-fired	1058	1844	3109	78.6%	73.9%	73.7%
	Oil-fired	46	20	27	3.4%	0.8%	0.6%
	Gas-fired	5	121	197	0.4%	4.8%	4.7%
	Hydropower	221	447	650	16.4%	17.9%	15.4%
	Nuclear Power	17	57	202	1.2%	2.3%	4.8%
	Renewable	0	7	34	0.0%	0.3%	0.8%

Seen from Table 5-3-8, fossil fuel power generation will be the main power supply in China. The diversified electricity supply structure varies responding to different incentive policies. In fossil fuel power generation, coal-fired power generation is the primary method. Coal consumption for power generation and heat supply in Scenario A, B and C is listed in Table 5-3-9.

Table 5-3-9: Coal used for power generation in the 3 scenarios

Unit: 100 Million tons

	2000	2005	2010	2020	Year 2000~2020
Scenario C	5.5	6.9	7.9	10.7	3.4%
Scenario B	5.5	7.2	8.8	12.4	4.1%
Scenario A	5.5	7.3	9.3	14.8	5.1%

5.3.4. CO2 emission

The CO2 emission in the 3 scenarios is listed in Figure 5-3-11.

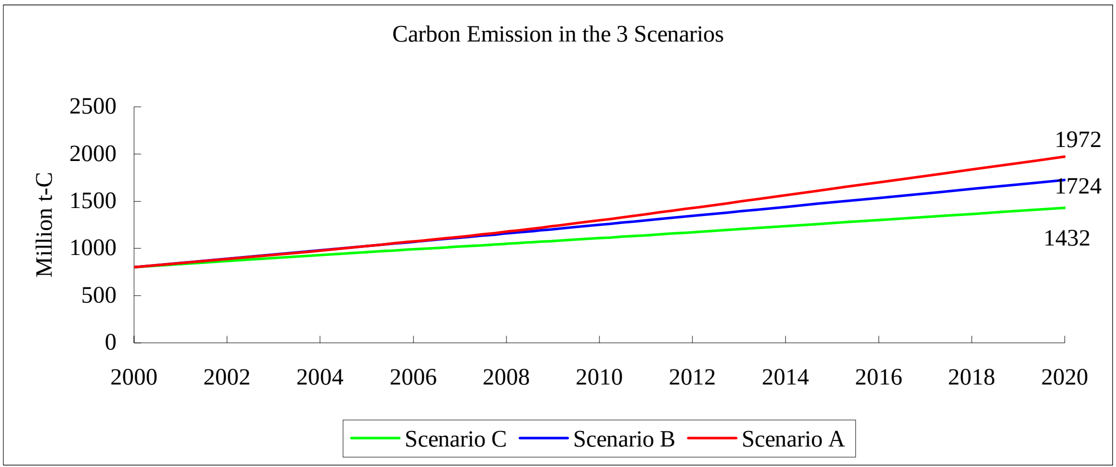


Figure 5-3-11 CO_2 emission in the 3 scenarios

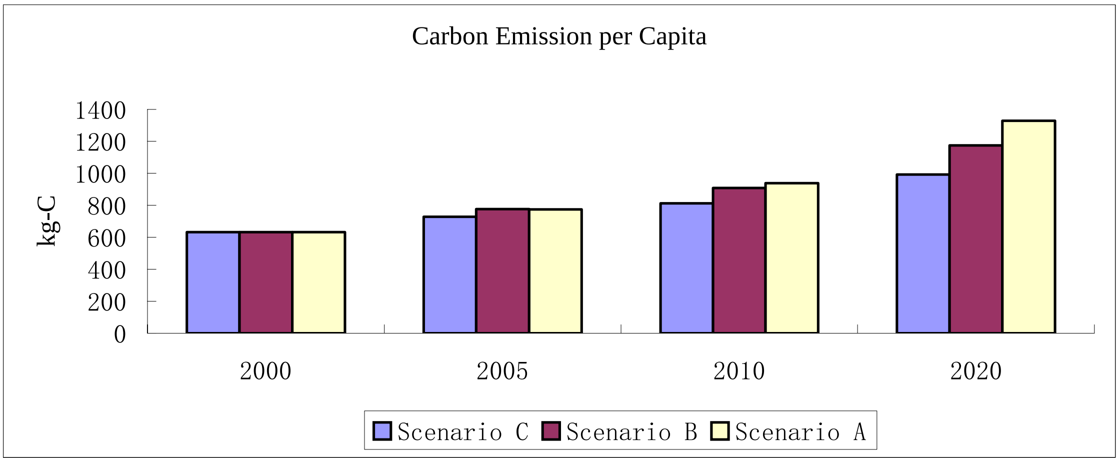


Figure 5-3-12 Carbon emission per capita

For the data of CO_2 emission per capita (Figure 5-3-12), if no additional measures are taken, the per capita emission will reach 1.33 t-C in year 2020. This value is over doubled than the value in year 2000, and higher than present international average level, which is still lower than the 3.02 t-C's level of OECD countries in year 2000. If measures for energy mix optimization and energy efficiency improvement are taken, the growth of per capita carbon emission can be kept at a low level, which will be lower than 1 t-C in year 2020. This is already 57% higher than year 2000's level. At that time, the per capita carbon emission amount is only 33% of present OECD level, and 93% of world average level.

Seeing from carbon emission by sector (see table 5-3-10), industry sector will continue to be the main CO_2 emission source in China. In year 2020, the CO_2 emission in the 3 scenarios varies from 8.2~11.7 t-C. This is 57~59% of total CO_2 emission.

