

Lund University
School of Economics and Management
Department of Economics
Spring Semester, 2008

**The Energy Demand Trend in Contemporary China:
The Case of Petroleum and Coal**

Author: Huan-Chun, Tung
Supervisor: Susanna Thede

Abstract

This study examines China's future energy trend by analyzing how the energy demand in China has changed and how it will change by looking at several domestic factors, such as structural and policy changes, as well as international factors that affect the country's demand for energy. The sector-specific energy consumption trend in the near future is also discussed in order to show what the main driving forces are behind the increasing petroleum and coal demand at a sector level and to assess likely sectoral consumption changes in the near future. The data is collected from China Statistics Yearbook and this study draws on the existing literature which projects China's future energy demand. However, due to a combination of the lack of data and measurement errors in the data that can be accessed, this study is focused on the energy demand trend and does not provide specific quantitative results. A main contribution of the study is that it covers more aspects likely to affect China's energy demand compared to previous studies and that it outlines the individual effects of each factor, providing a direct and simple examination of the aggregate future demand trend for petroleum and coal from a general perspective.

Keywords: Energy demand, Trend, China, Petroleum, Coal

Table of Contents

Abstract	2
1.1 Introduction	4
1.2 Background	5
1.3 Data and Research Question	6
1.3.1 Data.....	6
1.3.2 Research Question & Structures of the Study.....	7
2.1 Literature Review	8
2.2 Contributions and Limitations of the Study	9
3. Factors behind Energy Demand	11
3.1.1 Overview of Current Energy Demand.....	11
3.1.2 Current Energy Demand Composition.....	13
3.2 Domestic factors behind Energy Demand	15
3.3 International Factors behind Energy Demand	19
3.4 Sectoral Energy Demand Shifts	25
4.1 Environmental Issues	28
4.2 Future Energy Strategies for China	30
5.1 Conclusion	32
References	34
Appendix	40

1.1 Introduction

China is one of the fastest growing economies in the world and the country has maintained an impressive economic growth rate between 5% and 14% over the past 26 years, and with an average of around 10% during 1997-2006 (Yang, 2008). The economic growth was export-led where industry and manufacturing sectors were the main driving forces behind the growth over the period. As a result, these energy-intensive sectors pushed up energy demand and made the country the second largest energy consumer in the world, second only to the United States.

The relation between demand and production in China's energy market has been going through stages that roughly can be separated into three periods. The first period was between 1953 and the early 1970s where energy consumption matched production and grew at a slow speed. The second period was from 1973 to 1992 when energy production surpassed energy consumption with a moderate annual growth. The last period was from the early 1990s and the domestic production could no longer catch up to the energy demand. China therefore became a net energy importer (Zhao & Wu, 2007). Driven by its excessive energy demand during this period China started to import energy while at the same time still trying to maintain its impressive economic growth rate. The strong demand for energy was driven largely by sector-specific demand and now the sectoral composition is changing along with the economic growth.

The aim of this study is therefore to assess the likely development of energy demand in China by identifying the factors that affect and determine the current energy demand and the consequences of economic and political changes that may affect China's energy demand. The sectoral composition of energy consumption is also crucial to understand the sources of this demand and its potential future trend. The motive of this study is to examine the changes of energy demand that may occur in the near future. In order to do so, this study draws on previous works which have already projected the future energy demand by using different models and, due to the complexity involved in providing a credible economic overview of the main factors that affect energy demand and the difficulty to collect the data for all energy sources, this study is limited to the demand of petroleum and coal. The reasons for choosing coal and petroleum are due to China's substantial dependence on these two energy resources. The energy consumed by China accounted for 33% for coal and 7.7% for petroleum of the world total in 2004 (Mainland Affairs Council, 2008). Coal has been the major energy

resource in China and at the same time it has been the main energy source for heavy industries that have stood for the main part of China's successful economic performance in the past. Petroleum is currently the second largest energy resource and it is on the way to becoming a crucial energy source in many sectors.

This study also describes environmental damages which stem mainly from the use of coal and oil which are emission-intensive energies instead of using cleaner energies such as nuclear and hydro power.¹ The strategies for a more sustainable growth for China in the near future will therefore be drawn upon and discussed in this study as well.

1.2 Background

As mentioned before, the energy demand is currently skyrocketing along with the economic growth in China. Among energy resources, coal is the largest energy resource and it accounted for 70% in 1978 and now still accounts for 68% for current energy consumption (Holscher and Bachan, 2008, p. 55; Jiang & Hu, 2006). China has been heavily dependent on coal due to several factors as pointed out by Crompton & Wu (2005) and some other works. The first reason is the abundant reserve of coal in China which is mainly concentrated in western part of China such as Shangxi province, Henan province, and Inner Mongolia.² Second is the petroleum price is regulated, and third, the under-pricing of coal during the central planning era and the disregard of the environmental impacts for many years makes it rather cheap to use coal (Crompton & Wu, 2005, p. 196). As a result, the increasing demand has made China a net coal importer in 2007 despite its own large coal reserve.

China is ranked as the second largest petroleum consumer in the world only after the United States and it is expected to replace the U.S as the largest consumer in the near future. As can be seen from Figure.1, the strong energy consumption and demand made China a net petroleum importer since 1993 (around 47% in 2008) despite the fact that China is the fifth largest petroleum producer in the world³ (China daily, 2008; Holscher & Bachan, 2008, p. 55; Crompton & Wu, 2005; MOEA, 2008). The trend of market petroleum price seems to remain

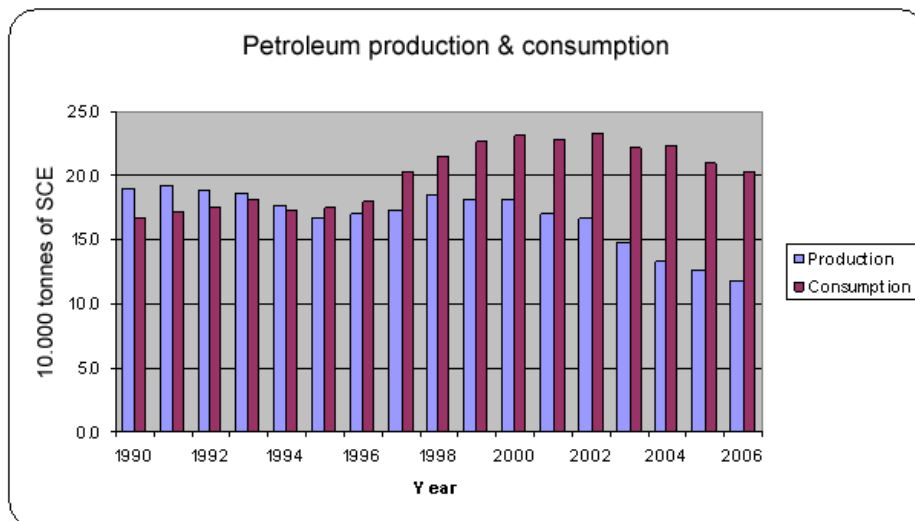
¹ According to statistics in National Bureau of Statistics, in 2006 the coal consumption still accounts for 69.4% of total energy consumption while natural gas accounts only for 3.0% and clean energy (wind power, nuclear power and hydro power) accounts for 7.2%.

² The information is from "Information of planned national and provincial (area/city) coal production and coal mines establishment". Database of Energy Research Institute National Development and Reform Commission, www.eri.org.cn

³ Petroleum production in 2003 was around 1,696 million tonnes which was world's 5th largest producer in the world.

high in the near future and it will be crucial for the country to secure its petroleum supply while competing with other petroleum-importing countries such as Japan and the United States (Kenny, 2004).

Figure.1. Petroleum Production and Consumption in China, year 1990-2006



Source: China Statistic Yearbook 2000-2007

*Note: SCE= Standard Coal Equivalent

China's fast-growing economy also brings negative consequences in the form of environmental degradation. According to the World Bank's ranking of local air pollution and most polluted cities, twenty out of the thirty most polluted cities are located in China (IEA, 2007). Awareness of environmental issues, therefore, has become a new concern for the Chinese government recently, which is driving China to develop cleaner energies such as hydroelectricity or natural gas in order to reduce dependence on coal (Zhang *et al.*, 2005).

1.3 Data and Research Question

1.3.1 Data

The data used in this study ranges from 1990 to 2006 and is collected from the China Statistics Yearbook which covers energy production and energy consumption.⁴ The time range is chosen to cover the trends of both energy production and consumption, especially at the sectoral level, in order to examine the changes of consumption shared across various

⁴ Energy (coal and petroleum) consumption is available at both aggregate and industrial level.

sectors. Another reason to cover a relatively long time period is to enable a comparison of figures from different yearbooks since the data can be adjusted after one or two years.

1.3.2 Research Question & Structures of the Study

The future energy demand is significant since China is growing at a speed that no country has ever experienced, and the energy demand is and will continue to be a substantial proportion of the world's total energy demand. Moreover, its heavy reliance on coal also brings environmental damage and causes concern from the world. Furthermore, the huge consumption can further affect world energy market price. As a result, it is important to project the trend of energy consumption in China in the near future.

Therefore, the research question of this study is aiming at finding out the future energy demand trend in China. In order to access the future energy composition, the study will first look at the current energy demand trend and the possible factors determining the changes in energy consumption in the near future. The factors include economic, political and external ones that have an impact on the Chinese energy market. After identifying the factors behind China's energy demand, the main sectoral energy demand trend will be discussed in detail. By examining various sectors that may have the tendency to change their demand in the near future, it will be easier to conceptualize the aggregate energy demand trend in China by summing up changes in individual sectors. Environmental issues will also be taken into account since economic growth brings up the demand for China's intensive energy use, and also emission and other environmental problems. This study focuses on petroleum and coal only due to the fact that these two are the most important energy resources in China, and they are also the main resources that have been used to create economic growth so far. Another reason to focus only on these two energy sources is due to the difficulty in collecting data for other resources which are less accessible compared to coal and petroleum given the limited time frame.

The rest of the study is structured as follows: Section 2 introduces the previous related research literature and the contribution as well as limitation of this study. Section 3 examines the current energy demand in China, the factors behind the demand changes, and the energy demand at a sectoral level in the near future. Section 4 discusses the environmental issues and possible policy solutions, and section 5 summarizes this study.

2.1 Literature Review

Energy, especially fuel energy has long been a broadly discussed issue due to its non-renewability and scarcity. The energy demand in developing countries has brought about substantial attention because the energy demand in these countries increase at a much faster speed than developed countries while the energy consumption is usually less efficient. Since the economic reform took place in 1980s, China has long been a research target regarding its energy consumption and demand, and many works have projected the future energy consumption for China.

Among the existing literature, Adams & Shachmurove (2008) use an econometric model to forecast the energy consumption and imports up to 2020. They assume a GDP growth rate ranging from 9% during 2002-2005 to 5.6% during 2015-2020. Their findings show that the energy imports of petroleum, coal, and total energy consumption (TEC) will all increase both during the 2002-2010 and 2010-2020 periods by 2.6% and 4.8% respectively (p.1269-1270). Other studies also forecast China's energy demand by using different methods. Crompton and Wu (2005), for example, make their forecast by using the Bayesian vector autoregressive methodology (BVAR), and the projections suggest that China's total energy consumption will be 2173 million tonnes of coal equivalent (MtCE) in 2010 while the growth of energy demand will decline gradually due to the slower economic growth and declining energy consumption. They also project that the total energy consumption will increase at an annual rate of 3.8% over the 2004-2010 period under their forecast with petroleum 4.5% and coal 3.3% (p. 205). Miranda-da-Cruz (2007) applies the UNIDO approach to energy supply and demand trend at the country level and he uses China and its industrial development as a case study. Miranda-da-Cruz projects that the total energy supply for China in 2020 is going to be around 3 billion tonnes of coal equivalent (TCE) and the industry sector will keep dominating the energy consumption followed by construction and transportation (2007, p. 920). The energy consumption composition in 2020 is projected to be the following: industry: 58%, construction: 26% and transportation: 16%. Dai & Zhu (2005, p. 142) also agree that transportation and construction will be the two key sectors for energy demand in the next twenty years.

