Discussion of Macro Assumptions

in

the Future Evolution of the Chinese Energy System

and

the Impact of Energy Security Considerations on Planning

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Abstract

The first section of this paper discusses the “macro” assumptions which are important in the future evolution of the Chinese energy system. Main points include: (1) Forecasts for population and urbanization rate. The population will be 1.28 billion in 2000, 1.38 billion in 2010 and 1.48 billion in 2020. The urbanization rate will be 31.5%, 37.5% and 45% in 2000, 2010, and 2020, respectively; (2) Forecast of economic growth rate. The growth rate will be 7.2% during 2001-2010 and 6% during 2011-2020; (3) Forecast of industrial structure. The ratio of primary, secondary and tertiary industry will be 17: 49: 34 in 2000, 12: 45: 43 in 2010 and 8.5: 41: 50.5 in 2020; (4) Forecast on energy conservation scenarios, based on energy consumption of per unit GDP. Energy intensity will be 2.8 tce/10,000 yuan (1990 price) in 2000, 1.7 tce/10,000 yuan in 2010 and 1.1 tce/10,000 yuan in 2020.

The second section of the report analyzes the end-use energy demand of the residential sector and different industries. The residential sector is broken into urban and rural. Major energy uses include cooking, hot water, space heating, lighting and appliance. Future energy intensity and fuel structure are forecasted. Energy demand of agriculture is analyzed. It is estimated that the efficiencies of energy-consuming devices will improve gradually in the future, however, because of the expansion of mechanization in agriculture, the energy intensities of devices will not change prominently, and the energy consumption per unit of output will go down slowly. The industrial sector is broken into 7 sub-sectors: iron and steel, building materials, chemical, nonferrous, light industry, machinery and electronics, and other. Energy intensity and output of major products are forecast. The transportation sector is divided into railway, road, waterway and air. Transportation volume, structure and energy intensity of the 4 sub-sectors are forecast. Energy intensity of construction and service sectors are also analyzed.

Finally, the third section analyzes the current situation of supply and demand of oil, and the future development trend. Domestic oil production will only meet 47% of demand in 2015 and China will face issues of energy security. How can this factor be incorporated into planning? First, based on the domestic resources, a basic supply of oil should be secured. Production in eastern China should be stabilized, and exploration in western China and of offshore oil should be expanded. Second, overseas resources should be used to supplement domestic demand. China should develop international oil trade and participate in overseas oil exploitation in order to establish long-term, stable and diverse oil supply channels. Third, China should speed up the exploitation and utilization of natural gas, and develop coal gasification and biomass technologies to replace oil. Fourth, the utilization efficiency of oil should be improved to save oil and gas resources. Fifth, China should establish national strategic oil reserves.

1 Macro Assumptions

1.1 Population

1.1.1 Present Situation

China is the largest country in the world in terms of population, and the majority of the population is distributed in rural areas (table 1.1).

Table 1.1
The Chinese Population in Recent Years, 1985-1998

	1985	**1990**	**1995**	**1998**
Population (million)	1058.51	1143.33	1211.21	1248.10
Urban (%)	23.7	26.4	29.0	30.4
Rural (%)	76.3	73.6	71.0	69.6
Birth rate (‰)	21.04	21.06	17.12	16.03
Death rate (‰)	6.78	6.67	6.57	6.50
Natural growth rate (‰)	14.26	14.39	10.55	9.53

Source: 1999 China Statistical Yearbook
Note: Population figures are estimated for the end of the year.

1.1.2 Forecast

Although population control is a fundamental national policy, and birth rate and population growth rate are steadily decreasing, there continues to be pressure from the unbalanced age structure. There will be a considerable increase in population before 2020, then the growth rate will drop. However, it is widely expected that the population will stop increasing only around 2050.

Many organizations have forecast the future population of China (Table 1.2). Generally speaking, the results from the earlier forecasts are lower, while the results from more recent forecasts are higher. The author favors the forecast made by Tian Xueyuan of the Population Research Institute, Chinese Academy of Social Sciences (CASS) (Table 1.3).

Table 1.2
Population Forecasts for China by Various Organizations, 2000-2020 (million)

Forecasting Organization	**2000**	**2010**	**2020**
Asia-Pacific Integrated Model (AIM)	1284	1393	1472
Quantitative Economic Institute of Chinese Academy of Social Sciences (CASS)	1330	1480	1518
Chinese Academy of Sciences (CAS)	1282	1400	1500
Asia Development Bank (ADB)	1294	1386	1498
The World Bank (WB)	1300	1400	1447
United Nations Environmental Program (UNEP)	1294	1390	1450
Energy Research Institute (ERI)	1304	1415	1496

Note: Population figures are estimated for the end of the year.

Table 1.3
Population Forecasts for China, By The Chinese Academy of Social Sciences, 1995-2020

	1995	**2000**	**2010**	**2020**
Population (million)	1216	1280	1379	1483
Birth rate (‰)	--	17.16	15.27	15.39
Death rate (‰)	--	6.48	7.77	8.09
Natural growth rate (‰)	--	10.7	7.5	7.3

Source: China: Stride forward 2020, China Planning Publishing House, 1997
Note: Population figures are estimated for the end of a given time period. Birth rates, death rates, and natural growth rates refer to the period of time leading up to the year indicated in the column. For instance, 17.16 ‰ birth rate under the 2000 column refers to the period from 1995 to 2000. The 15.27 ‰ birth rate under the 2010 column refers to the period between 2000 and 2010.

Table 1.4
Population Forecast for China, United Nations, 1995-2020

	1995	**2000**	**2010**	**2020**
Population (million)	1221	1285	1388	1488
Birth rate (‰)	--	17.30	15.20	14.90
Death rate (‰)	--	7.10	7.30	7.90
Natural growth rate (‰)	--	10.10	7.80	6.90

Source: World Population Prospect, UN, New York, 1996
Note: Population figures are estimated for the end of the year. Please see notes under Table 1.3 for details about rates.

Table 1.4 shows the results of a moderate forecast made by the United Nations (UN). The forecasts are similar to the results forecast by CASS. The general trend is that natural growth rate will gradually decrease. The target of the Chinese government, namely, to maintain the population at less than 1.3 billion by 2000 and 1.4 billion by 2010.

1.1.3 Forecast for Population Urbanization

The urban population accounted for 26.4% of the total population in 1990, and it increased to 30.4% in 1998. Urbanization naturally occurs as a result of urbanization. However, urbanization is not occurring as rapid as many organizations estimated. On the one hand, the capacity of big cities in China is limited, and the construction of medium and small cities and towns is very slow. Domestic and international constraints on economic development also limit large-scale migration from rural areas to urban areas. Table 1.5 shows the urbanization forecasts made by different organizations. Based on the present situation, the author favors the forecast made by ERI.