With rapid development of transportation and building energy demand, the CO_2 emission proportion of these two sectors will increase, too. In Scenario A, the CO_2 emission from residential/commercial sector will increase from 130 million t-C in year 2000 to 490 million t-C in year 2020, with an annual growth rate of 6.9%. The proportion will increase from 16.1% in year 2000 to 24.9% in year 2020. In Scenario C, due to various measures in energy efficiency improvement, the total CO2 emission amount and its growth rate is lower. The emission of residential/commercial sector in year 2020 is 376 million t-C, with 5.5%'s annual growth rate. However, the proportion is still as high as 26.2%.

Table 5-3-10 CO_2 Emission by Sector

		CO2 Emission（Mt-C）			Annual growth rate	Proportion		
		2000	2010	2020	2000~2020	2000	2010	2020
Scenario C	Industrial	586	745	818	1.7%	73.2%	67.1%	57.1%
	Transportation	85	144	239	5.3%	10.7%	13.0%	16.7%
	Residential/ commercial	129	221	376	5.5%	16.1%	19.9%	26.2%
	Total	801	1111	1432	2.9%	100.0%	100.0%	100.0%
Scenario B	Industrial	586	843	999	2.7%	73.2%	67.4%	57.9%
	Transportation	85	161	289	6.3%	10.7%	12.9%	16.8%
	Residential/ commercial	129	246	436	6.3%	16.1%	19.7%	25.3%
	Total	801	1250	1724	3.9%	100.0%	100.0%	100.0%
Scenario A	Industrial	586	876	1168	3.5%	73.2%	67.4%	59.2%
	Transportation	85	165	313	6.7%	10.7%	12.7%	15.9%
	Residential/ commercial	129	258	491	6.9%	16.1%	19.8%	24.9%
	Total	801	1299	1972	4.6%	100.0%	100.0%	100.0%

5.3.5. Influence of industrial structure changes on energy demand

Scenario calculation results have shown, if policy combination can be optimized (including industry development policy, adjustment of all structures, adjustment of import/export trade and the import/export policy of energy-intensive product etc.), the reliance of economic growth to energy demand increase will be 50% lower than before (See Table 5-3-11).