Chan and Lee (1997) use a cointegration analysis and an error-correction model (ECM)⁵ to model the demand for coal in the country and they conclude that Engle-Granger's type ECM fits China's demand for coal better than Hendry's type ECM. The findings suggest that aside from prices and income levels, the relative size of heavy industry is important while determining the coal demand. What is interesting is that Chan and Lee find that the structural change played no role in determining the energy demand following the economic reform (p.286). This argument was also mentioned by Levine & Sintone (1994 & 1996) which are the key papers regarding China's energy intensity. Holscher and Bachan (2008, p. 54) also use the Engle-Granger error-correction model to create a short-term model for petroleum demand in China. Their results show that in the short term real GDP and the numbers of vehicle are the determinants of the energy demand and the adjustment from the short term to the long term period is pretty slow.

Furthermore, the International Energy Agency (IEA) creates projections according to three different scenarios: reference scenario, alternative policy scenario and high growth scenario.⁶ The reference scenario suggests that the coal demand will increase from 1563 to 3426 million tonnes during the 2005-2030 period with an annual growth rate of 3.2%. Coal production, on the other hand, is projected to increase from 1636 to 3334 million tonnes from 2005 to 2030. The projection for petroleum consumption is that it will increase from 346.6 million tonnes in 2006 to 407 million tonnes in 2010 and 563 million tonnes in 2020. The consumption of petroleum is expected to increase by 62.5 percent in 2020 compared to 2006 (Chinadaily, 2008-04-03).

Therefore, the projections above show that coal will remain the dominant energy source but its share will decline while petroleum will catch up and become the major energy source in many sectors. The industry sector will be the largest energy consumer but other sectors will also need much more energy than before.

2.2 Contributions and Limitations of the Study

As shown in the previous section, many works have projected China's future energy demand by using varied quantitative models and empirical data, as well as different scenarios and to

⁵ More explanation of ECM (error-correction model) can refer to Chan and Lee's (1997) study.

⁶ "The Reference Scenario lays out the energy trends up to 2030 based on existing policies. The Alternative Policy Scenario describes what will happen if China takes stronger action to curb demand and develop

predict the demand under various policy conditions and periods. However, the energy demand forecast is very sensitive to the data period covered, the data sources, and also the quality of the data. In fact, the quality and reliability of China's official data can be questionable (see Appendix B for a detailed description of this problem). Moreover, different data and methods also make these studies difficult to compare with each other.

Furthermore, the quantitative energy demand models used in the literature often requires assumptions which are not applicable in reality, and therein lie the limitations of the studies. In other words, these papers set up some rigid assumptions that are very unlikely to give realistic predictions of the future demand. On one hand, each of these studies abstains from incorporating some of the determinants that are likely to impact energy demand in the near future, such as the impacts of the regional composition and dependence of energy demand or the domestic and international policy intervention that is likely to occur. On the other hand, they make long-term predictions which are unreasonable given the large and frequent price fluctuations in the international energy markets. As a consequence, the high sensitivity of energy demand projections lead to varied results of demand in different existing literature and is therefore difficult to compare. As a consequence, the results obtained from these literature need to be treated with great cautions. Nevertheless, readers are able to identify the rough demand trend from these projections and further determine the factors can possibly affect future demand and in this way these works are still valuable.

Because of the sensibility of the data selected and the difficulties in collecting reliable data, this study intends to understand the energy demand by examining how the energy demand in China has changed and how it will continue to change by looking at several domestic factors, such as structural and policy changes, as well as international factors that affect the country's demand. In doing so, this study draws on the previously mentioned papers in the sense that it uses the same data foundation as part of the literature (China Statistics Yearbook) to assess current tendencies. This study also complements these data with other information sources, such as current news reports from the media and multinational organizations to form the expectations on the most likely developments in the Chinese energy markets.

alternatives. The High Growth Scenario details the consequences for energy demand, imports, investments and CO₂ emissions if China continues to grow at today's fast pace." Cited from WEO (world energy outlook) 2007.

However, there are also limitations in this study. The data is collected from the China Statistics Yearbook, the official data published by the government. However, the concerns about the credibility of the statistics should be highlighted and treated carefully. Another limitation is the difficulty in accessing yearly data which can provide the current trend on some of the factors explaining the trend, and therefore this study is limited to a descriptive rather than empirical approach.

3. Factors behind Energy Demand

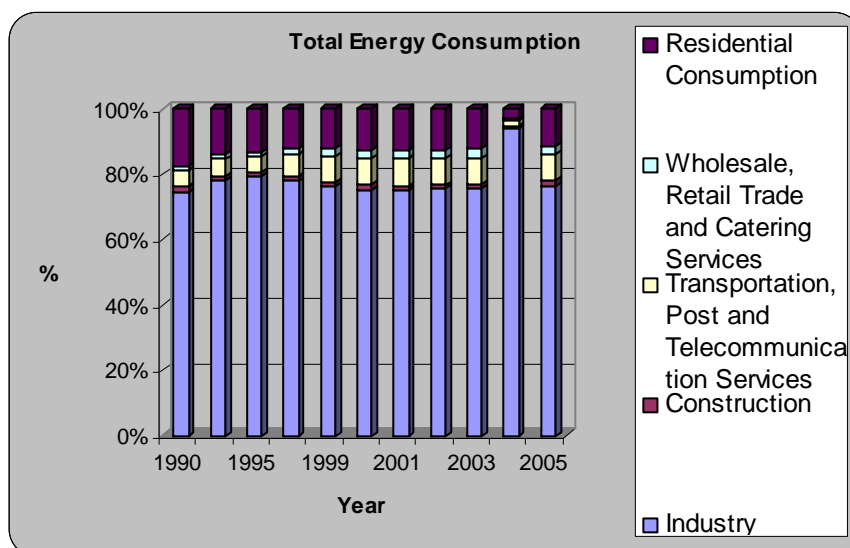
The energy demand has long been led by industry and manufacturing, however, the current trend and data shows that the demand composition among sectors will change in the near future. Section 3.1.1 introduces the overall energy demand in the country and 3.1.2 shows the current energy composition. There are numerous factors behind the change in energy demand composition, and section 3.2 and 3.3 focus on the domestic and also international factors. Section 3.4 examines the sector-specific energy demand trend with particular reference to the main sectors that are likely to change the energy consumption pattern. This examination is of particular interest, since the Chinese economy is undergoing a production structural shift.

3.1.1 Overview of Current Energy Demand

The rapid economic growth pushes forward the demand for energy, making China one of the major energy importers in the world. China's economic growth is largely contributed by industrialization and it leads to growing export and exporting sectors, namely manufacturing and industry sector which are more energy-intensive (IEA WEO, 2007, P. 245). Moreover, the regional distribution of population also has a considerable impact on the demand for different energy sources.

The economic reform which started in the 1980s led China into a market-oriented economy and part of the labor was shifted from agriculture to the industry and service sector. Moreover, the productivity improvements and accumulated capital boosted the growth of the industry sector and further contributed to the increased rate of overall economic growth (IEA WEO, 2007). The industry and manufacturing sectors have been two of the largest energy consuming sectors with industry still accounted for over 70% of total consumption in 2005 (see Figure.2). During the primary stages of the economic reform, China focused on developing the export sectors which were largely contributed to by heavy manufacturing and

Figure.2. Total Energy Consumption in China



Source: China Statistics Yearbook, 2000-2007

heavy industrial⁷ products. Many foreign companies also invested in these two sectors due to the abundant and low-cost labor supply. As a result, the demand for coal and petroleum became extensive. In 2006 China imported around 194.5 million tonnes of petroleum and 38 million tonnes of coal to fill the gap between domestic production and consumption⁸ (see China Statistics Yearbook, 2007). Export sectors crave a huge amount of energy which can no longer be matched by domestic production, so the reliance on imported energy makes China vulnerable to international energy prices fluctuations. Nevertheless, the government has further encouraged labor and capital to locate to in other sectors to balance the energy demand and also to improve the efficiency of resource allocation.

Aside from the economic growth, the domestic production structural changes have also led to increasing energy demand. In 2006, industrial production contributed 49% to the country's GDP (IEA WEO, 2007). On the production side, manufacturing and industrial production contributes substantially to the phenomenal growth rate and the low labor cost environment also attracts foreign companies to set up manufacturing factories in China. FDI⁹ also accounts for a crucial share of the growth. On the consumption side, high economic growth raises

⁷ Heavy industry refers to industries such as iron and steel, machinery, chemical, heavy chemical and car industry.

⁸ The consumption of petroleum and coal in 2006 was 348.8 million and 2.3 billion tonnes.

people's income and reduces poverty to a substantial level. People's consumption power is rising, in particular in the coastal region (IEA WEO, 2007). As a consequence, the transportation and construction sector will also be the main driving forces of the future energy demand (IEA, 2007; Adams & Shachmurove, 2008; CHINAdaily, 2008; Jiang & Wu, 2006; Skeer & Wang, 2007; Nel & Cooper, 2008).

3.1.2 Current Energy Demand Composition

What are the main sectors that lead the country's consumption and import of energy resources? According to previous studies and reports, major energy demanding sectors are industry, manufacturing, transportation and households. This section explores the current sectoral composition of petroleum and coal consumption.

Table 1.a to 1.d shows sectoral-specific energy consumption from 2002 to 2006. Overall, the industrial sector still dominates energy demand in both petroleum and coal. The consumption of coal is far larger than that of petroleum within the industrial sector mainly because a tremendous coal demands from the power-generation (news.bbc.co.uk, 2005-03-09). Furthermore, coal has long been the major energy source consumed in the industry because of its own reserve and convenience.¹⁰ Households also consume substantial amounts of coal, but the share is very small compared to the industry sector (For example, 3.52% compared to 94.59% in 2006). The energy consumption in the households has moved from coal to petroleum and the trend is shown in Table 1.c and 1.d. Moreover, the transportation sector and households are becoming the major determinants of the energy demand although they still account for less than industry's consumption. However, the petroleum consumption by the transportation sector is catching up to the industrial sector while the construction sector still takes a relatively small share (see Table 1.d). Energy consumption in agriculture and business also accounts for relatively small shares of the total coal and petroleum consumption. The explanations behind the low demand might be due to the fact that agriculture in China is labor intensive and does not require as much energy as in the United States or other countries that have capital intensive agricultural sectors. In addition, the contribution of agriculture to the GDP is declining (IEA, WEO 2007). For the business sector, the main energy needed is electricity and coal, and the share is relatively small. Construction also takes a very small

⁹ The "open-door" policy initiated in 1978 successfully attracted large amounts of FDI into China, with the fixed investment share rising from 34% to 52% during the 2002-2006 period (IEA, WEO 2007).

¹⁰ The convenience stems from the sufficient domestic supply instead of importing from foreign countries.

share of the energy demand as shown in Figure.2 and Table.1.a to 1.d, and it mainly consumes petroleum but coal which can be seen from Table 1.c and 1.d.