Table 1.5

Forecasts for Urbanization Rates in China by Various Organizations, 2000-2020

	2000	**2010**	**2020**
AIM (%)	32.1	38.1	43.0
CASS (%)	37.6	--	48.4
ADB (%)	32.4	38.4	44.4
WB (%)	31.0	--	42.0
UNEP (%)	31.4	37.4	44.8
ERI (%)	31.5	37.5	45.0

1.1.4 China's Future Population forecast

Table 1.6 shows the author's forecast for population and urbanization in China in the future.

Table 1.6
Population and Urbanization in China, 2000-2020

	2000	**2010**	**2020**
Total Population (million)	1280	1379	1483
Urban (million)	403.2	517.1	667.4
Rural (million)	876.8	861.9	815.6
Urbanization rate(%)	31.5	37.5	45.0

Source : Author's forecast

1.2 Economic Growth

During the past 20 years (1979-1998) when reform and the open door policy were practiced, the average annual GDP growth rate of China was as high as 9.7%. During 1991-1995, the GDP growth rate was 12.0%, and it decreased after 1996 due to the Asian financial crisis. If the GDP growth rate stays at 7% in 2000, then the average annual GDP growth rate during 1996-2000 will be 8%. It should be noted that it will be difficult to maintain the same high growth rate over the next 20 years. The reasons are: the baseline gets larger and larger; the constraints on economic growth due to insufficient demand is still not solved; 'qualitative' increase is more difficult to achieve than 'quantitative' increase; it is a universal law that some adjustments are necessary after a long period of rapid growth. However, the Chinese economy will maintain a relatively high growth rate during the next 20 years because system innovations will improve efficiency, structural adjustment will create new points for economic growth, and the increase of per capita income and consumption will bring about bigger development potential. The market will expand because of industrialization, urbanization, globalization, and the development of western China, and export and import will expand because of China's entry into the World Trade Organization (WTO). All of these will be benefits to economic growth in China in future.

Many organizations have forecast the economic growth rate in China during the next 20 years (Table 1.7). Based on the above analysis, the author supports the forecast made by Energy Research Institute (ERI). In the first decade of the next century,

average annual economic growth rate could be 7.5% during the first 5 years and 7.0% during the last 5 years.

Table 1.7
Forecasts for Economic Growth Rates in China by Various Organizations, 2001-2020

	2001-2010	**2011-2020**
AIM (%)	7.5	6.5
CAS (%)	8	7
CASS (%)	8.2	--
ADB (%)	7	6
WB (%)	8	6.5
UNEP (%)	7.5	6.0
ERI (%)	7.2	6.0

1.3 Industrial Structure

1.3.1 Present Situation

Table 1.8 shows the industrial structure change in China during the last 15 years.

Table 1.8 Industrial Structure of GDP, 1985-1999 (%)

Industry	**1985**	**1990**	**1995**	**1998**	**1999**
Primary	28.4	27.1	20.5	18.4	17.3
Secondary	43.1	41.6	48.8	48.7	49.7
Tertiary	28.5	31.3	30.7	32.9	33.0

Source : Statistic Communique of National Economic and Social Development of China, 1999

1.3.2 Industrial Structure Forecast

Table 1.9 shows forecasted results of the industrial structure in China in the future, as predicted by different organizations.

1.3.3 Analysis

Industrial structure reflects economic development level. According to the 1996 World Development Report of the World Bank, in 1994 the shares of primary, secondary, and tertiary industry of China were 21%, 47% and 32% respectively. Those of average low-income countries were 28%, 34% and 36%; those of average medium-income countries were 10%, 36% and 52%. Those of the United Kingdom, a high income country, were 2%, 32% and 66%; those of another high income country, France, were 2%, 28% and 70%. The share of tertiary industry in China is even lower than that of most low-income countries.

According to the circumstances of the past 20 years, the share of tertiary industry

increased from 23.7% in 1978 to 32.9% in 1998, increasing 0.46% per year. This rate will increase considerably in future, therefore making a high forecast is reasonable.

The share of secondary industry is stable. It was 48.2% in 1978 and 48.7% in 1998. This means that China is still in the industrialization stage, and the growth of GDP relies mainly on the growth of secondary industry. However, according to the experiences of developed countries, the share of secondary industry in China should decrease gradually.

The share of primary industry has decreased rapidly in the past 20 years, decreasing from 28.1% in 1978 to 18.4% in 1998. It is estimated that this trend will continue.

According to the above analysis, the author supports the forecast by ERI. It is relatively high, yet it does not meet government goals. *The China Economic Herald* published the paper of Jiang Junlu, from the State Development Planning Commission (SDPC) on March 31 1999. The paper, which concentrated on formulation of the Tenth Five-year Plan, stated that the average ratio of industries will be 14: 40: 46 between 2001-2005. This demands an even greater decrease in the share of secondary industry and an increase in the share of tertiary industry.

Table 1.9
Forecast for Industrial Structure of GDP by Various Organizations, 2000-2020 (%)

	2000			**2010**			**2020**		
	Primary	**Secondary**	**Tertiary**	**Primary**	**Secondary**	**Tertiary**	**Primary**	**Secondary**	**Tertiary**
CASS	17	51.7	31.0	14	51.5	34.4	11	50.2	38.3
SDC*	14.73	47.68	37.59	9.38	48.96	41.66	6.85	48.35	44.79
ADB	23	44.0	33.0	--	--	--	15	42.0	43.0
WB	16	50.0	34.0	--	--	--	7.0	48.0	45.0
UNEP	18.4	45.16	36.3	12.2	43.36	44.44	8.7	41.0	50.3
ERI	17.0	49.0	34.0	12.0	45.0	43.0	8.5	41.0	50.5

Source : State Development Research Center

1.3.4 Forecast for the Future Economy of China

Table 1.10 shows the forecasted results of GDP and industrial structure of China in future, as predicted by the author.

Table 1.10
Forecast for the Economy of China, 1995-2020

		1995	2000	2010	2020
GDP(1995 price), (billion yuan)		5847.8	8592.3	17184.6	30775.0
Annual average GDP growth rate (%)		--	8.0	7.2	6.0
Industrial structure (%)	**Primary**	20.5	17.0	12.0	8.5
	Secondary	48.8	49.0	45.0	41.0
	Tertiary	30.7	34.0	43.0	50.5

Source: Author's forecast
Note : Please see note under Table 1.3 for details about rates.

1.4 Energy Conservation Scenario

1.4.1 Present Situation

Since the 1980s, the Chinese government has strengthened the work of energy conservation. The government put energy conservation into economic and social development planning; established an energy conservation management system and technology service system; formulated policies, laws, regulations and standards; provided financial support and information services; encouraged the research, development, and expansion of energy conservation technologies; publicized energy conservation; and carried out energy conservation education and training activities. China has made great progress in energy conservation in the last 20 years.

From 1980 to 1998, the annual average GDP growth rate of China was as high as 9.87% while the annual average energy consumption growth rate was only 4.87%. The energy consumption elasticity coefficient was 0.47. Half of the energy demand for economic growth was met by new development, and the other half was met by conservation.