Table 5-3-11 The Relationship of newly increased GDP & Energy Demand

		Unit	2000~2005	2005~2010	2010~2020
Scenario C	Newly Increased GDP	100 million Yuan	39274	54798	174335
	Newly Increased energy demand	Million tce	277	285	607
	Newly Increased energy demand/Newly Increased GDP	tce/10,000Yuan GDP	0.704	0.520	0.348
Scenario B	Newly Increased GDP	100 million Yuan	39274	54798	174335
	Newly Increased energy demand	Million tce	375	396	828
	Newly Increased energy demand/Newly Increased GDP	tce/10,000Yuan GDP	0.954	0.723	0.475
Scenario A	Newly Increased GDP	100 million Yuan	39274	54798	174335
	Newly Increased energy demand	Million tce	374	466	1143
	Newly Increased energy demand/Newly Increased GDP	tce/10,000Yuan GDP	0.952	0.851	0.655

The difference of energy demand in the 3 scenarios is the comprehensive result of many policy factors. In order to analyze the influence of industry structure change to China's energy demand, based on Scenario B, the industry structure shift was assumed to be the same as in Scenario C, i.e. fast 3rd industry development speed and strong influence of technology advancement. And the assumptions in population, urbanization, energy efficiency, industry sector, product structure etc. remained to be the unchanged as Scenario B. The result of this new scenario is shown in Figure 5-3-13. It can be seen that in this scenario, the energy demand in year 2020 will be 2327 million tce, which is 2.3% lower than the total energy demand in scenario B.

In order to analyze the influence brought by new industrialization progress to China's energy demand, another case was analyzed. In this case, the GDP growth structure is the same as year 2000, and energy efficiency improvement in energy-intensive industry, light industry and manufacture industry is the same as Scenario B. The result is shown in Figure 5-3-14. In year 2020, the end-use energy demand in industry sector will be 1260 million tce, which is 7.7% higher than the result of Scenario B (90 million tce).

It can be seen that, regardless other policy measures, the shift of economic growth mode itself will provide prominent influence to China's future energy demand.

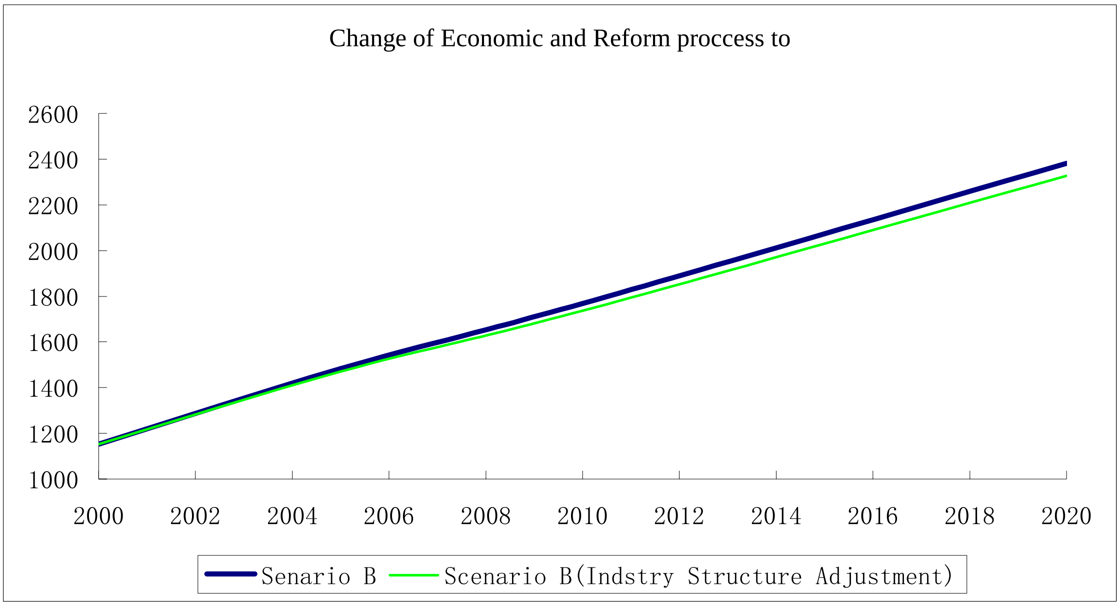


Fig. 5-3-13 Influence of Industry Structure Adjustment on Energy Demand (I)