Table 1.a Coal consumption by sector

	coal consumption (10,000 tons)				
	2002	2003	2004	2005	2006
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy	1622,9	1683,3	2251,2	2315,2	2309,6
Industry	124195,4	156168,5	180135,2	202609,1	225539,4
Construction	553,5	577,2	601,5	603,6	582
Transport, Storage and Post	1055	1067,3	832,1	815,3	724,8
Wholesale and Retail Trades, Hotels and Catering Services	809,1	860,4	871,8	874,4	891,5
Household Consumption	7602,6	8174,7	8173,2	8739	8386,3
Total Consumption	135838,5	168531,4	192865	215956,6	238433,6

Table 1.b Petroleum consumption by sector

	petroleum consumption (10,000 tons)				
	2002	2003	2004	2005	2006
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy	1674,1	1681,4	2001,3	2072,9	2213,6
Industry	12489,6	12886,5	14857,3	14462,6	14972,3
Construction	410,4	1230,6	1422,3	1502,2	1648,5
Transport, Storage and Post	6156,6	7093,2	8620,6	9708,5	10969,2
Wholesale and Retail Trades, Hotels and Catering Services	593	682,3	818,7	915,6	992,2
Household Consumption	1477,5	1635,8	1778	1794,4	1992,5
Total Consumption	22801,2	25209,8	29498,2	30456,2	32788,3

Table 1.c Coal consumption by sector (%)

	coal consumption (10,000 tons)				
	2002	2003	2004	2005	2006
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy	1,19	1,00	1,17	1,07	0,97
Industry	91,43	92,66	93,40	93,82	94,59
Construction	0,41	0,34	0,31	0,28	0,24
Transport, Storage and Post	0,78	0,63	0,43	0,38	0,30
Wholesale and Retail Trades, Hotels and Catering Services	0,60	0,51	0,45	0,40	0,37
Household Consumption	5,60	4,85	4,24	4,05	3,52

Table 1.d Petroleum consumption by sector (%)

	petroleum consumption (10,000 tons)				
	2002	2003	2004	2005	2006
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy	7,34	6,67	6,78	6,81	6,75

Indurstry	54,78	51,12	50,37	47,49	45,66
Construction	1,80	4,88	4,82	4,93	5,03
Transport, Storage and Post	27,00	28,14	29,22	31,88	33,45
Wholesale and Retail Trades, Hotels and Catering Services	2,60	2,71	2,78	3,01	3,03
Household Consumption	6,48	6,49	6,03	5,89	6,08

Source: China Statistics Yearbook 2000-2007

3.2 Domestic factors behind Energy Demand

Continuous economic growth: As mentioned earlier, the rapid economic growth during the past two decades pushes up demand for both coal and petroleum. During the early period the growth has been mostly contributed to by the industrial and manufacturing sectors which still account for a big share today. Moreover, increasing per capita GDP also adds to the increasing demand for energy. The real GDP growth rate, which was 9.8% every year since the 1980s, speeded up to 11% in 2006 and is projected to be 11.5% in 2007 (IEA, 2007; the World Bank, 2008) The high growth rate brings up the energy demand from both the production side and consumption side, and thus stimulates the demand for both coal and petroleum.

Altered production Structure: Since the economic reform which started in the 1980s the government has switched its economy from planned to market economy which allowed market forces to work in China. Before the economic reform all the resources were allocated through central planning and the heavy industry was the sector that benefited most. Most of the energy resources were concentrated in the industry while other sectors such as services and light industry¹¹ suffered from lack of resources. However, the situation has been changed and now the government focuses on the transition from heavy industry to light industry and also the service industry (IEA WEO, 2007). Market forces also allocate the energy more efficiently to in-need sectors, as these newly developing sectors grow larger and need more energy. More electricity is needed and the demand for petroleum also expands due to increased residential and business usage, and as a result the demand for both petroleum and coal are boosted.

Governmental energy transporting policy: In order to supply the coastal region with resources from the inner part of the country, the Chinese government has carried out several policies. The implementation include energy projects such as the West-East Power Project and the

West-East Gas Project which can help to smooth out the demand for coal and increase the utilization of hydropower and natural gas market in generating electricity (Dai & Zhu, 2005, p. 140). The West to East Electricity Transfer Program is another national project which sets up coal-power plants in western and inner China and transport the electricity to the eastern China (Larssen, 2006). However, these power plants can further worsen the environmental damage and the waste of energy. Furthermore, in order to reduce the shortage of domestic energy supply, China is taking both energy conservation policy and improving energy efficiency as priorities (Zhang *et al.*, 2005, p. 179).

Governmental environment policy: The growth pattern in China was “growth first, environment later” for nearly two decades by only focusing on the growth rate and ignoring sustainable environment. Now the government has started to take the environmental damage into account. In this context, the central government has carried out several policies to press factories to limit their emissions, improve energy utility rates and change to cleaner energy sources (Levine & Sinton, 1996; Energy Development 11 FYP, 2007). Furthermore, the government is also seeking assistance from developed countries in mitigating the damage. The environmentally friendly policies will control the consumption of energy especially bad quality fuel¹² in rural residential areas as well as in the industry sector. It can be expected that the demand for both coal and petroleum will decrease after the policies are implemented. Even if it is only on a small scale, the attention drawn to the environment is important for the country to sustain its growth. The eleventh five-year-plan (eleventh FYP) also started to focus on the environmental issues and starts from education, promotion and training in order to equip citizens and industries with environmental concern (Energy Development 11 FYP, 2005). After that the most important issue will be to monitor and control the implementation.

Regional energy distribution and dependence: Geographically, China’s coastal region is the main area that drives up the energy demand since it is where most industries and large cities are located. In addition, the populations that reside in the coastal regions are wealthier than those residing in rural areas and inner China. The production of primary and final petroleum products in China is mostly concentrated in the east where the most important petroleum field is Daqing, located in Heilongjiang province, followed by Shengli in the northern part of Shandong province. Moreover, the new petroleum fields such as Songliao and Bohai Bay

¹¹ Light industry refers to industry that produces consumer goods such as clothes, leather and food processing.

basins¹³ are also located in the northeastern part of China and have started to share the petroleum production (see Appendix A for petroleum and coal distribution). The eastern part of China produced 63% of total production in 2004 compared with a much larger proportion 94% in 1984 (Feng *et al.*, 2008). Nevertheless, the most utilized petroleum fields are still located in the east. The inequality among the coastal and other regions in China contributes to higher energy demand in particular of petroleum products in the coastal region. Coal mines, on the other hand, are concentrated in the western part of the country, and this encourages the rural population to consume more coal or other fossil fuels than residents in the coastal region due to the abundant reserve¹⁴ (see Appendix C). The costs of transporting energies from coastal region to the inner China or vice versa makes the energy demand in China depend on locality strongly. Demand for coal in the coastal regions is satisfied mostly by the production in inner China and partly by the coastal region itself as well as importing (IEA WEO, 2007).

In urban areas, increasing numbers of the middle-class citizens boost up energy demand (IEA WEO, 2007). Domestic consumption demand is still weak compared to the export sector, and the increasing real estate prices and the lack of social security systems further lead many people to save instead of consume. Nevertheless, the middle-class consumes more than before and is pushing the country towards a consumption-driven economy, which stimulates the demand for energy (*ibid*). Economic growth and a rising per capita GDP benefit the wealthy urban population and they start to consume more electronic equipment¹⁵ such as refrigerators, TVs and air conditioning as well as more cars, which are all energy intensive products. The urban population contributes to economic growth and a higher GDP and they start to use more energy fuels such as natural gas and petroleum. According to Zhang *et al.* (2005, p. 171), the urbanization rate in China increased to 41% in 2006 from 20% in the 1980s, and the rate is expected to reach 70% by 2050. In addition, the urban population will account for 90% of GDP in China (IEA WEO, 2007). The migration from rural to urban area will further increase the demand for petroleum. However, being a transition economy, consumers in China have not yet changed its consumption habits to choose environmentally friendly products over more energy-consuming products. It might be due to the fact that the environmentally friendly products are not available yet or hard to access on the Chinese market, or Chinese people are

¹² Bad quality refers to coal and biomass which require a large volume to produce relatively limited heat.

¹³ Bohai bay basin and Songliao basin both locate in northeastern China.

¹⁴ Unit GDP energy consumption (ton/ten thousand RMB) are higher in inner China than in coastal region (WTI, 2006-06-30).

not yet concerned about taking care of the environment as a consumer, or both. The urban population prefers to purchase products that can show their status and wealth, and in the meantime they consume more than before. In short, the economic growth leads to a higher consumption of energy, both petroleum and coal.

Market-driven energy efficiency improvement: The economic reform carried out during the 1980s led China towards a more market-oriented society. Furthermore, the energy intensity¹⁶ has dropped substantially compared to other developing countries although the total energy demand has increased. There are two main factors behind improved energy efficiency: sectoral shift and technological improvement (Appendix D includes more discussion about energy intensity). After phasing out most of the regulation prices light industries obtained more resources and the advantages heavy industries used to receive regarding securing energy resources changed accordingly. The introduction of more advanced technology also helped various sectors to utilize energy more efficiently. Although some researchers, such as Levine and Sinton (1994), argue that it is the change within heavy industries that contributes to the energy savings, the structural shift of the economy still plays an important role and leads to less energy demand. Technological progress also improves productivity especially on the firm-level (Crompton & Wu, 2005). The firms improve their productivity while consuming the same level of energy so the total energy is used in a more efficient way. Nevertheless, even though the energy intensity has significantly changed, there is space for further improvement as the strong economic development craves more energy despite the improvement of energy efficiency.

Domestic price effect: Energy prices such as coal and petroleum have been under governmental regulation in order to stimulate an industry growth and further economic growth. However, the coal price was liberalized through a two-tier pricing policy since 1993 and is now following market prices (ce.cn, 2006-12-27). Nevertheless, due to the strategic role of petroleum, the government still keeps fuel prices below market price. Low fuel prices can help sectoral growth since they are not being hampered by increasing market fuel prices (MOEA, 2008). This, therefore, can lead to higher coal prices compared to subsidized petroleum prices which lead the industrial sector to shift from coal to petroleum to save costs.

¹⁵ China is now the second largest consumer (after Japan) of electronic devices in the aggregate level (IEA, WEO 2007).

The debate between price control and liberalization is catching attention and if the fuel prices regulation is removed the demand for coal and petroleum will be controversial since part of the industries or consumers might shift back to coal or other sources such as hydropower or nuclear. Nevertheless, since petroleum prices are kept low in the domestic market, there is no negative impact on industrial or consumer demands. Yet, there are debates on whether or not to raise domestic fuel prices (Appendix E discusses about petroleum price regulation in China). Moreover, the demand for petroleum is rather inelastic and cannot be replaced or adjusted in a short-run, and in this context, the petroleum demand is likely to hold instead of shifting to other energy sources in the near future. Table.2 summarizes the domestic factors and their impacts on the energy demand.

Table.2. Summary of domestic factors and impacts on energy demand

Factors	impacts on demand	
	petroleum	coal
Domestic		
economic growth	+	+
altered production structure	+	+
governmental energy transporting policy	+	+
governmental environment policy	-	-
regional energy distribution and dependence	+	+
market-driven efficiency improvement	-	-
domestic price effect	+	-

3.3 International Factors behind Energy Demand

International price effect:

Petroleum price effect: China consumes huge amounts of petroleum (349.8 million tonnes) and accounts for 9% of world consumption while it only has 1.3% of the world's proved reserve (BP, 2007). Heavy reliance on imported petroleum makes China vulnerable to petroleum price fluctuations, in particular energy-intensive sectors which act as the main driving force of economic growth in the country. Market petroleum prices have been climbing and reached a record high as shown in Table.3 that indicates that the price has increased from 41.39 USD/barrel to 102.45 USD/barrel from 2004 to 2008. Therefore, it is relatively expensive for China to import petroleum at the market price and sell it at a lower price

¹⁶ Energy intensity is defined as real energy consumption divided by real GDP (Fisher-Vanden *et al.* 2004 & 2006).

domestically. Although China has planned to increase its domestic petroleum production¹⁷ in order to compensate part of the imports from foreign countries (ChinaReviewNews.com, 2008), the petroleum price effect will have a large impact on China but not on its petroleum demand since the demand is rather inflexible.