From 1981 to 1998, energy consumption per unit GDP (1990 price) decreased from 7.89 tce/10,000 yuan to 3.3 tce/10,000 yuan, decreasing 58.05%. The difference of unit energy consumption of major energy intensive products between China and international advanced standards decreased considerably. From 1980 to 1997, the difference of unit energy consumption for thermal power supply in China versus overseas decreased from 32.5% to 25.8%, and comparable unit energy consumption for steel production decreased from 70.4% to 48.8%.

1.4.2 Forecast for Energy Consumption Per Unit GDP

In the Ninth Five-year Plan, the Chinese government chooses the energy development strategy of relying on "both resource development and conservation, and giving the priority to conservation". The Energy Conservation Law was issued in November of 1997. Energy conservation is still in an important part of the Tenth Five-year Plan, through 2015. During the next 20 years, along with adjustment of the economic structure and the upgrading of industries, the trend of energy conservation will not change.

Energy consumption per unit GDP decreased more rapidly in the 1990s. It decreased from 5.2 tce/10,000 Yuan in 1990 to 4.0 tce/10,000 Yuan. The annual average energy conservation rate was 5.1%. The Chinese government has strengthened the adjustment of industrial structure in recent years, limiting the production of some energy intensive products. Energy consumption in China decreased from 1,389 Mtce in 1996 to 1,360 Mtce in 1998, while the national economy still increased rapidly. The resulting annual average energy conservation rate was over 8% during these two years. It is estimated that this trend will continue until 2000. However, because energy consumption per unit GDP of China is still very high (7 times higher than Japan, and 50% higher than India), there is still huge potential for energy conservation after 2000. According to this analysis, the author made a forecast on energy consumption per unit GDP in China in future (Table 1.12).

Table 1.11
Key indices of Selected Countries, 1996

	China	**USA**	**Japan**	**Russia**	**India**	**World**
GDP (billion 1987 US$)	760	5554	3147	473	439	21342
GDP Per Capita (1987 US$)	626	20936	25025	3200	464	3732
Primary Energy Consumption (MTOE)	891	2135	510	599	262	8478
Primary Energy Consumption Per Capita (TOE)	0.733	8.05	4.06	4.05	0.277	1.48
TOE/million 1987 US$	1172	384	162	1267	597	397

Source: EDMC, 1999

Table 1.12
Forecast for Energy Consumption Per Unit GDP of China, 1990-2020

	1990	**1995**	**1998**	**2000**	**2010**	**2020**
tce/10,000yuan (1990 price)	5.2	4.0	3.3	2.8	1.7	1.1
Annual average energy conservation rate, %	--	5.1	6.2	7.0	5.0	4.0

Source: Author's Forecast
Note : Please see note under Table 1.3 for details about rates.

2 End-Use Energy Demand Analysis

2.1 End-use Energy Consumption and Structure of the Base Year

End-use energy consumption data for the base year is a fundamental element of energy demand forecasts, so it is necessary to ensure that the model input data of the base year is close to the end-use energy consumption data presented in the 1990 China Energy Balance Sheet. Meanwhile, the end-use energy consumption structure of 1995 and 1996 were carefully studied. End-use energy consumption and the industrial structure of China in 1990, 1995 and 1996 by sector are listed in Tables 2.1, 2.2 and 2.3.

Table 2.1
1990 China End-use Energy Consumption and Structure by Sector

		Residential		Agriculture		Industry		Transportation		Construction		Service		Total	
		Mtce	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**
Energy variety	**Coal**	119.29	75.5	14.96	30.8	255.53	40.4	15.44	34.6	3.13	25.8	21.70	46.0	430.05	45.6
	Coke	0.26	0.2	0.58	1.2	65.47	10.3	0.04	0.1	0.05	0.4	0.10	0.2	66.50	7.0
	Fuel oil	0	0	0.04	0.1	25.23	4.0	2.97	6.6	0.67	5.5	0.26	0.5	29.19	3.1
	Gasoline	0.26	0.2	2.15	4.4	8.67	1.4	9.12	20.4	1.31	10.8	6.43	13.6	27.94	3.0
	Diesel oil	0	0	12.84	26.5	8.76	1.4	10.33	23.1	1.94	16.0	3.48	7.4	37.37	4.0
	LPG	2.71	1.7	0	0	1.34	0.2	0	0	0.02	0.2	0.22	0.5	4.29	0.4
	Nat. Gas	2.47	1.6	0	0	14.43	2.3	0.07	0.2	1.41	11.6	0.16	0.3	18.54	2.0
	Electr.	18.80	11.9	16.73	34.5	174.0	27.5	4.15	9.3	2.55	21.0	10.92	23.1	227.20	24.1
	Others	13.9	8.8	1.21	2.5	79.05	12.5	2.55	5.7	1.05	8.7	3.92	8.3	112.2	11.9
	Biomass	(263)													
Total (vertical)		158	100	48.52	100	632.39	100	44.66	100	12.13	100	47.20	100	942.89	100
Total (horizontal)		158	16.8	48.52	5.1	632.39	67.1	44.66	4.7	12.13	1.3	47.20	5.0	942.89	100

Note: Biomass consumption is not counted in the total.
Source : China Energy Statistical Yearbook, Chinese Energy Publishing House, 1991

Table 2.2
1995 China End-use Energy Consumption and Structure by Sector

		Residential		Agriculture		Industry		Transportation		Construction		Service		Total	
		Mtce	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**
Energy variety	**Coal**	94.9	60.3	13.24	24.0	327.43	36.6	9.35	16.5	3.15	23.6	20.86	31.9	468.94	37.7
	Coke	1.28	0.8	1.25	2.3	100.39	11.2	0.10	0.2	0.10	0.7	0.31	0.5	103.43	8.3
	Fuel oil	0	0	0.12	0.2	28.05	3.1	3.23	5.7	0.20	1.5	0.53	0.8	32.13	2.6
	Gasoline	0.94	0.6	2.64	4.8	11.95	1.3	14.45	25.5	1.52	11.4	11.3	17.3	42.81	3.4
	Diesel oil	0.23	0.1	14.52	26.4	15.32	1.7	18.08	31.9	1.71	12.8	10.86	16.6	59.01	4.7
	LPG	9.13	5.8	0	0	3.26	0.4	0.01	0	0.01	0.1	0.39	0.6	12.80	1.0
	Natural gas	2.58	1.6	0	0	19.03	2.1	0.09	0.2	0.04	0.3	0.23	0.4	21.98	1.8
	Electricity	38.07	24.2	22.05	40.0	261.77	29.3	6.90	12.2	6.04	45.2	16.42	25.1	351.24	28.3
	Others	10.39	6.6	1.27	2.3	127.05	14.2	4.36	7.7	0.57	4.3	4.51	6.9	149.10	12.0
	Biomass	(251)													
Total (vertical)		157.4	100	55.05	100	894.73	100	56.58	100	13.34	100	65.37	100	1242.53	100
Total (horizontal)		157.4	12.7	55.05	4.4	894.73	72.0	56.58	4.5	13.34	1.1	65.37	5.3	1242.53	100