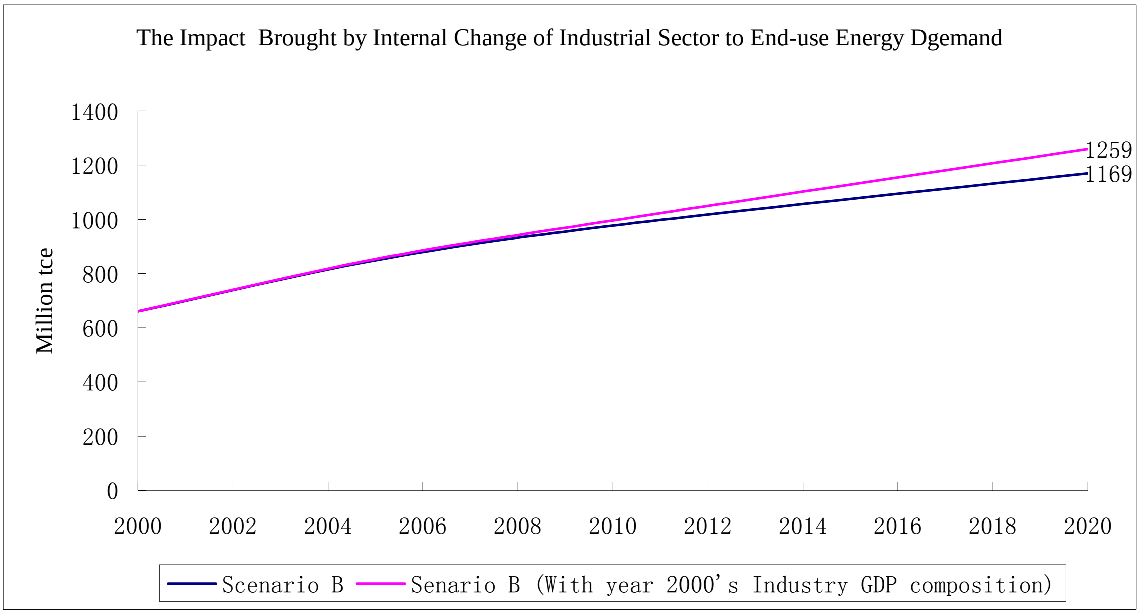


Fig. 5-3-14 Influence of Industry Structure Adjustment on Energy Demand (II)

5.3.6. Influence of energy mix adjustment on energy demand

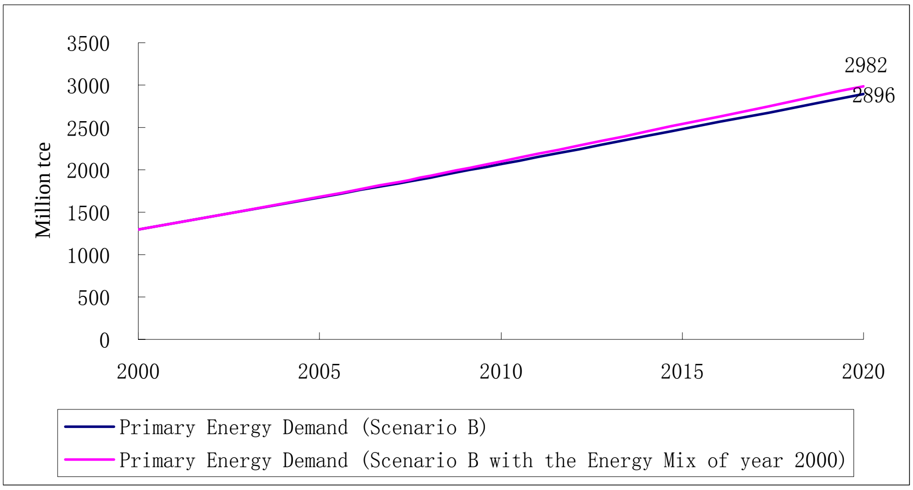


Figure 5-3-15 Influence of Energy Mix Adjustment to Total Energy Demand（I）

In order to analyze the influence of energy consumption structure optimization to total energy demand and carbon emission, two cases were designed to implement sensitivity analysis. In one case, energy consumption structure remains to be the same as year 2000 in Scenario B, i.e. coal consumption remains to be 70%, and other assumptions remain unchanged. The result have shown (in Figure 5-3-15) that in year 2020, China's energy demand will reach 2982 million tce, which is 86 million tce higher than the value of Scenario B (3.2%).