Table.3. Petroleum market price 2004-2008

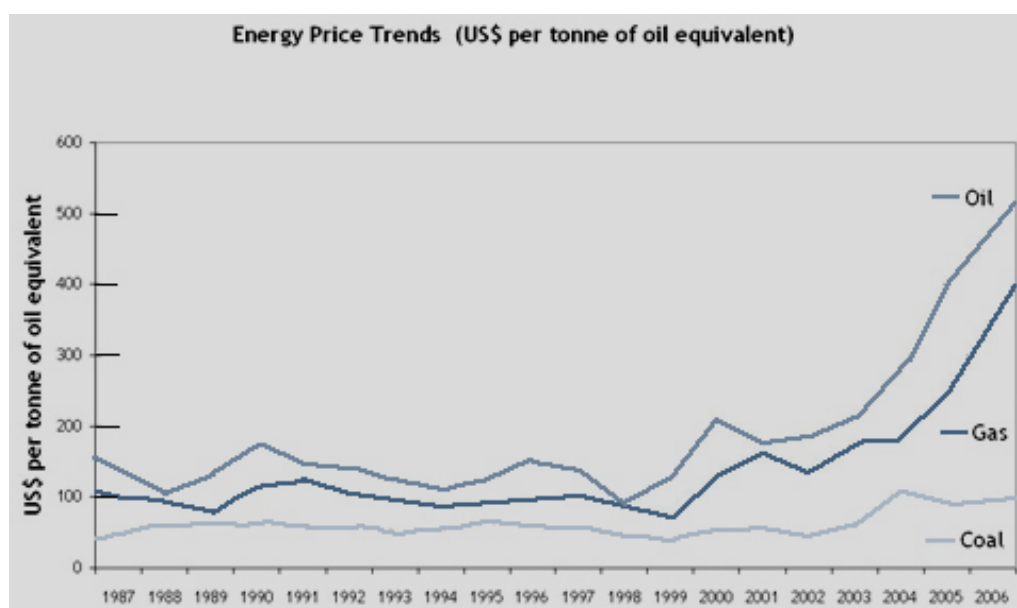
year	petroleum price* (USD per barrel)
2004	41.39
2005	56.54
2006	66.01
2007	72.29
2008 YTD	102.45

*West Texas Intermediate

*YTD: year-to-date (average price of the year)

Source: West Texas Intermediate Crude, Dollars per barrel

Figure.3 World market prices for Coal, Petroleum (oil) and Gas



Source: World Coal Institute

<http://www.worldcoal.org/pages/content/index.asp?PageID=438>

Coal price effect:

The price for coal, on the other hand, has been much more stable compared to petroleum. Figure.3 shows that the price of coal has been much lower than petroleum and gas prices from

¹⁷ The production of Daqing petroleum field will be adjusted the target production upwards in eleventh FYP in order to cover part of domestic petroleum demand. Petroleum basins such as Ordos, Junggar and Chaidamu in

1987 to 2006. Although price has gone up since 2003, the fluctuation has been relatively stable if one compares prices to other energy resources. The stability of coal prices may be in part due to the fact that many countries have moved from coal to petroleum and other cleaner sources of energy, and now coal only plays an important role in transit countries like China which has a large reserve that supports the domestic demand to a large extent. China owns around 39% of world's coal reserve,¹⁸ and its coal consumption in 2004 accounted for 33.8% of the world's consumption while it produced 35.5% of world's coal. As for petroleum, China consumed 7.7% of the world's consumption in 2004 and 4.4% of the world's production (Mainland Affairs Council, 2008). Because China constitutes a large share of its coal provision, it is less dependent on international sources for coal compared to petroleum. Furthermore, the coal market is less dominated by certain areas like the Middle-East which controls petroleum to a large scale, so the market price is rather stable. Overall, the coal prices do not have specific impacts on China's coal demand, so the large coal consumption from industry and other sectors can be satisfied without worries about fluctuating market prices.

Change of world supply:

Petroleum Supply: Table.4.a shows that the proved world's reserve has increased from 1986 to 2006; however, petroleum has a reserve limit due to its non-renewability characteristics. Therefore, small changes in supply have enormous impacts on petroleum market prices. The petroleum crisis in the 1970s and the Hubbert Peak Theory¹⁹ prove that the supply of petroleum is fragile and needs to be mitigated before the production reaches its peak, otherwise an energy crisis will occur. Along with global integration the government is diversifying its international petroleum suppliers by cooperating with petroleum-exporting countries (Jiang & Wu, 2006). The main supplies now are the Middle-Eastern countries but imports from Central Asia and Africa are gradually becoming crucial for China (see Appendix G for more details about potential suppliers for China). However, turbulence in the Middle-East, especially after the United States invaded Iraq in 2003, along with the growing demand from China has further worsened the stability of petroleum supply. The petroleum supply from the Middle-East has been unstable from 2003, and altered circumstances in other

the west, middle, and offshore will also contribute to the petroleum production in China (Feng *et al.*, 2008).

¹⁸ See <http://www.in-en.com/coal/UploadPic/2007-8/2007839183366448.gif>

¹⁹ Hubbert Peak Theory warns that the consumption of petroleum should be mitigated before the production reaches peak point, if the consumption is not mitigated then after the peak point production will decrease and price will increase dramatically and forms an energy crisis.

petroleum exporting countries such as Venezuela and Angola also have negative impacts on world petroleum supply. Although coal has filled up the energy demand in China, the demand for petroleum is still hard to substitute in some sectors. As a result of unstable supply and skyrocketing petroleum prices China has to import petroleum at a very high cost to satisfy domestic energy demand.

Coal Supply: According to the International Energy Outlook (IEO) 2007, the world coal production is projected to increase until the year 2030 (see Table 4.b and 4.c). However, the world reserve of recoverable coal has been adjusting downward since the 1990. The coal supply and price is seen as more stable than petroleum and therefore the coal supply is less worrisome. Furthermore, China has its own coal production which satisfies most of its domestic consumption although it still imports coal to satisfy the domestic demand.²⁰ As a result, China is less restricted by coal. Although small and inefficient coal mines in China have been closed down, the production volume is still among the top in the world.²¹ In addition, China now is planning to renovate some of its old coal mines to further boost up domestic production. The demand for coal in China is likely to be satisfied without extra efforts to secure international sources.

Table.4.a World proved petroleum reserves

	proved petroleum reserves	(millions barrels)			
	At end 1986	At end 1996	At end 2005	At end 2006	share of total
China total	17.01	16.4	16.2	16.3	1.30%
world	877.4	1049	1209.5	1208.2	100.00%

Table.4.b World proved coal reserves

	proved coal reserves	(million tonnes)
	At end 2006	share of total
China total	114500	12.60%
world	909064	100%

Sources: BP Statistical Review of World Energy June 2007

²⁰ China is likely to import coal from Indonesia, Australia, South Africa and Vietnam in near future to support domestic coal demand (IEA, WEO 2007).

²¹ China, Russia, the United States and India contributed 66% to total world coal production in 2004 (EIA, IEO 2007)

Table.4.c IEO 2007 World coal production by region, 2004-2030
(Million Short Ton)

	2004	2010	2015	2020	2025	2030
Total OECD	2277	2463	2542	2604	2824	3036
Non-OECD	3802	4751	5465	6202	6817	7437
China	2156	2772	3242	3732	4188	4690
Total World	6079	7214	8006	8806	9642	10473

Note: 1 short ton = 0.8928571428571429 long ton (tonnes)

Source: International Energy Outlook 2007, Chapter 5- Coal

Pressure on environmental issues: As discussed before, China's heavy dependence on coal and other energy sources has caused environmental damages such as greenhouse gas emission and air pollution. The Kyoto Protocol has been a protocol that contributed to emission reduction and mitigated climate change. China also ratified the protocol but it was only obligated to monitor and report its emission level (Fisher-Vanden & Ho, 2007). However, after China entered the World Trade Organization (WTO) the global concern toward the environment has put pressure on China. In order to reduce greenhouse gas emission and other types of pollutions such as water and air pollution, the WTO member countries might put direct political or trade pressure on China to reduce its environmental damage which may affect trade regulations among the countries. Furthermore, the internationalization of environmental externalities can increase the cost of energy consumption substantially and alter the comparative value of energy resources (Dai & Zhu, 2005, p.141). Therefore, it is important to notice that concerns towards environmental issues can drive up the cost of energy resources and reduce consumption in China. The government itself also has recognized that the environment has to be taken care of in order to maintain a sustainable economic growth. As a result, and as Dai & Zhu (2005) suggest, the environmental policy in China can have an impact on both industrial policy and energy consumption policy. Environmental issues will be discussed in more detail in the later section. Table.5 summarizes domestic and international factors behind the energy demand and their impact on coal and petroleum respectively.

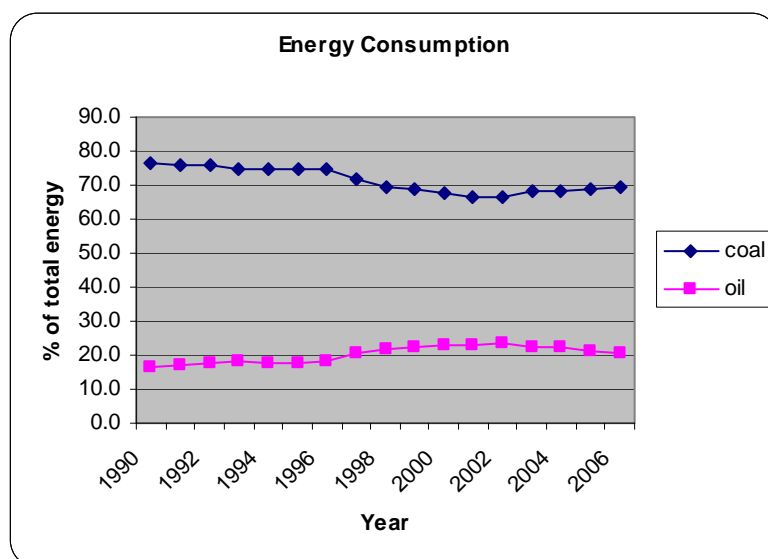
Table.5 Summary of factors behind energy demand in China

Factors	impacts on demand	
	petroleum	coal
Domestic		
economic growth	+	+
altered production structure	+	+
governmental energy transporting policy	+	+
governmental environment policy	-	-
regional energy distribution and dependence	+	+
market-driven efficiency improvement	-	-
domestic price effect	+	-
International		
international price effect	-	+
change in world supply	-	+
pressure on environment issues	-	-

The discussions above have shown that the demand for coal and petroleum is influenced by various factors, and the impact of the factors is summarized in Table.5, it shows that the overall demand for petroleum will increase in an aggregate level in the near future. Figure.4 shows the percentage taken by petroleum and coal and it looks like the share of coal has decreased since 1996 but since 2003 has slightly gone back up, while petroleum has increased its share along the way and only decreased slightly after 2005. However, the downward adjusting petroleum share is likely due to the high market price, but because of the inelasticity of the petroleum demand and the lack of substitute products, the general petroleum demand will still be growing. As for coal, it remains the main resource to generate electricity in China and it is believed that in the near future the demand for coal will also increase before other substitute energies such as hydropower and nuclear can start to supply electricity for the domestic need.