Note: Biomass consumption is not counted in the total.
Source: State Statistical Bureau, The Ministry of Agriculture, 1996

Table 2.3
1996 China End-use Energy Consumption and Structure by Sector

		Residential		Agriculture		Industry		Transportation		Construction		Service		Total	
		Mtce	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**	**Mtce**	**%**
Energy type	**Coal**	106.25	60.0	14.63	25.6	363.51	38.5	8.89	15.4	3.39	23.4	21.62	27.9	518.30	39.0
	Coke	1.21	0.7	1.15	2.0	100.30	10.6	0.06	0.1	0.13	0.9	0.39	0.5	103.25	7.8
	Fuel oil	0	0	0.04	0.1	27.76	2.9	3.18	5.5	0.20	1.4	4.78	6.2	32.84	2.5
	Gasoline	1.27	0.7	2.65	4.6	13.17	1.4	14.58	25.3	1.56	10.8	13.57	17.5	46.81	3.5
	Diesel oil	0.32	0.2	14.95	26.1	15.61	1.7	18.33	31.8	1.88	13.0	12.98	16.7	64.08	4.8
	LPG	12.01	6.8	0	0	2.98	0.3	0.03	0.1	0.01	0.1	0.73	0.9	15.75	1.2
	Natural gas	2.63	1.48	0.03	0.1	19.53	2.1	0.16	0.3	0.20	1.4	0.29	0.4	22.85	1.7
	Electricity	42.90	24.2	23.41	40.9	275.38	29.2	7.48	13.0	6.87	47.4	22.27	28.7	378.35	28.5
	Others	10.55	6.0	0.31	0.5	125.14	13.3	4.86	8.4	0.25	1.7	0.89	1.1	145.08	10.9
	Biomass														
Total (vertical)		177.14	100	57.17	100	943.42	100	57.57	100	14.49	100	77.52	100	1327.31	100
Total (horizontal)		177.14	13.4	57.17	4.3	943.42	71.1	57.57	4.3	14.49	1.1	77.52	5.8	1327.31	100

Source: China Energy Statistical Yearbook (1991-1996), China Statistical Publishing House

2.2 Analysis and Forecast of Residential Energy Demand

In 1990, residential energy consumption was 168 Mtce, accounting for 16% of the total commercial end-use energy consumption, which was only second to industrial energy consumption. However, the share was far below the average level of developed countries, which was 28%. Table 2.4 shows non-traditional residential energy consumption and structure in 1990 and 1995.

Table 2.4
Non-traditional Residential Energy Consumption and Energy Mix in 1990 and 1995

	Unit	**1990**		**1995**	
		Consumption	**Share (%)**	**Consumption**	**Share (%)**
Total	Mtce	158	100	157	100
Coal	Mt	166.997 (117.1)	74.11	135.30 (94.9)	60.45
Kerosene	Mt	1.046 (1.55)	0.98	0.64 (0.95)	0.60
LPG	Mt	1.586 (2.71)	1.72	5.34 (9.13)	5.82
Natural gas	Mm^3	1860 (2.47)	1.56	1941 (2.58)	1.64
coal gas	Mm^3	2870 (1.15)	0.73	5669 (2.27)	1.45
Heat	TJ	89715 (3.84)	2.42	126371.4 (5.39)	3.43
Electricity	TWh	48.08 (18.85)	11.93	100.56 (39.42)	25.11
Other	Mtce	10.34	6.54	2.36	1.50

Note: The data in parenthesis are in units of Mtce.
Source: State Statistical Bureau

In addition, large quantities of biomass are consumed in rural areas. The biomass consists mainly of firewood and straw. In 1990, biomass accounted for about 80% of total rural residential energy consumption. Due to the low efficiency of biomass, total per capita energy consumption for livelihood in rural areas was higher than that of urban areas. See Table 2.5 and Table 2.6.

Table 2.5
Urban and Rural Energy Consumption For Livelihood, 1990

	Urban		**Rural**	
	Consumption (Mtce)	**Share (%)**	**Consumption (Mtce)**	**Share (%)**
Coal	66.77	75.81	53.52	16.31
Coke gas	1.44	1.64	0	0
LPG	2.72	3.09	0	0
Nat. Gas	2.47	2.81	0	0
Oil products	0	0	1.54	0.47
Heat	3.84	4.44	0	0
Electricity	10.75	12.22	8.10	2.47
Biogas	0	0	3.09	0.94
Firewood	0	0	129.97	39.61
Manure	0	0	4.64	1.41
Straw	0	0	127.26	38.79
Total	88.00	100.00	328.13	100.00

Source: China Energy Statistical Yearbook, 1991

Table 2.6
Residential Energy Consumption in Rural and Urban Areas, 1990 and 1996

	1990		1996	
	Urban	Rural	Urban	Rural
Total (kgce/person)	291.5	389.97	261.6	380*
Electricity (kWh/person)	90.1	24.8	226.1	67.0

*Note: * is estimated*

Residential energy consumption includes energy for cooking, hot water, space heating, lighting, and electric appliances. The largest portion of energy is consumed by cooking and producing hot water. See Table 2.7.

Table 2.7
1990 residential energy consumption by usage

Usage	**Urban**		**Rural**	
	Con.(Mtce)	**Share (%)**	**Con.(Mtce)**	**Share (%)**
Cooking, hot water	40.82	46.34	318.46	97.06
Space heating	36.50	41.44	--	--
Lighting & appliance	10.76	12.22	9.64	2.94
Total	88.08	100	328.13	100

Source: Incorporation of Environmental Considerations in Energy Planning in China

(1) Current State and Future Outlook of Residential Energy Consumption in Urban Areas

In 1990, urban residential energy consumption for cooking and hot water was 40.82 Mtce, accounting for 46% of total residential consumption. It is estimated that the future increase in effective energy demand for cooking will be small, but the increase for hot water will be rapid. Along with more environmental regulations for residential consumers, the energy structure will gradually improve. There will be efficiency improvements of energy consuming devices and an increase in the use of gas for cooking, resulting in a gradual decrease in energy intensity before 2020. See Table 2.8.

Table 2.8
Energy Intensity and Energy Structure Outlook for Urban Residential Cooking and Hot Water

	1990	**2000**	**2010**	**2020**
Intensity (tce/household)	0.514	0.397	0.378	0.361
Coal (raw coal + briquette), (%)	70.90	35	20	10
Gas (natural gas + coal gas), (%)	17.17	40	55	60
LPG (%)	11.93	20	15	10
Electricity (%)	0	5	10	20

Source : Author's forecasts

In 1990, urban residential energy consumption for space heating was 36.5 Mtce, which was also a considerable portion in total energy consumption for livelihood. Energy consuming devices for space heating mainly include raw coal stoves, briquette stoves, individual boilers and central boilers. Most of the fuel that they consumed was coal. It is estimated that the share of central boilers will increase gradually in the future because of improvements in boiler efficiency and changes in dwelling features. Thus, energy intensity of space heating will decrease gradually. Following improvements in residential standard of living, more residents will demand space heating, and the proportion of space heating will gradually increase (Table 2.9).