In the second case in Scenario B, the energy consumption structure is the same as Scenario C. The total energy demand in year 2020 decreased to 2771 tce, which is 4.3% lower.

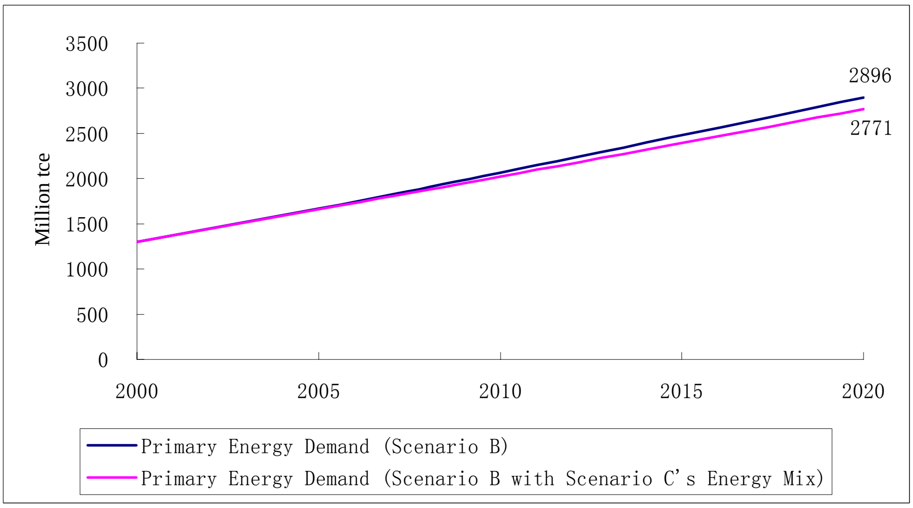


Figure 5-3-16 Influence of Energy Mix Adjustment to Total Energy Demand（I）

5.3.7. Influence of energy supply pattern on energy demand and carbon emissions

How to choose energy supply method to satisfy China's growing end-use energy demand will not only bring strong impact to China's primary energy demand in the future, but also change the tendency of greenhouse gas emission greatly.

Due to the great variety of end-use energy demand in the 3 scenarios (the end-use energy demand in Scenario C is 23.3% lower than that of Scenario A), concerning of carbon emission reduction, it is very difficult to identify the contributions brought by power supply optimization or by energy efficiency improvement in conversion sector. For the convenience of comparison, based on Scenario B, a sensitivity analysis for power generation structure is done. Main assumptions include: by satisfying same end-use electricity demand, in one case, the proportion of primary power generation is increased (the proportion of primary electricity increased from Scenario B's level up to 38%); in another case, low primary electricity development is designed (primary electricity occupies 22% of total power generation). Figure 5-3-7 shows the difference of carbon emission result of the 2 cases.