As a short conclusion, this study believes that demand for both coal and petroleum will keep increasing in the near future under the impacts of the factors discussed earlier, and one needs to notice that the share of coal will decrease along in time. In addition, China's demand for crude petroleum will also intensify the domestic need for refining capacity (Skeer & Wang, 2007, p. 688).

Figure.4. Coal and Petroleum Consumption in China during 1990-2006



Source: China Statistics Yearbook, 2000-2007

3.4 Sectoral Energy Demand Shifts

Section 3.2 and 3.3 has examined different factors behind the altering energy demand in China. These factors will impact the energy demand composition in the sectoral level. Therefore it is crucial to explore the impact on sectors after examining the reasons behind the demand trend. This section will explore more on the main sectors that are likely to change the energy consumption pattern.

Industry sector: In the primary stage of China's growth, the heavy industry and manufacturing sectors which focused on exporting energy-intensive products were main driving forces behind the economic growth. The export percentage grew from 6.1% in 1999 to 25.7% in 2007 (the World Bank-China Economic Indicators, 2008). However, after the country joined the WTO in 2001 China has reintegrated itself into the world economy. The early concentration on the heavy industries is therefore turning gradually to other industries such as the consumer goods industries. The industry sector which includes electricity generation will continue to be the major consumers (as can be seen from Table 6.a & 6.b²² and previous Table.1.a to 1.d) of coal and the growth of these two sectors therefore strengthens the need for coal. Therefore, the demand of coal is expected to increase regardless of the share of total

²² The data presented in Table.6.a and 6.b is only available in the yearbook 2007 but not the yearbooks before, so this study can only access and use these available data.

energy composition.²³ The transition from heavy to light industries is also likely to release part of the energy used exclusively by heavy industry before and transfer these energy to newly growing sectors. The transportation and construction sectors will become crucial growth contributors and demand more petroleum in coming years, and it is argued that these two sectors will be main growth drivers in the near future (Miranda-da-Cruz, 2007; Hirschhausen & Andres, 2000; Dai & Zhu, 2005; Zhang *et al.*, 2005).

Household Consumption: Coal usage in residential areas is likely to follow the current trend and continue to decline (which was previously reported in Table.1.c) and be replaced by gas and non-coal generated electricity, and the use of coal will be concentrated in industry and electricity generation (Jiang & Wu, 2006; Dai & Zhu, 2005). Petroleum consumption among construction and residential areas is rising from 1990 to 2006, as can be seen from Table.1.a and 1.b which shows that the energy demand has been moving from coal to petroleum and other energy sources (Wei *et al.*, 2007, p. 251). In households' consumption, the increasing purchasing power of urban population now consumes more consumer products which are partly based on inputs produced from petroleum. Nevertheless, the energy intensity in the residential area is still high because the electricity generating process needs a large amount of coal and it also produces a lot of waste (Wei *et al.*, 2007, p. 253). Therefore, there is great potential to improve the quality of energy sources and utility rate in households, especially in the rural area.

Table 6.a. Consumption of petroleum by sector (2006)

	Consumption (10,000 tonnes)				
	Crude Petroleum	Gasoline	Kerosene Petroleum	Diesel Petroleum	Fuel Petroleum
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy		239.64	1.54	1965.04	0.69
Industry	32081.54	468.5	48.19	1961.58	3036.11
Mining	1171.41	55.86	5.72	363.07	43.15
Manufacturing	30898.48	386.63	42.18	1240.33	2013.75
Electric Power, Gas and Water Production and Supply	11.65	26.01	0.29	358.18	979.21
Construction		180.75		428.66	16.34
Transport, Storage and Post	163.66	2722.35	1000.54	5747.32	1280.6
Wholesale and Retail Trades, Hotels and Catering Services		323.34	3.77	529.77	21.44
Household Consumption		343.04	22.73	170.59	

Sources: China Statistic Yearbook 2007

²³ The energy share of industry will decrease from 73% to 58% from 2002 to 2020, according to Hirschhausen &

Table.6.b Consumption of Coal by Sector 2006

	Consumption (10,000 tonnes)	
	Coal	Coke
Agriculture, Forest, Animal Husbandry, Fishery and Water Conservancy	2309.64	79.61
Industry	225539.36	27328.55
Mining	15436.83	194.06
Manufacturing	88408.97	27098.39
Electric Power, Gas and Water Production and Supply	121693.57	36.11
Construction	582.00	18.50
Transport, Storage and Post	724.80	0.85
Wholesale and Retail Trades, Hotels and Catering Services	891.46	65.39
Household Consumption	8386.34	90.45

Source: China Statistics Yearbook 2007

Construction Sector: Along with the strong economic growth, the construction sector in China is also growing rapidly to support new factories, offices and residential buildings. The surge of the cement sector production reflects a large investment in infrastructure and real estate, and the sector has grown more than 20% per year during the past a few years (IEA WEO, 2007, p. 247). Most cement producers still use coal and petroleum coke²⁴ as primary energy resources while a few rely on a combination of petroleum and natural gas. Therefore one can see that the growth of the construction sector will increase the coal and petroleum (mainly petroleum).

Transportation sector: In many studies, the transportation sector has been projected to be the main petroleum consumer in the near future. The production and consumption of private cars will grow at a double digit rate (Skeer & Wang, 2007) and thus transportation will be one of the main driving forces behind the thirst for petroleum. Motorization boosts up the petroleum demand²⁵ and the growth of the transportation sector (IEA, 2007; Adams & Shachmurove, 2008; CHINAdaily, 2008; Jiang & Wu, 2006; Skeer & Wang, 2007; He *et al.*, 2005) and that the transportation sector is projected to account for two-thirds of total petroleum demand in coming years (Kenny 2004, p.37). The specific demand for petroleum is mainly due to its high energy intensity and transportability. Moreover, Chinese refineries also concentrate on producing gasoline and other transport fuels rather than other petroleum products (Nel &

Andres (2000).

²⁴ Petroleum coke is a carbonaceous solid derived from oil refinery coker units or other cracking processes, and other cokes are derived from coal.²⁵ Petroleum is the dominant fuel consumed in transportation sector and accounts for 88% of total transport energy consumption (Skeer & Wang, 2007, p. 678).

Cooper, 2008; Skeer & Wang, 2007). As can be seen from Table.7 the usage of vehicle is growing fast and it will have a strong impact on the petroleum demand in China. Although the government has increased its fuel price in order to compensate for the high market petroleum prices but despite the increase, it renders far lower than what would be necessary to create a strong impact on petroleum consumption for car owners (Chinareviewnews.com, 2008-03-15). In short, transport in China has quadrupled during 1980 and 2002, and the numbers of vehicles will keep increasing due to urbanization and motorization, and China's future demand for petroleum will to a large extent be supplied by imports.

Table.7. Growth of motor vehicle population in China between 1990 and 2002

Motor Population	Vehicle	1990	1995	2000	2002	Absolute Annual Increase		
						1990-1995	1995-2000	2000-2002
Civilian (thousand)	Vehicles	5514	10,4	16,089	20,532	977	1138	2221
Private (thousand)	Vehicles	816	2500	6253	9690	337	751	1718

Source: Skeer & Wang, 2007, p. 680

*Note: Civilian vehicles include motorcycles while private vehicles exclude them.

As discussed before, the demand for both coal and petroleum in China will increase (IEA World Energy 2007, as cited in Izundu, 2007). Although Zhang *et al.* argues that due to the competition from alternative fuels for transportation, the demand for petroleum will decrease from 2020 (2005, p. 172). However, current statistics and literature have not yet shown similar projections and suggest that the demand for petroleum will be driven up by the transportation sector in the near future. Other sectors such as the construction and households will also contribute to the petroleum demand (Miranda-da-Cruz, 2007; Hirschhausen & Andres, 2000; Dai & Zhu, 2005; Zhang *et al.*, 2005; Skeer & Wang, 2007; Wei *et al.*, 2007; IEA WEO, 2007; EIA IEO, 2007). In short, the petroleum demand will keep rising in the near future.

4.1 Environmental Issues

China's rapid growth during the past twenty years has brought positive and negative impacts. A high economic growth rate puts China into the top six largest economies in the world but at the same time the extensive expansionary development pattern induces heavy environmental damage (Dai & Zhu, 2005, p. 138). China is now the largest coal producer and consumer in

the world, and the heavy dependence on coal leads to increasing SO_2 emissions (Jiang & Hu, 2006, p. 246). The emission of SO_2 leads to acid rain and is mainly from the coal-fired power plants. Compared with the 1980s, as Zhang *et al.* points out, the area covered by acid rain has increased substantially since the 1990s (2005, p. 171). The total SO_2 emission released into the atmosphere in 2003 was around 22 million tonnes which was more than the total anthropogenic European emissions of 17 million tonnes in 2002. Many Chinese cities are covered by highly concentrated particles and SO_2 in the air (Larssen *et al.*, 2006). In addition to SO_2 emissions, China is also ranked as the second largest emitter of CO_2 emitting with more than three billion tonnes and it is expected to be the largest emitter by 2025 (Fisher-Vanden *et al.*, 2006, p. 691; Zhang *et al.*, 2005; The Japan Times, May 2008). The CO_2 emission also comes from household consumption. Home energy use, cooking, and recreational services are all energy-intensive and carbon-emission-intensive (Wei *et al.*, 2007).

The heavy reliance on coal accounts for 70% of the total energy mix, and is the main factor behind CO_2 emission (Dai & Zhu, 2005). The transport of coal from inner China²⁶ to the coastal region further consumes even more coal. The projections for carbon dioxide emissions, by Dai & Zhu, are between 1437 to 1940 million tonnes of carbon by 2020 (Mt-C) (2005, p. 138). The results strongly recommend an environmental friendly policy to reduce the carbon emissions.

Transportation, on the other hand, is a main producer of NO_x ²⁷ emissions but a comparably small producer of other emissions such as CO_2 , SO_2 , and particles (Sadownik & Jacaard, 2007, p. 59). The emissions produced by the transportation sector are expected to be a problem due to the increase of vehicles and the growth of the energy demand by transportation. Therefore, it is still crucial to control the pollution from the transportation sector and to improve the carbon efficiency rate.

Environmental degradation does not solely come from emissions but also from water pollution and solid industrial waste. However, the most severe problem is air pollution which

²⁶ The coal mines in China concentrate in inner China instead of coastal region which needs large amounts of coals. Therefore, the coal has to be transported from western part of China to the coast.

is a consequence of the rapid growth and the disregard for environmental issues. Now the government is taking environmental issues as priority and has taken as well as plans to take numerous policies that can control and curtail the environmental damages.

4.2 Future Energy Strategies for China

As the study has discussed so far, energy consumption along with the ignorance of environmental protection has had considerable consequences and now the country must develop new strategies in order to secure the sustainable growth. There have been some suggestions made by scholars and various organizations in an effect to help China curtail environmental damage and use energy more efficiently. This section will explore possible future strategies to improve China's current situation.

First is the power-generating sector. In order to provide electricity for the immense land, power-plants have played an important role. However, in China most power-plants are coal-fired. Some authors suggest that these coal-fired power-plants will gradually lose market share by 2020, and be replaced by other power-generators, such as hydropower and nuclear (Zhang *et al.*, 2005; Hirschhausen & Andres, 2000). Nevertheless, others think that most new power plants will still be fired by coal. The largest consumer of coal within the industrial sector is still power generation and the second is industrial use (Skeer & Wang, 2007, p. 685). The consumption of coal will be around 2.9 billion tonnes and reach its production capacity by year 2020 (2005, p. 175). Therefore, it is most likely that power generation will still demand huge amounts of coal even if the percentage is decreasing gradually. Under these circumstances, the government needs to develop alternative sources of renewable energy.