Table 2.9
Energy Intensity and Energy Structure for Urban Residential Space Heating, 1990-2020

	1990	**2000**	**2010**	**2020**
Intensity (tce/household)	0.957	0.940	0.90	0.88
Heating share (%)	45	48	50	52
Coal (raw coal + briquette), (%)	75	65	50	40
Boiler (individual + central), (%)	17.5	23	37	50
Other (%)	7.5	12	13	10

Source : Author's forecasts

In 1990, urban residential electricity consumption for lighting and electric appliances was 10.75 Mtce, per capita electricity consumption was 90 kWh, which was only one-

tenth of that of developed countries. It is estimated that the electricity demand increase for lighting will be small. However, along with the rise in residential standard of living, electric appliances will become more popular, and the electricity intensity will increase rapidly. See Table 2.10.

Table 2.10
Energy Intensity for Urban Residential Lighting and Electric Appliances, 1990-2020

	1990	**2000**	**2010**	**2020**
Intensity (tce/household)	0.150	0.25	0.45	0.60

Source : Author's forecasts

(2) Current State and Future Outlook of Residential Energy Consumption in Rural Areas

In 1990, residential energy consumption for livelihood in rural areas was 328.13 Mtce, of which about 80% was biomass. Although per capita energy consumption in rural areas was higher than that in urban areas, because of low energy efficiency, per capita effective energy use in rural areas was lower than that in urban areas.

Following improvements in residential standard of living, it is estimated that the effective energy demand for cooking, hot water and space heating in rural areas will increase rapidly. However, because of changes in energy structure and energy efficiency improvements of energy consuming devices, the total energy intensity will decrease. The energy structure change will be as follows: biomass will continuously decrease ; LPG will increase rapidly ; and the share of coal will decrease. See Table 2.11.

Table 2.11
Energy Intensity and Energy Structure of Rural Residential Cooking, Hot Water, and Space Heating, 1990-2020

	1990	**2000**	**2010**	**2020**
Intensity (tce/household)	1.65	1.45	1.35	1.3
Coal (raw coal + briquette), (%)	16.8	20	20	20
LPG (%)	0	5	10	12
Biomass (%)	83.2	75	70	68

Source : Author's forecasts

In 1990, electricity consumption in rural areas for livelihood was 8.1 Mtce, which was less than 3% of the total energy consumption for livelihood. Per capita electricity consumption was only 25 kWh, with an estimated 100 million people who were unable to access electricity. Some residents depended on kerosene lamps for lighting. It is estimated that electric appliances will gain popularity as residential standard of living in rural areas improves. Along with the implementation of gasification programs in rural areas, more and more rural residents will use electricity for lighting. Use of kerosene lamps will decrease, and will probably vanished by 2010. Because per capita electricity consumption in rural areas in 1990 was very low, consumption will likely grow rapidly in the future. See Table 2.12.

Table 2.12
Energy Intensity and Energy Structure for Rural Residential Lighting and Electric Appliances, 1990-2020

	1990	**2000**	**2020**	**2020**
Intensity (tce/household)	0.07	0.15	0.30	0.45
Electricity (%)	84	90	100	100
Kerosene (%)	16	10	0	0

Source : Author's forecasts

On the whole, residential energy demand will gradually increase. However, the situation in urban and rural areas differ markedly. Urban energy demand will increase rapidly, and its share will also continuously go up. Rural living energy demand for livelihood will increase slowly between 1990 and 2020. In addition, the share of coal will decrease gradually, the share of biomass will decrease rapidly, and the shares of electricity, natural gas and LPG will continuously increase. As a result, the energy structure of residential will continuously improve.

2.3 Analysis of Agricultural Energy Demand

China is one of the world's largest agricultural countries, and agriculture is the basis of the national economy. In 1990, the added value of agriculture was 501.7 billion yuan, accounting for 27.0% of the GDP. Agriculture still accounted for 17.3% of GDP in 1999. Agriculture includes 5 subsectors: farming, forestry, animal husbandry, fisheries, and sideline production.

The energy consumption in agriculture is confined to cultivation machines, irrigation pump sets, tractors, farming trucks and motor fishing boats. Energy consumption of agriculture was 48.52 Mtce in 1990, accounting for only 5.1% of the total end-use energy consumption ; the share decreased to 4.3% in 1997. As shown in Table 2.1, the energy mix for agriculture is dominated by electricity, coal and diesel oil. It is predicted that the share of coal will decrease year to year, while the share of electricity will increase. The shares of other types of energy will not change significantly.

In the future, the efficiencies of energy consuming devices will improve gradually. However, because of the expansion of mechanization in agriculture, the energy intensities of devices will not change significantly, and the energy consumption per unit of output will go down slowly. See table 2.13.

Table 2.13
Energy Consumption Per Unit Output of the Agricultural Industry, 1990-2050

Energy Consumption	**1990**	**2000**	**2010**	**2020**	**2050**
tce/10000 yuan	0.967	0.713	0.526	0.388	0.212

Source : Author's forecasts

2.4 Analysis of Industrial Energy Demand

Industry is the biggest economic sector in China. Industrial output was 685.8 billion yuan in 1990, accounting for 37% of the GDP. In the recent decade, industry has developed rapidly, with an annual growth rate that is higher than that of GDP. In 1998, industry accounted for 42.1% of GDP, up 3% from 1990.

At the same time, among all economic sectors, energy consumption of industry is the highest. In 1990, the end-use energy consumption of industry was 632.39 Mtce, accounting for 67.1% of total end-use energy consumption. In 1995, consumption increased to 894.73 Mtce, and the share further increased to 72.0%. It is estimated that the increasing trend of industrial energy consumption will not change before 2000 or in the next several years.

Coal (including coke) and electricity are the most important energy sources for industry. In 1990, the share of coal was as high as 50.7%. However, it decreased yearly, and was reduced to 47.8% in 1995. The share of electricity was 27.5% in 1990, and increased rapidly to 29.3% in 1995. Following development of the economy and improvement of the end-use energy consumption structure, the share of coal will further decrease, while the share of electricity will further increase.

The end-use energy efficiency of industry was only 40% in 1990. Energy consumption per output of major industrial products in China was 30-40% higher than that of the same kinds of products manufactured internationally in 1980s. therefore, there are huge potential of energy conservation in the industrial sector.

Predicted changes in energy efficiencies in 2000 are positive. It is assumed that general technical levels will reach the international levels of the 1980s. Unit energy consumption of major energy intensive products will decrease to the 1980s level of advanced countries. Heat efficiencies of industrial boilers and kilns will increase by 10-20%, reaching international standards of the 1980s. The efficiencies of wind generators and water pumps will increase by 10-15%. Meanwhile, the industrial structure and product structure will improve gradually.