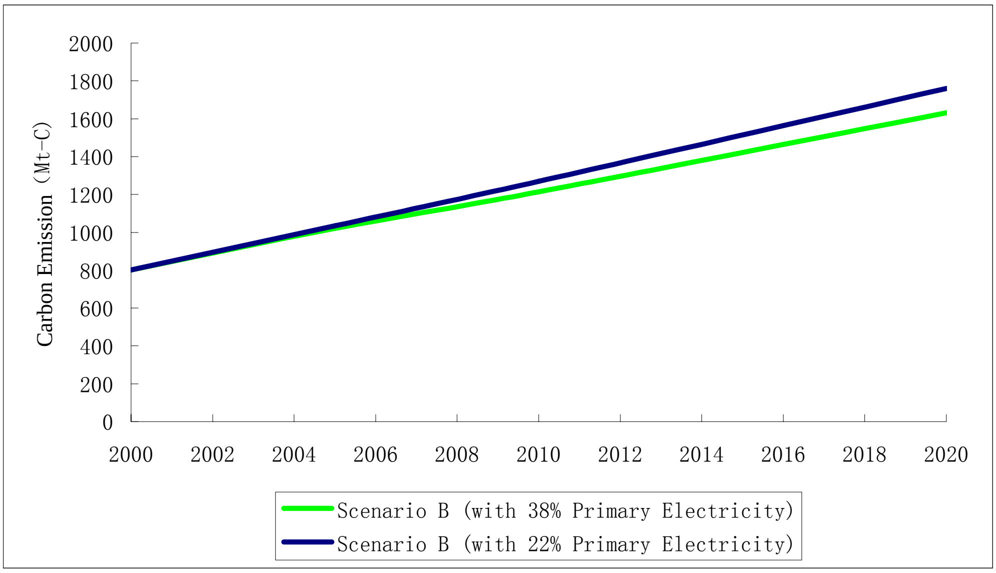


Figure 5-3-17 Influence of Power Generation Mix Optimization on CO_2 emission

It can be seen that, if primary electricity like hydropower or nuclear power is promoted, in year 2020, the carbon emission of China will reach 1630 million t-C, which is 129 million t-C lower than the weak primary development case. This figure equals to 7.3% CO2 emission reduction, and the influence is obviously strong.

Besides the shift of economic growth mode and energy mix adjustment, energy efficiency policy and environment policy will influence China's energy demand and carbon emission. The influence of energy efficiency policy to China's future energy demand lies in two aspects: one is to influence newly added production capability and living standard, which mainly referred to building, transportation (private cars) and household electricity facilities; another is to influence the improvement of existing production capability. Scenario analysis has shown that once energy conservation policy is settled down and energy conservation potential can be dug out. Energy intensive industries like iron & steel industry or building material industry may achieve "increase production with no energy consumption growth" in year 2020.

As an external factor that can change other policies, environment policy will bring strong impact to energy supply technology, energy policy or even industrial policy. In the scenario analysis, the standard for choosing environment policies (mainly environment emission control indexes) mainly refers to field environment indexes, including total amount control indexes, city air quality control indexes etc. For the global greenhouse emission, though international emission reduction actions are concerned in the research, no detailed indexes are designed. Still, the impact of different environment policy to total carbon emission is strong.

6. Basic Conclusions and Recommendations

6.1. Basic Conclusions

The results of scenario analysis have shown:

Energy demand is the comprehensive result of many factors, such as economic development, economic structure shift (including industry and product), technology advancement, implementation of energy conservation policy, energy mix etc. Different economic development road and policy options can provide strong influence to energy demand. Instead of a fixed value, China's energy demand may sit in a range with large variation (the primary energy demand of China in year 2020 lies between 2.4~3.2 billion tce).

Although same economic growth rate is used, the difference in energy mix and energy improvement strength may result to 800 million tce's difference in total energy demand.

The energy demand of Scenario C is based on the assumption of smooth economic structure adjustment, and effective implementation of energy and environment policies. This value can be regarded as the lowest bound for China under the foreseeable social / economical / technological / environmental development. Great efforts should be made to attain this level.

Basic conclusion of scenario analysis can be summarized as below:

1. If the sustainable development strategy consisting of improving energy efficiency, improving the energy mix, and strengthening environmental policies can be fulfilled, China can realize the goal of doubling energy demand to support quadrupling GDP in the next 20 years.

2. The basic factor to determine future energy demand in China is to choose a sustainable economic development road.

3. Energy demand of industry sector could be much lower than other sectors, and some energy-intensive industries may achieve "more production with no energy consumption growth" after some period.

4. Energy consumption in building and transportation sectors will become the main drivers for energy demand growth. More attention should be attached to energy supply and energy efficiency improvement problem in building and transportation sector.

The growth rate of end-use energy demand in transportation sector and building sector will be higher than the average growth rate of the total and that of industry sector. The proportion of building and transportation energy consumption increase to total energy consumption increase will rise from 35% in current level to 57%~75% in year 2020.