In fact, the development of renewable energy is a broadly discussed alternative to help satisfy the strong energy demand. In the more developed areas of China, nuclear power can be developed as a feasible solution while rural areas mostly consume biomass and low quality coal. The energy demand in rural area can be replaced by improving the quality of biomass energy and more advanced technology. Zhang *et al.* predict that most of the incremental energy demand will be satisfied by cleaner renewable energy sources in the future, and part of primary energy along with total electricity generation will result from cleaner energy resources (2005, p. 180). Although the development of renewable energy in China is still progressing and cannot be a major energy source in the coming years, it is still a possible way

²⁷ NO_x refers to mono-nitrogen oxide (NO and NO_2) and is produced during combustion.

to diversify the heavy reliance on coal and petroleum in the future, and also to enhance environmental protections. China will need to transplant more advanced technologies from developed countries to develop its hydropower and nuclear power.

Aside from renewable energy, several other recommendations are made by Dai & Zhu (2005) to improve the energy consumption pattern and to protect the environment. One is to import high-quality energy²⁸ and change the economic development pattern to import energy-intensive products while reducing the export of energy-intensive ones, as well as to improve the energy mix. As He *et al.* (2005) argue, China should improve its vehicle fuel economy in the transportation sector to reduce CO_2 emissions since it will be one of the largest petroleum consumers in the near future.

As previously mentioned, the Chinese government is improving its environmental policies. There are many detailed suggestions about which policies are suitable to implement to ease environmental damage (Skeer & Wang, 2007; Jiang & Wu, 2006; Sadownik & Jacaard, 2001). The implementation of vehicle fuel taxes, subsidies for renewable energy, the charge of emission taxes and resource taxes (Jiang & Wu, 2006) can reduce the demand for non-renewable fuel in both households and industries, and also increase the consumption of renewable energy such as hydro- and nuclear power. Improved automobile energy efficiency or modal shifts such as shifting from highways to railways or seaways can also help moderate energy intensity (Skeer & Wang, 2007, p. 683). Higher energy efficiency and technological improvements can also help protect the environment and control emissions through improved carbon efficiency (Fisher-Vanden & Ho, 2007). Another possible ways to improve productivity and energy efficiency can be foreign direct investment (FDI) and in-house R&D. Like many developing countries do, China also receives a lot of FDI projects. The FDI usually utilizes technology or knowledge that has been transplanted from more developed countries which are more energy efficient and can lead to higher productivity (Crompton & Wu, 2005). However, the institutional quality in China, especially the weak legislation and enforcement, might be an obstacle to the implementation of clean energy use (Jiang & Wu, 2006, p. 249). As a result, the weak legislation needs to be strengthened in order to monitor and control the level of emission produced by industries and other sectors.

²⁸ Take coal as an example, the coal from different mines or even from the same mines have varied qualities.

China's eleventh FYP sets a target to lower its total emission by 10% and energy intensity by 20% (4.36% per year) by 2010, beginning in 2006, on the 2005 level (Yang, 2008). However, statistics show that China did not reach its goal in 2006²⁹ and it seems that it will be difficult to achieve the eleventh FYP if China keeps up the current energy consumption pattern. Therefore, it is important for China to improve its energy efficiency and to reduce energy end use in order to catch up to its target. The transportation sector has been singled out as a key energy-saving sector since it is highly energy intensive thus the potential is great. The idea is to develop mass transportation and substitute highways and airways with increasing railway transport. The increase of 2.3% railway passengers can save two million tonnes of petroleum every year, according to Yang (2008).

China has started to implement environmental policies such as energy conservation programs and to put environmental issues into the eleventh FYP and other important policy guidelines, and it is also active in climate change talks at the international level. However, what is more important for China is if the policies can be carried out and monitored properly under the weak institutional system. What is for certain is that environmental policies are and will continue to be considered as a priority issue in China (Zhang *et al.*, 2005). Nevertheless, the effectiveness of the policies will depend on the local government as well as the citizens.

5.1 Conclusion

As a transition economy, China has maintained a high economic growth rate during the past two decades and it is expected to continue with a high growth rate in the near future. The heavy industry, manufacturing and other energy-intensive sectors have been the main growth driving forces and will keep increasing its demand for coal and petroleum even though the production structure has changed from the primary growth period.

Coal has long been the dominant energy source for China and the increasing demand renders China a net coal importer despite of its own large reserve. Petroleum, which is now the second largest type of energy consumed in China, is expected to grow at a more rapid speed in the future due to changes in demand-related factors as well as alterations in the sector-specific energy composition.

²⁹ The energy consumption elasticity was larger than 1 between year 2002 and 2006, according to Yang's definition, if the elasticity of energy consumption is greater than 1 then the growth rate of energy/electricity

Although many studies have projected the future demand trend of China, the sensitivity of the data and rigid assumptions makes it difficult to compare and to consider them as reliable projections. Therefore this study has focused on the future energy demand composition trend in a more general perspective by using the data collected from China Statistics Yearbook and other sources. The various factors discussed in section 3.2 and 3.3 are the main determinants behind the energy demand and will have impacts on the future energy demand trend. The result in section 3.4 further shows that the consumption of both coal and petroleum will increase in the near future due to a higher energy demand by the industrial sector as well as growth in other sectors such as transportation and construction.

This study shows that coal will remain the main sources of power-generation while petroleum will be used more for transportation, construction sector and household consumption. Although the existing literature has incoherent future demand projections but those papers as well as this study all point out that the transportation sector will become the main petroleum consumer in China even though the world market fuel prices have reached a record. As a result, China has to secure its energy sources by intensifying domestic production and cooperation with petroleum exporting countries.

The strong demand for energy, especially coal and low quality energy used in rural areas has caused environmental degradation. The heavy reliance on coal makes China one of the largest emitters of both SO_2 and CO_2 , and greenhouse gases have polluted most of the cities in the country and affected people's standards of living. The government is now striving to reduce emissions by implementing emission controls, cutting down energy consumption, improving energy efficiency and also developing renewable energy sources. It will be a major challenge for the country to create a sustainable growth after ignoring the impacts on the environment for many years.

Therefore, the increasing energy demand, especially for coal and petroleum by different sectors, the changing demand composition influenced by various factors, and the increasing concern over the environment will be China's main challenges in the future.

References

Journal Articles:

- Adams, Gerard F. and Shachmurove, Yochanan (2008), "Modeling and Forecasting Energy Consumption in China: Implications for Chinese Energy Demand and Imports in 2020", in *Energy Economics*, 30, 1265-1278
- Bahgat, Gawdat G. (2007), "China Expands Energy, Seeks Investment", in *Petroleum & Gas Journal*, Vol. 105, No. 16, 20-24
- BP Statistical Review of World Energy June 2007
- Crompton, Paul and Wu, Yanrui (2005), "Energy Consumption in China: Past Trends and Future Directions", in *Energy Economics*, 27, 195-208
- Chan, Hing Lin and Lee, Shu Kam (1997), "Modelling and Forecasting the Demand for Coal in China", in *Energy Economics*, 19, 271-287
- Dai, Yande and Zhu, Yuezhong (2005), "China's Energy Demand Scenarios to 2020: Impact Analysis of Policy Options on China's Future Energy Demand", in *International Journal of Global Energy Issues*, Vol. 24, No. 3-4, 131-143
- Feng, Lianyong; Li, Junchen; Pang, Xiongqi; Tang, Xu; Zhao, Lin and Zhao Qingfei (2008), "Peak Petroleum Models Forecast China's Petroleum Supply, Demand", in *Petroleum & Gas Journal*, Vol 106, Issue 2, 43-47
- Fisher-Vanden, Karen., Jefferson, Gary H., Ma, Jingkui., Xu, Jianyi (2006), "Technology Development and Energy Productivity in China", in *Energy Economics*, 28, 690-705
- Fisher-Vanden, Karen and Ho, Mun S. (2007), "How Do Market Reforms Affect China's Responsiveness to Environmental Policy?", in *Journal of Development Economics*, 82, 200-233
- He, Kebin, Huo, Hong, Zhang, Qiang, He, Dongquan, An, Feng, Wang, Michael and Walsh, Michael P. (2005), "Petroleum Consumption and CO_2 Emissions in China's Road Transport: Current Status, Future Trends, and Policy implications", in *Energy Policy*, 33, 1499-1507
- Hirschhausen, Christian von and Andres Michael (2000), "Long-term Electricity Demand in China- From Quantitative to Qualitative Growth?", in *Energy Policy*, Vo. 28, 231-241
- Holscher, Jens and Bachan, Ray (2008), "Petroleum Demand in China: An Econometric Approach", in *International Journal of Emerging Markets*, vol. 3, no. 1, 54-70
- Izundu, Uchenna (2007), " IEA Warns of Coal Comeback in Energy Mix by 2030", in *Petroleum & Gas Journal*, Vol. 105, No. 42, 28-30

- Jiang, Kejun and Hu, Xiulian (2006), "Energy Demand and Emissions in 2030 in China: Scenarios and Policy Options", in *Environmental Economics and Policy Studies*, 7, 233-250
- Kenny, Henry J. (2004), "China and the Competition for Petroleum and Gas in Asia", in *Asia-Pacific Review*, Vol. 11, No. 2, 36-47
- Larssen, Thorjorn; Lydersen, Espen; Tang, Dagang; He, Yi; Gao Jixi; Liu, Haiying; Lei, Duan; Seip, Hans M.; Vogt, Rolf D.; Mulder, Jan; Shao, Min; Wang, Yanhui ; Shang, He; Zhang, Xiaoshan; Solberg, Svein; Aas, Wenche; Okland, Tonje ; Eilertsen, Odd; Angell, Valter; Li, Quanru; Zhao, Dawei; Xiang, Renjun; Xiao, Jinshong; Luo, Jiahai (2006), "Acid Rain in China", in *Environmental Science and Technology*, Vol. 40, No. 2, 418-425
- Miranda-da-Cruz, Sergio M. (2007), "A Model Approach for Analysing Trends in Energy Supply and Demand at Country Level: Case Study of Industrial Development in China", in *Energy Economics*, 29, 913-933
- Nel, Willem P. and Cooper, Christopher J. (2008), "A Critical Review of IEA's Petroleum Demand Forecast for China", in *Energy Policy*, 36, 1096-1106
- Wei, Yi-Ming, Liu, Lan-Cui, Fan, Ying, and Wu, Gang (2007), "The Impact of Lifestyle on Energy Use and CO₂ Emission: An Empirical Analysis of China's Residents", in *Energy Policy*, 35, 247-257
- World Energy Outlook (2007), IEA (International Energy Agency)
- Sadownik, Bryn and Jacaard, Mark (2001), "Sustainable Energy and Urban Form in China: the Relevance of Community Energy Management", in *Energy Policy*, 29, 55-65
- Sinton, Jonathan E. (2001), "Accuracy and Reliability of China's Energy Statistics", in *China Economic Review*, 12, 373-383
- Sinton, Jonathan E. and Levine, Mark D. (1994), "Changing Energy Intensity in Chinese Industry: The Relative Importance of Structural Shift and Intensity Change", in *Energy Policy*, Vol. 22, No. 3, 239-256
- Sinton, Jonathan E. and Levine, Mark D. (1996), "Energy Conservation Programs in China", in *Energy Conversion Engineering Conference, IECEC 96. Proceedings of the 31st Intersociety, IEEE*, Vol. 4, 2324-2329
- Skeer, Jeffrey and Wang, Yanjia (2007), "China on the Move: Petroleum Price Explosion?", in *Energy Policy*, 35, 678-691
- Snow, Nick (2005), "Surging Asian Demand Dominates World Energy Outlook", in *Petroleum & Gas Journal*, Vol. 103, No. 6, 26-27