The following are analyses of the development scenarios and energy intensity changes in the future for specific industrial sectors:

- Iron and Steel Industry

Iron and steel is an important basic industry, and is a major energy consumer. In 1990, steel output reached 66.35 Mt, and energy consumption reached 98.78 Mtce. The main energy sources for the ferrous sector are cooking coal, steaming coal, electricity, fuel oil and natural gas. The major processes are cooking, sintering, blast furnace operation, steel conversion and rolling. In recent years, steel output has increased rapidly, and reached 124.26 Mt in1999. However, along with changes in the economic growth model, it is estimated that the growth rate will slow down. Unit energy consumption of steel in China is very high, about two times that of Japan in the mid-1990s. Due to the improvement of processes, the elimination of many energy inefficient technologies and practices, and the installation of new energy saving facilities, the integrated energy consumption per ton of steel will fall. See Table 2.14.

2.14
Steel Output and Energy Intensity, 1990-2020

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/t-steel)	1.488	1.2	1.0	0.9
Steel output (Mt)	66.35	110	140	160

Source : Author's forecasts

- Building Material Industry

The building materials sector includes the manufacture of construction materials, non-metallic mineral products and inorganic materials. The sector covers over one thousand products, with the main products being cement, plate glass, ceramics, brick, tin and lime.

In 1990, end-use energy consumption of this sector was 91 Mtce, accounting for 14.4% of the total end-use energy consumption of industry. The energy consumption of brick and cement was the largest, accounting for nearly 80% of the total end-use energy consumption of this sector. Energy consumption increased to 137 Mtce in 1996, accounting for 14.6% of total end-use energy consumption of industry.

In recent years, the building materials industry has been expanding rapidly in China, and the outputs of the main products have increased rapidly. As the economy develops and the industrial structure adjusts, the growth rate will go decrease. There are considerable differences in unit energy consumption of major products between China and developed countries. However, with technological improvements, unit energy consumption in China will decrease. See Table 2.15.

Table 2.15
Energy Intensity and Output of the Building Materials Industry, 1990-2020

		1990	2000	2010	2020
Cement	tce/t	0.197	0.147	0.125	0.105
	Mt	209	550	700	800
Brick	tce/10,000 piece	1.10	0.73	0.63	0.53
	billion pieces	458.5	800	1000	1200
Plate Glass	tce/case	0.039	0.020	0.016	0.014
	million cases	80.67	180	220	250
Others	tce/10,000 yuan	2.68	1.70	1.50	1.31
	billion yuan	58.02	182	361.39	533.14

Source : Author's forecasts

- Chemical Industry

The chemical industry is an energy intensive industry. It includes more than 20 subsectors, including fertilizer, basic chemicals, agricultural chemicals, organic chemicals, rubber goods, and chemical machinery.

In 1990, the end-use energy consumption of the chemical industry was 102.83 Mtce, accounting for 16.3% of total end-use energy of industry. Energy consumption increased to 199.35 Mtce in 1996, when the chemical industry accounted for 21.1% of total energy. The output of fertilizer was 18.8 Mt in 1990, and energy consumption for fertilizer production was 51.97 Mtce, accounting for about half of this sector. Fertilizer production increased to 32.51 Mt in 1999.

Nitrogen fertilizer is the most important subsector in the chemical fertilizer industry in China. The main product is synthetic ammonia, with three different processes for ammonia synthesis, defined by raw material: natural gas, fuel oil, and coal. In 1990, 42% of energy was used for raw materials, while the other 58% was used for fuel. Coal accounted for more than 50% of total energy consumption.

In recent years, the output of chemical fertilizer and other chemical products has increased rapidly. It is estimated that the growth rate of chemical fertilizer will slow down while the other chemical products will increase relatively rapidly. There is big gap between unit energy consumption in China versus other countries. Unit energy consumption of synthetic ammonia and as well as ethylene (1.285 tce/t) are twice that of Japan. See Table 2.16.

Table 2-16
Energy Intensity and Output of the Chemical Industry, 1990-2020

		1990	**2000**	**2010**	**2020**
Fertilizer	**Energy Intensity (tce/t)**	2.45	1.8	1.5	1.2
	Output(Mt)	18.8	32	35	38
Other	**Energy Intensity (tce/10,000 yuan)**	3.76	2.8	2.2	1.8
	Output (billion yuan)	151	387	720	1104

Source : Author's forecasts

- Non-Ferrous Industry

The main products of the non-ferrous industry are copper, aluminum, lead, and zinc. At the same time, sulfuric acid is produced as a side product, which accounts for around 20% of the total output of sulfuric acid in China. In 1990, the total non-ferrous output was 2.4 Mt, and the corresponding energy consumption was 18.55Mtce. The non-ferrous industry mainly consumes electricity, coal, coke, fuel oil and natural gas. The total energy consumption of the non-ferrous industry was not large, but the per unit energy consumption was high, and the share of electricity was high.

Unit energy consumption of non-ferrous products in China is high. Comprehensive unit energy consumption of unit aluminum was higher than international levels by approximately 30% in 1994. Comprehensive energy consumption of copper was 7.863

tce/t in 1995, about twice of that of international standards. Due to improvements in processes, the energy intensities will go down each year, and the output of non-ferrous products will continuously go up. See Table 2.17.

Table 2-17
Energy Intensity and Output of the Non-Ferrous Industry, 1990-2020

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/t)	7.73	6.67	6.03	5.63
Output (Mt)	2.4	4.4	6.0	7.0

Source : Author's forecasts

- Light Industry

Light industry includes paper, textile, wine and beer, medicines, sugar, tobacco, and food processing.

In 1990, the total output value reached 1181.3 billion yuan, accounting for about a half of total industry output. Energy consumption reached 137.19 Mtce, accounting for 20% of total energy consumption of industry. Coal and electricity are the most significant in the energy mix, accounting for 56% and 30% respectively. However, the share of coal will decrease yearly, while the share of electricity will increase. In addition, there are other important sources of energy, including coke, oil products, heat and gas. The main energy intensive industries are paper, textile, and sugar. As the economy develops, it is estimated that light industry will grow rapidly. With the improvement of processes and energy efficiencies, the energy intensity of light industry will go down. See table 2.18.

Table 2.18
Energy Intensity and Output of Light Industry, 1990-2020

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/1000 yuan)	1.07	0.65	0.45	0.31
Output (billion yuan)	1181	3000	5500	8500

Source : Author's forecasts

- The Machinery and Electronics Industry

The machinery and electronics sector includes the manufacture of automobiles, boilers, furnaces, telecommunications equipment, electronic equipment and other special equipment.

In 1990, the output value of the machinery and electronics industry reached 376 billion yuan, accounting for 16% of total industry output, which is only second to light industry in terms of industrial output structure. Energy consumption reached 45 Mtce, accounting for 7% of total energy consumption of industry. Coal and electricity are the main energy types used in this sector. The shares of coal and electricity were 47% and 32% respectively. In addition, coke, oil products and natural gas were also important energy sources.