Table 6-1-1: All Sectors' Contribution to energy demand increase in the future

		2005	2010	2020
Scenario C	Industrial Sector	65.2%	40.6%	26.5%
	Transportation	14.5%	21.6%	26.7%
	Commercial/residential	20.4%	37.8%	46.9%
	Total	100.0%	100.0%	100.0%
Scenario B	Industrial Sector	67.8%	46.3%	34.4%
	Transportation	13.6%	20.7%	26.1%
	Commercial/residential	18.6%	33.0%	39.5%
	Total	100.0%	100.0%	100.0%
Scenario A	Industrial Sector	65.6%	51.3%	43.0%
	Transportation	13.8%	18.8%	22.5%
	Commercial/residential	20.6%	29.8%	34.5%
	Total	100.0%	100.0%	100.0%

Energy demand in building and transportation sector may have different development tendency in the future. Energy conservation policies and technical measures will strongly influence building and transportation energy demand. If transportation mode is further optimized, i.e. to exert the advantage of public transportation system and rail system, to develop lowest energy efficiency standard and related financing and economic policies, the oil demand in Scenario C will be 8700 tons lower than Scenario A, which is about half of total crude oil production at that time. Presently, only 0.5% buildings have reached energy conservation design standard for buildings with heat supply. The proportion for reaching this standard for new houses is merely 2%, which result to high energy consumption. Comparing with countries of same latitude, the heating and cooling energy consumption for unit building area is 2 times higher. By improving the proportion that can reach the standard, total building energy consumption in year 2020 may be 160 million tce lower.

5. The optimization of energy mix will reduce the growth rate of China's future energy demand greatly. In order to achieve the economic development objective, energy consumption structure optimization, especially the optimization of end-use energy consumption, should be promoted.

6. Great efforts should be devoted to energy mix optimization, and there is a long way to go. Medium-and-long term energy development strategies should be developed as soon as possible. The steady supply of natural gas, oil and hydropower should be planned in advance.

7. Strengthened energy efficiency improvement measures will provide strong impact for China's future energy supply and demand.

Basically, before industrialization, the energy consumption elastic coefficient is in present developed countries and newly industrialized countries are high. For example, the energy consumption elastic coefficient in Korea and Malaysia in year 1971~1999 is higher than 1. After the developed countries had entered the post-industrialized period, the energy consumption elastic coefficient is generally less than 1. But in the fast economic development periods, the elastic coefficient is relatively higher.

If the elastic relationship of China's economic growth and energy consumption keeps being 1, the primary energy demand of China in year 2020 will be about 6 billion tce. If energy improvement of China keeps in the pace of 1.1%'s energy conservation rate, which is the average value of world, the annual energy demand growth will still be higher than 6.0%, corresponding to 4.8 billion tce's primary energy demand in year 2020. Based on the sustainable development route constructed in this scenario analysis, China's energy growth rate maybe greatly reduced.

Strengthening energy conservation and promoting energy efficiency may exert active influence in inducing China's energy demand to a sustainable way. In the fields with great energy growth potential such as transportation and residential/commercial sector, practical energy conservation policies should be developed as early as possible to generate larger influence. It has been shown in the scenario analysis that strengthened energy conservation policy may reduce 15% to 27% of net energy consumption increase. The energy consumption of industrial sector is relatively large. China is in the progress of industrialization, industry sector will remain to be the biggest energy consuming sector. The development of strict energy conservation policies can produce prominent benefit. Still, Energy conservation policy can provide strong influence to improve current production capabilities' energy efficiency. Different analysis have shown that the reasonable energy conservation potential, which is technologically available and economically reasonable, is still as high as 150~200 million tce.

6.2. Recommendations

In order to achieve the goal of building a well-off society in an all-round way, which was setup by the 16th CPC congress, following recommendations are put forward:

1. Identifying the leading department of government's energy management to improve decision-making efficiency and fully exert government's macro-control functions. Energy market should be induced and pushed by government to achieve projected energy conservation objective.

2. Putting forward "Adjust Energy Mix to Enhance the Ratio of High-quality Energy" in advance. Strategies of promoting high-quality energy import and developing renewable energy should be developed as soon as possible.

3. Economic growth mode should be changed. More energy-intensive products should be imported, and no special commercial export of energy-intensive product should be forbidden to reduce the reliance of China's economic development to energy consumption.

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