- Yang, Ming (2008), "China's Energy Efficiency Target 2010", in *Energy Policy*, 36, 561-570
- Zhang, Ailing, Zhang, Xiaohua and Wu, Zongxin (2005), "China's Longer-term Energy Strategy and Its Implication on CO2 Emissions", in *International Journal of Global Energy Issues*, Vol. 24, No. 3-4, 170-182
- Zhao, Xingjun and Wu, Yanrui (2007), "Determinants of China's Energy Imports: An Empirical Analysis", in *Energy Policy*, 35, 4234-4246

Archive Resources:

- China Statistics Yearbook 2000, by China Statistics Press
- China Statistics Yearbook 2001, by China Statistics Press
- China Statistics Yearbook 2002, by China Statistics Press
- China Statistics Yearbook 2003, by China Statistics Press
- China Statistics Yearbook 2004, by China Statistics Press
- China Statistics Yearbook 2005, by China Statistics Press
- China Statistics Yearbook 2006, by China Statistics Press
- China Statistics Yearbook 2007, by China Statistics Press

Internet Resources:

9-joy.com, retrieved May 9 2008, from http://9-joy.com/?action_viewthread_tid_254104.html

BBC Chinese.com, published November 7 2007, retrieved April 16 2008, from http://news.bbc.co.uk/chinese/trad/hi/newsid_7080000/newsid_7082300/7082303.stm

BBC News: A Coal Dependent Future?, March 3rd 2005, retrieved May 22 2008, from <http://news.bbc.co.uk/2/hi/programmes/newsnight/4330469.stm>

Bloomberg.com: Angola Overtakes Saudi Arabia as Largest Petroleum Supplier to China, April 21st 2008, retrieved April 22 2008, from <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aqJ3Wjxs.OWs>

Bloomberg.com: Japan Consumer Price Rise at Fastest Pace in Decade, April 25th 2008, retrieved April 25 2008, from <http://www.bloomberg.com/apps/news?pid=20601068&sid=axp8dBDSnu2c&refer=economy>

ce.cn, April 3rd 2008, retrieved April 29 2008, from
http://big5.ce.cn/cysec/ny/hgny/200804/03/t20080403_15050287.shtml

ce.cn, December 27th 2006, retrieved May 22 2008, from
http://big5.ce.cn/cysec/ny/meitan/200612/27/t20061227_9900066.shtml

“China’s Petroleum Consumption to Hit 563M Tonnes in 2020”, CHINA.daily.com.cn, 2008-04-08, retrieved April 10 2008, from
http://www.chinadaily.com.cn/china/2008-04/08/content_6599920.htm

ChinaReviewNews.com, published March 11 2008, retrieved April 20 2008, from
<http://www.chinareviewnews.com/doc/1006/0/2/4/100602408.html?coluid=10&kindid=253&docid=100602408&mdate=0323113826>

ChinaReviewNews.com, March 15th 2008, retrieved April 20 2008, from
<http://www.chinareviewagency.net/doc/1005/8/8/8/100588801.html?coluid=50&kindid=1110&docid=100588801>

ChinaReviewNews.com, March 23rd 2008, retrieved April 24 2008, from
<http://www.chinareviewagency.net/doc/1005/9/2/6/100592693.html?coluid=53&kindid=0&docid=100592693&mdate=0313082227>

“Energy Development 11th five year plan”, National Development and Reform Commission, published April 2007, retrieved March 22 2008, from
<http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File186.pdf>

Energy Development Eleventh Five-Year-Plan, National Development and Reform Commission, April 2007, retrieved March 28 2008, from
<http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File186.pdf>

Euromoney: Country Risk September 2006: The Repercussions of Petroleum and Conflict, by Paul Pedzinski Florian Neuhof, published September 4 2006, retrieved February 15 2008, from
<http://www.euromoney.com/Article/1079265/Category/16/ChannelPage/10683/Country-risk-September-2006-The-repercussions-of-petroleum-and-conflict-.html>

HKtdc.com, January 28th 2008, retrieved April 22 2008, from http://emerging.hktdc.com/content_chi.aspx?data=emergingmkt_content_chi&contentid=1005897&SRC=BNT_Russia&w_sid=194&w_pid=1402&w_nid=13519&w_cid=1005897&w_idt=1900-01-01&w_oid=292&w_jid=

“Information of planned national and provincial (area/city) coal production and coal mines establishment”, Database of Energy Research Institute National Development and Reform Commission, retrieved March 22 2008, from <http://www.eri.org.cn>

International Energy Outlook 2007, Chapter 5 – Coal, Energy Information Administration, retrieved May 10 2008, from <http://www.eia.doe.gov/oiaf/ieo/coal.html>

Mainland Affairs Council, Taiwan, retrieved May 25 2008, from <http://www.mac.gov.tw/big5/rise/2-1.pdf>

MOEA (Department of Investment Services, Ministry of Economic Affairs, Taiwan), published Nov 22, 2005, retrieved March 20, 2008, from <http://twbusiness.nat.gov.tw/asp/left-08.asp>

National Bureau of Statistics of China, published June 30 2006, retrieved April 2 2008, from http://www.stats.gov.cn/tjgb/qttjgb/qgqttjgb/t20060630_402334002.htm

Price of West Texas Intermediate Crude; Monthly NSA, Dollars Per Barrel, retrieved April 29 2008, from <http://www.economagic.com/em-cgi/data.exe/var/west-texas-crude-long>

“Strategic points and measures of 11th 5YP’s energy development”, Database of Energy Research Institute National Development and Reform Commission, published October 15, 2005, retrieved March 22 2008, from <http://www.eri.org.cn>

The Japan Times: China Warms to Emission Goals, published May 3 2008, retrieved May 6 2008, from <http://search.japantimes.co.jp/mail/nn20080503a1.html>

World Bank: China- Figures and Facts, retrieved May 10 2008, from http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/C_HINAEXTN/0,,contentMDK:20680895~isCURL:Y~menuPK:318976~pagePK:141137~piPK:141127~theSitePK:318950,00.html

World Bank: China Economic Indicators- Cumulative, retrieved, May 10 2008, from
<http://siteresources.worldbank.org/CHINAEXTN/Resources/chinaei.pdf>

WSJ.com (Wall Street Journal Chinese version), January 3rd 2008, retrieved April 24 2008,
from
<http://chinese.wsj.com/big5/20080103/BCH012528.asp?source=NewSearch>

WSJ.com (Wall Street Journal Chinese version), November 2nd 2007, retrieved April 25 2008,
from
<http://chinese.wsj.com/big5/20071102/bch170227.asp?source=whatnews1>

Appendix

Appendix A: Distribution of Petroleum and Coal in China

Figure.1: Locations of China's Main Petroleum Fields



Source: <http://home.hiroshima-u.ac.jp/er/Resources/Image1091.gif>

Figure.2: Locations of China's Main Coal Mines

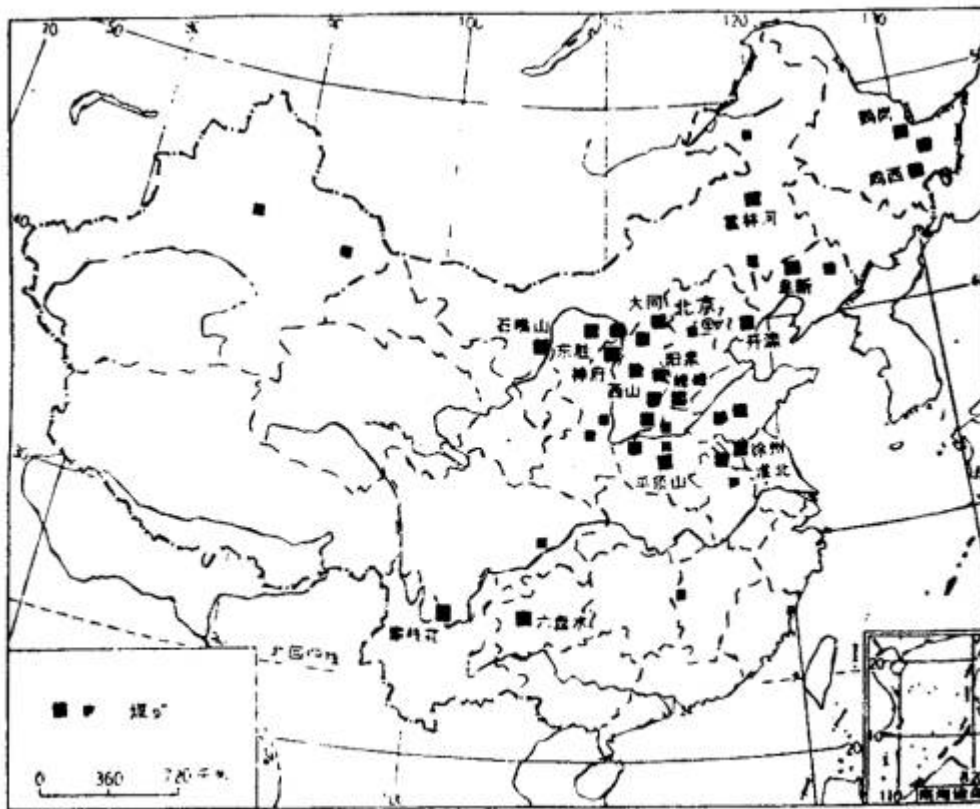


图 8—1

Source: <http://www.cbe21.com/subject/geography/images/030102/269/269002.jpg>

Appendix B: Credibility of China's Statistic Figures

Several previous studies have pointed out that there are measurement error problems in Chinese energy data. The problems with the existing energy statistics comes from the fact that country has kept its high economic growth rate while dropping its energy intensity substantially during late 1990s, the significant mismatch led to doubts regarding the credibility of both economic and energy statistics (p. 375). The reports from lower-level units are particularly uncertain and the information needs to be revised and corrected to a large extent after initial publication. As a result the information regarding production of small coal mines in China is argued to be unreliable and the exact amount of production is under-reported. Sinton (2001) even argues that the revised statistics after 1998 also needs to be treated with great caution due to suspicion of under-counting (p.379). What is interesting is that the statistics of petroleum production are seen as more reliable than coal, and this might

be due to the fact that petroleum production in China is strictly controlled and only a few companies produce and refine crude petroleum.

As can be seen from table B1 and B2 below, we also find inconsistencies in the reported statistics after 1998 in the China Statistics Yearbook which supports Sinton's observation. Both the production and consumption of total energy in the 2006 yearbook do not match the figures in the 2005 yearbook, and the numbers in 2006 are apparently higher than the ones in the Yearbook from 2005. The consumption of coal also shows inconsistencies when comparing the 2005 yearbook with the 2006 and 2007 yearbooks, and again the figures reported in 2006 are higher than the ones in 2005. However, the petroleum statistics is comparably correct and no adjustments have been made between the years 2005 to 2006. The upward adjusted figures can be proof of under-reported statistics in the first year which statistics are published. The industrial level statistics also proved to be *at odds*.