Along with development of the entire economy and extremely rapid development of transportation and telecommunications, it is estimated that the machinery and electronics sector will develop rapidly in the future. With the technological advances, the energy intensity will decrease significantly. See table 2.19.

Table 2.19
Energy Intensity and Output of the Machinery and Electronics Industry, 1990-2020

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/1000 yuan)	1.16	0.66	0.44	0.27
Output (billion yuan)	376	1200	3000	6000

Source : Author's forecasts

- Other Industries

The energy intensity change and future development scenario of other industries are listed in table 2.20.

Table 2.20
Energy Intensity and Output of Other Industries

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/1000 yuan)	3.89	2.15	1.17	0.78
Output (billion yuan)	204	529	1140	2040

Source : Author's forecasts

2.5 Analysis of Transportation End-use Energy Demand

In 1990, the end-use energy consumption of transportation was 44.66 Mtce, only accounting for 4.7% of the total end-use energy consumption in China (because a considerable portion of vehicle do not actually belong to the transportation sector, the share may in fact be smaller than that). However, following the development of the national economy and the improvement in residential standard of living, transportation will develop rapidly, and thus energy consumption will also increase rapidly. In order to further study and forecast energy consumption of the transportation sector, it is broken down into 4 sub-sectors in this study: passenger transportation, freight transportation, motor and private car.

It is estimated that the future structural changes to the transportation sector will follow these trends:

(1) The share of road transportation will go up, with short distance passenger and freight transportation which are completed by railways and waterways being substituted by roadways in the future. The share of diesel oil vehicle for freight will go up.
(2) More and more motorcycles and cars (especially cars) will be possessed by residents, and a considerable portion of short distance passenger transportation will

be completed by private cars.

(3) The shares of diesel and electrical engines will increase, and steam engines will be eliminated gradually.

(4) In terms of freight transportation, because water way transportation has some advantages, such as the ability to transport long distances, take large loads, and achieve high energy efficiency, it will make up a large share in near future. However, because of disadvantages such as low speed, low future potential compared to roads, its share will go down in the long-term.

(5) Along with improvement in residential standard of living, the share of air transportation, especially the share of passenger transportation, will go increase prominently.

Along with improved efficiency of different vehicles and the improvement of transportation conditions, the energy intensities of roads, railways, waterways and air transportation will decrease by various extents.

According to the above analysis, the energy intensity change of passenger transportation, freight transportation, motorcycles, and private cars and their future development are listed in Tables 2.21-2.24. It should be noted that the listed energy intensities are the weighted results of different transportation vehicles. The energy intensities of freight transportation will not decrease obviously, as a result of the continuous increase in the share occupied by road transportation. It has been established that the energy intensity of roads is higher than railways and waterways.

Table 2.21
Energy Intensity Development Scenarios of Passenger Transportation, 1990-2020

	1990	**1998**	**2000**	**2010**	**2020**
Energy Intensity (tce/million-km-person)	17.10		12.5	10.5	9.0
Passenger-kilometers (billion km-person)	562.8	1056	1200	2000	3200
Railway (%)	46.4	35	34	32	28
Road (%)	46.6	56	57	57	55
Water way (%)	2.9	1	1	1	1
Air (%)	4.1	8	8	10	16

Source : Author's forecasts

Table 2.22
Energy Intensity and Development Scenario of Freight Transportation, 1990-2020

	1990	**1998**	**2000**	**2010**	**2020**
Energy intensity (tce/Mt-km)	15.79		14.14	15.42	15.71
Freight-kilometer (billion t-km)	2621	3784	4269	6950	10290
Railway (%)	40.53	32.5	32	32	30
Road (%)	12.81	14.5	15	18	25
Water way (%)	44.23	51.3	51.2	47.5	42
Air (%)	0.03	0.1	0.1	0.5	1

Pipeline (%)	2.39	1.6	1.7	2	2

Source : Author's forecasts

Table 2.23
Energy Intensity and Development Scenario of Motorcycles, 1990-2020

	1990	**1997**	**2000**	**2010**	**2020**
Energy intensity (tce/vehicle-year)	0.58		0.5	0.45	0.40
Stock (million)	4.213	20.22	25	50	80

Source : Author's forecasts

According to the report 'Study on the Strategy of Private Car Development in China', which was completed in 1994, the stock of private cars will reach 1.3-1.6 million in 2000, and 13-17 million in 2010. The author believes this figure is an underestimate. The stock of private car will more realistically amount to about 2 million in 2000 and 18 million in 2010. See Table 2.24.

Table 2.24
Energy Intensity and Development Scenario of Private cars, 1990-2020

	1990	**2000**	**2010**	**2020**
Energy intensity (tce/vehicle-year)	1.2	1.0	0.90	0.80
Stock (million)	0.034	2	40	100

Source : Author's forecasts

2.6 End-use Energy Demand Analysis of the Construction Industry

In 1990, the output of construction was 85.9 billion yuan, accounting for 4.63% of the GDP. End-use energy consumption was 12.13 Mtce, accounting for 1.3% of total end-use energy consumption.Thus, energy consumption per unit of construction was small.

The energy consumption structure is dominated by coal and electricity, and oil products. In addition, natural gas is also consumed in construction. Coal is mainly used in ovens and stoves of construction enterprises and teams ; electricity and a portion of oil products are used to power construction machines ; and a portion of diesel oil is used for vehicle transportation. It is estimated that there will not be a significant change in the energy consumption structure, though the share of coal will go down gradually and the share of electricity will go up slowly.

Due to the improvement of the energy efficiencies of construction devices, energy intensity will decrease gradually. In fact, the share of end-use energy consumption of the construction industry decreased to 1.1% in 1995, even while the construction industry developed rapidly. The energy savings in this sector is obvious. Energy intensity change in the future is listed in Table 2.25.

Table 2.25
Energy Intensity in the Construction Industry, 1990-2020

	1990	2000	2010	2020
Energy Intensity (tce/10,000 yuan)	1.412	0.68	0.40	0.25

Source : Author's forecasts

2.7 Services End-use Energy Demand Analysis

In this study, services include commerce and non-material production sectors. In 1990, the output of services was 466.6 billion yuan, accounting for 25% of GDP. Energy consumption was 47.20 Mtce, accounting for 5% of total end-use energy consumption. The share rose to 5.3% in 1995.

At present, the share of tertiary industry in China is small. As the national economy develops, the industrial structure will improve gradually. Services, as the main body of tertiary industry, will develop rapidly.

Energy consumption of services is dominated by coal, electricity, and oil products. Coal is mainly used for space heating and cooking. Along with improvement in residential standard of living, demand for environmental standards will increase and the energy consumption structure will be improved significantly. The share of coal decreased from 46% in 1990 to 32% in 1995, while the share of electricity increased from 21% to 25%. It is estimated that this trend will continue. In addition, the share of natural gas will increase prominently.

Due to social changes, the specialization of services, the improvement of energy efficiency of devices, and the increase of the share of high value-added services, the energy intensity of services will decrease. See Table 2.26.

Table 2.26
Energy Intensity of the Service Sector, 1990-2020

	1990	2000	2010	2020
Energy Intensity (tce/10,000 yuan)	1.012	0.60	0.45	0.30

Source : Author's forecasts

3 Energy Supply Security Issues

3.1 Current Status and Development Trends of Oil Supply and Demand in China

Since the 1990s, annual average growth rate of oil production was 1.7% while that of oil consumption was 4.9%. The demand was far greater than supply. China became a net oil importer in 1993 and a net crude oil importer in 1996. Net import of crude oil and oil products was 29.22 Mt in 1998 and 4381Mt in 1999. It is estimated to be over 50 Mt in 2000.

Crude oil output was over 160 Mt in China in 1997, and it is estimated that the output in 2000 will stay at the same level. Because a majority of oil fields have entered into the stage of 'high water content and high production', it is more and more difficult to stabilize production. During the next 10-15 years, if there is no significant increase in reserves and no breakthrough in technological advances, domestic oil output will increase slowly and it will be around 165-170 Mt in 2015. The plateau will last as long as 20 years. China's GDP growth rate will be around 7% in the first decade of the next century. Table 3.1 shows forecasts for oil demand in China made by different organizations. On the whole, demand will be around 200 Mt in 2000 and 300 Mt in 2010.

Table 3.1
Oil Demand Forecasts for China, 2000 and 2010 (100 Mt)

	2000	**2010**
International Energy Agency (IEA)	2.1	3.4
East-west Center, US	2.13	
Integrated Energy Survey Association, Japan	2.04	3.26
Energy Research Institute (ERI)	1.99	2.95
China National Petroleum Corporation (CNPC)	1.96	2.82
Average	2.01	3.05

According to preliminary analyses, crude oil output of China is 158 Mt in 2000, import is 50 Mt, export is 10 Mt, with a total demand of 200 Mt. If we assume that the annual growth rate of oil consumption is 1% lower than that of the past during the next 10-15 years, namely 4%, the crude oil shortage will be 78 Mt in 2005, 128 Mt in 2010 and 190 Mt in 2015. See table 3.2. Domestic oil production can only meet 47% of demand in 2015.

Table 3.2
Forecast for Crude Oil Demand and Supply in China, 2000-2015 (100 Mt)

	2000	**2005**	**2010**	**2015**
Demand	2.0	2.43	2.96	3.6
Domestic Production	1.58	1.65	1.68	1.7
Shortage	0.42	0.78	1.28	1.9
Self-supply Rate	79	68	57	47

Source : Author's Forecasts

The above analysis indicates that as the crude oil gap increases, China will rely more and more on overseas resources. 53% of oil consumed in China will come from outside sources in 2015. This means that China will face issues of energy supply security. How might these factors be taken into account in planning?

3.2 Energy Security Considerations

The sections below discuss ways in which China might address energy security issues.

3.2.1 The Majority of Oil Supplies Depend on Domestic Resources

China is a large oil producer and a big oil consumer in the developing stage. Oil supply should be based on domestic resources. Strengthen exploration to increase oil reserve and output, increase the self-supply rate, and secure the basic domestic oil supply.

According to the characteristics of oil resource distribution and current situations of oil field development, first it is necessary to stabilize the production in east China. Keep rolling exploration and development at the old oil fields and peripheral areas, strengthen comprehensive adjustment of old oil fields to try to increase recoverable reserve, improve the recovery factor, and extend stable production period. At the same time, speed up exploration in west China and offshore areas. Try to achieve big discover, increase new reserves production capacity. Realize strategic substitution of oil resource and stable and sustainable increase of oil production.

3.2.2 Utilize Overseas Resources to Reduce the Gap Between Domestic Demand and Supply

There is no doubt that there will be an oil shortage in China. Therefore, it is necessary for China to develop channels of trade, and participate in the exploration and development of overseas oil resources in order to create long-term, stable, and diverse international oil supply channels. There are basically two methods to utilize world oil resources. One is to directly buy crude oil and oil products through trade, trying to diversify the source of import, the channel of import, and products, in order to secure oil supply. The second is to participate in the exploration and development of overseas oil resources and to establish overseas crude oil and oil product bases.

3.2.3 Speed up the Development of Substitute Products for Oil

Natural gas can replace oil in many fields, and it is a cleaner fuel. At present, the share of natural gas in primary energy in China is only 2%, or less than one-tenth of the world average. It is hope it hoped that it can reach 6% in 2010 and 10% in 2020, thereby replacing 200 Mt of oil.

It will be similarly difficult for domestic natural gas production to meet demand. Import would still be necessary, and thus new energy security issues would come into play.

In addition, although the technologies for coal liquefaction have maturated, there are economic barriers. If crude oil prices reach and remain at US $ 30/barrel, coal liquefaction will inevitably realize commercialization. China is carrying out activities in this field with enterprises from the US, Germany, and Japan.

Finally, relevant research and development on replacing oil through biomass

liquefaction should be take into account.

3.2.4 Improve Energy Utilization Efficiency to Save Oil and Gas Consumption

With regard to energy reserves, the Chinese government follows the principle of ‘carrying out both development and conservation, and giving priority to conservation’. Therefore policies of efficiency and conservation should be practiced in oil utilization.

First, it is necessary to improve refining efficiency and reduce energy consumption of the oil and chemical industry. Average capacity factor of a domestic refinery is 67.32%, while the factor for advanced international refineries is 92.7%. Light oil output rate in china is 90.61%, while the advanced international output rate is 93.61%. Rate of loss from processing is 1.46% in China while the international advanced level is 0.2%. Domestic comprehensive energy consumption is 82.12 kgoe/t while the international advanced level is only 66.18% of that. There is great potential in efficiency improvements and oil conservation.

Secondly, the energy efficiency of vehicles should be improved and public transportation should be developed. According to experience, if energy consumption per capita by bus is 1, then energy consumption is 0.45 for light railway, 0.5 for subway and urban express railway, 5.6 for motorcycle, and 8.1 for car. Among cars, energy consumption of compact cars is 0.75 of that of common cars.

Thirdly, the government should steer consumption through economic policies which encourage oil conservation. China might follow the modem of Japan, where a family owns a car but does not necessarily use it every day, in order to save gasoline.

3.2.5 Establish National Strategic Oil Reserve

The International Energy Agency (IEA) considers energy security to be threatened when interrupted oil supply reaches 7% of demand. To secure oil supply, it requires OECD countries to have strategic oil reserves which are equivalent to 90 days of import, at a minimum.

At present, China has not yet established a strategic oil reserve system. Along with an increase of oil imports, it is necessary to establish strategic oil reserves to improve the capability to respond in an emergency.

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