Table.B1: Inconsistencies between China Statistics Yearbooks

year	Total Energy Production		Total Energy Consumption	
	2005 YB	2007YB	2005 YB	2007YB
1999	109126	125935	130119	133831
2000	106988	128978	130297	138553
2001	120900	137445	134914	143199
2002	138369	143810	148222	151797
2003	159912	163842	170943	174990
2004	184600	187341	197000	203227

Source: China Statistic Yearbook 2005 & 2007

Table.B2: Inconsistencies between China Statistics Yearbooks

(10,000 tonnes)

year	Coal Production			Coal Consumption		
	2005 YB	2006 YB	2007 YB	2005 YB	2006 YB	2007 YB
2000	98176.1	128297.1	128297.1	124537.4	132000.0	132000.0
2002	129604.8			136605.5		
2003	157902.0	163402.0		163732.0	169232.0	
2004		192265.5	192265.5		193596.0	193596.0
2005		214462.1	214462.1		216557.5	216722.5

(10,000 tonnes)

year	Petroleum Production			Petroleum Consumption		
	2005 YB	2006 YB	2007 YB	2005 YB	2006 YB	2007 YB
2000	22631.8	22631.8	22631.8	22439.3	22439.3	22439.3

2002	24925.1		24779.8		
2003	27540.5	27540.5	27126.1	27126.1	
2004		32116.2	32116.2	31699.9	31699.9
2005		32539.1	32539.1	32535.4	32535.4

Source: China Statistics Yearbook 2005-2007

There are more explanations that the political climate behind the incorrect reporting of statistics in China. Fisher-Vanden *et al.* (2004) points out the possible explanations for the under-reporting of energy usage or over-estimation of output growth in China. The factors behind the mismatch between the statistics could be due to the fact that production from small coal mines, which are officially prohibited to produce in China, is absent in the official statistics, or the smuggling of fuel from outside China which is not reported to the authorities. Therefore the energy resources in China are in fact more than the official statistics and the energy intensity is not reflecting the true energy usage in China (p. 83). This point was also examined further by Sinton (2001) in his analysis of why the energy statistics appeared to contain more measurement errors after the middle of 1995.

Appendix C: Unit GDP energy consumption in various cities

Area	unit GDP energy consumption (Ton/ten thousand RMB)
Beijing	0.8
Shangxi	2.95
Inner Mongolia	2.48
Shanghai	0.88
Jiangsu	0.92
zhejiang	0.9
Anhui	1.21
Fujian	0.94
Jiangxi	1.06
Shandong	1.28
Guizhou	3.25
Gansu	2.26
Qinghai	3.07
Ningxia	4.14
Xinjiang	2.11

Resource: NBS (National Bureau of Statistics of China) 2006-06-30

Appendix D: Energy intensity in China

The relationship between energy intensity and energy demand is crucial because the lower the energy intensity is, the more efficient utilization of energy resources become. Since the economic reform was carried out in the late 1970s the energy intensity in China has dropped substantially and the growth rate of energy use is much less than the economic output growth. It has been argued that China's energy intensity remains lower than other developing countries. During the period 1997-1999 both energy use and energy intensity declined further (Fisher-Vanden *et al.* 2006). As many researchers have pointed out, the declining energy intensity is due to two major factors: a structural production shift and technological improvements (Fisher-Vanden *et al.* 2004 & 2006; Zhang *et al.* 2005).

Levine and Sinton (1994) point out that the reduced energy intensity during the 1980s was due to the real intensity change in a few energy intensive sectors such as building materials, machinery and metals (p. 239). This result shows that the decline of energy intensity within sectors accounts for a substantial share of total intensity change and it also suggests that there is a strong relationship between the governmental policies which began in the 1980s and the impact on energy consumption (p. 240).

However, Sinton & Levine (1996) argue that the decline of energy intensity has surprisingly little to do with structural change (such as a sector shift from heavy to light industries), and most of the contributions come from technological improvements. The technological change in the energy intensive sub-sectors such as chemicals, machinery, metals and building materials can explain a lot of the decreasing energy intensity. Therefore a substantial share of energy saving is due to the technological change within heavy industries instead of the shift from heavy to light industries (Sinton & Levine, 1994). Energy conservation programs in China such as state sponsored investments have also had a substantial impact on energy efficiency by enhancing energy consumption per unit of economic output in real terms. Therefore the state policies are argued to be part of the drivers behind the technical efficiency improvements (Sinton & Levine 1996, p. 2324). The policies include for example the *Energy efficiency and energy conservation management*, and the aim is to control the unit energy consumption and energy supply via quotas. Regulations are used to reduce petroleum use, to substitute coal for petroleum, and to set up a standard of energy efficiency for buildings and

residential areas³⁰ (p. 2326). Energy conservation is one target in the eleventh five-year-plan and China intends to further reduce the energy consumed per unit of gross domestic product (Yang, 2008).

The central administrated energy conservation program, as argued by Sinton & Levine (1994), contributes not only to energy saving but also to the preservation of the environment. This is because by reducing energy intensity, the use of fossil fuels and other energies will be reduced or be used more efficiently. The rapid economic growth can thus be accompanied by a more environmentally friendly energy consumption pattern.

In contrast to Sinton & Levine (1994 & 1996), Crompton & Wu (2005) points out that the sectoral shift from heavy industry to light industry contributes largely to the declining energy intensity. According to Sinton & Levine (1994 & 1996), technological improvements are also the main reason behind the more efficient energy use in the country. Crompton & Wu (2005) instead argue that, along with market reform and the more open international trade environment in China, the intervention policy and state-controlled price scheme has been phased out (except petroleum price) and this changes the profitability of heavy industries which were the beneficiaries of government's intervention.

Appendix E: Petroleum price regulation in China

Petroleum is the second largest source of energy consumed in China only after coal and it accounted for 23.2% and 20.4% of total consumption in China in 2000 and 2006 respectively (China Statistics Yearbook, 2007).

Price control enables China's industry and other petroleum demanding sectors to continue to grow at a rapid pace without being hampered by expensive market petroleum price. China is also trying to boost domestic petroleum production in order to replace part of the expensive import of crude petroleum from other countries. However, the production of China's most important petroleum field Daqing has declined gradually which shows that this old petroleum field is drying out little by little³¹ (WSJ.com, 2008). Therefore, Chinese petroleum producers are planning to find new petroleum fields which reserves more than 100 million tonnes each

³⁰ Details about the energy conservation program can refer to Levine & Sinton (1996).

³¹ The production of Daqing is 471 million tonnes which is 4% less than 2006.

year by 2010 in order to increase domestic supply and also compensate the reducing petroleum supply from Daqing petroleum field (CHINAdaily, 2008-04-08).

The reason for the low petroleum price is to keep strong economic growth and the government subsidizes petroleum companies to run their business. Why is it so difficult to remove the petroleum price intervention in China? What are factors behind the demand of keeping petroleum price low? What will happen if the price regulation in China is removed?

The consumer price index (CPI) in China is largely influenced by food prices since food still dominates the consumption market, therefore the increasing food price tightens up the CPI and drives up both CPI and inflation. Under these circumstances, if the government releases the intervention on petroleum price then the CPI and inflation will go further up (ce.cn 2008).

There are some warnings about possible chain effects after raising the petroleum price in China. First, although the stock market has a positive response to the increasing petroleum price, it has been pointed out by experts that burden of increased prices will eventually fall on consumer's shoulders and drive consumer side to reduce their demand toward petroleum and possibly shifting back to coal (WSJ.com, 2007). In addition, the low-income citizens will have a hard time paying higher prices (WSJ.com, 2007). Secondly, if the government raises the price of petroleum it can induce an even higher inflation rate. Japan also suffers from high energy demand and the inflation rate has been driven by the price instead of demand (Bloomberg.com, April 2008). Therefore, the petroleum price has to be controlled in order to limit inflation in China. Thirdly, an increase in the price of petroleum will lead to less petroleum consumption and more use of substitute energies such as natural gas and coal, and the use of coal is even less environmentally friendly than petroleum. Furthermore, the energy intensive industries such as mining, manufacturing and other petroleum-demanding industries will also be affected negatively.

However, the price intervention will eventually harm the competitiveness of domestic petroleum industry by pressing the price lower than the market one and the subsidies for petroleum industry in the country further increase the demand for petroleum and results in inefficient consumption of petroleum and environmental damage. Furthermore, the low petroleum price distorts real inflation and can mislead decision-making of monetary policy

and industry policy (ce.cn, 2008-04-03). Therefore, it will be a difficult task for Chinese government to deal with its policy regarding the petroleum prices.

Appendix F: Petroleum Suppliers for China: Current and Potential

As discussed before, the energy production within China is not sufficient to supply domestic demand and therefore China has to step outside and compete for energy with other countries. China imported in 1968 a billion tonnes and the dependence rate has reached 50%. Under the condition that it can hardly increase domestic production the petroleum demand has to be satisfied by importing petroleum from other countries (Chinareviewnews.com, 2008-03-11).

China's petroleum reserve is declining and it only accounts for a small proportion of world's reserve and at the same time exploration so far is still a disappointment. The way for China to secure petroleum resources and to fill the gap between consumption and production, as suggested by Feng *et al.* (2008, p. 46), is to cooperate with petroleum exporting countries. The external dependence on petroleum exporting countries is increasing and it is projected to be 50% in 2010, 64% by 2020 and 69% by 2030. Since petroleum is a crucial and strategic energy resource, it is important to limit the dependence on foreign countries. Therefore, it is necessary for China to find partners to cooperate with instead of only importing petroleum from exporting countries (*ibid.*).

In the middle of the 1990s China concentrates its petroleum deals in Indonesia, Oman and Yemen. However, after a decade Chinese companies have expanded to North and South America, Africa, Asia and Middle East (Bahgat, 2007).

The current main petroleum supplying countries for the Chinese market include countries in the Middle-East and the imports from this area account for 50% of China's total import (Kenny, 2004). As a need of diversifying and stabilizing petroleum supply³² China is now expanding petroleum import proportionally from Russia, Central Asia, South America, Southeast Asia and Africa (mainly Angola) while maintaining imports from the Middle East (Holscher *et al.* 2008, p. 55; HKtdc.com, 2008).

³² The situation in Middle East is not stable and the country risk is also high, in this situation China needs to diversify the petroleum import from other countries (Euromoney, 2006)

The cooperation with Kazakhstan is expected to be a new important petroleum supply for China and the petroleum pipe which link China with Central Asia will bring China substantial amount of crude petroleum (MOEA 2008; Kenny 2004). The cooperation will further release the thirsty demand for petroleum in China's coastal region. The abundant petroleum supply in Central Asia, according to Kenny (2004, p. 41) can be a promising resource for China but on the other hand it needs to take the cost of extraction and delivery into account.

Aside from Central Asia, the petroleum supply from Africa and South America is another option for China. China has succeeded in accessing agreements with Sudan and Nigeria (Snow, 2005). Another African country, Angola, has surpassed Saudi Arabia and become the largest petroleum exporter to China in the first quarter of the year 2008³³. Current petroleum imports from Africa constitute around one-third of China's total import (Bahgat, 2007). Furthermore, the delivery from South America, especially Venezuela can also become a major supply source for China (BBC Chinese.com, 2007). It is argued that the long-term supplier can no longer satisfy China's strong petroleum demand and thus the spot purchase of petroleum will increase to fill up the domestic demand (Bloomberg.com, 2008).

China has, so far, many cooperation programs going on with petroleum exporting countries in order to diversify and secure its demand, and on the other hand the country is also intensifying domestic petroleum production in order to maintain a rapid economical growth. It will still be an interesting topic in the near future if China has any new movements regarding importing petroleum from foreign countries.

³³ The export of crude petroleum reaches 8.48 million tonnes within the first three months of the year 2008 which equals to 688,000 b/day. Saudi Arabia reach exports of around 8.18 million tonnes to China under the same period of time (Bloomberg.com, 2008)