China's Energy Situation and Its Implications in the New Millennium

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Motu Working Paper 09-04
Motu Economic and Public Policy Research

April 2009

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Acknowledgements
The research was partially supported by The College of Business, University of Canterbury and the Marsden Fund.
This paper has also been published as a University of Canterbury College of Business and Economics Working Paper.

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Abstract

Many are interested in China's energy situation, however, numerous energy related issues in China still remain unanswered. For example, what are the potential forces driving energy demand and supply? Previous reviews focused only on fossil fuel based energy and ignored other important elements including renewable and 'clean' energy sources. The work presented here is intended to fill this gap by bringing the research on fossil-based and renewable energy economic studies together and identifying the potential drivers behind both energy demand and supply to provide a complete picture of China's energy situation in the new millennium. This will be of interest to anyone concerned with the development of China's economy in general, and in particular with its energy economy.

JEL classification
D24, O33, Q41

Keywords
China; Energy; Fossil fuels; Renewable Energy

Contents

1 Overview

Understanding China's energy economy in the new millennium is crucial for politicians, business people and energy economists. In particular, China's energy policy directions will present both challenges and opportunities to the world in terms of an increasing share of primary energy consumption and investment opportunities (Wang, 1995; CIAB, 1999). China's industrialisation, modernisation and urbanisation affect the way in which energy resources will be developed as the basis of economic growth (Dean, 1974).

Many authors have focused on the energy situation in China (Dean, 1974; Dorian and Clark, 1987; Kambara, 1992; Wu and Li, 1995; Smil, 1998; CIAB, 1999). However, many energy related issues in China still remain unanswered - for example, what are the potential forces driving energy demand, and what are the potential forces driving energy supply? Previous reviews focused only on fossil fuel based energy and ignored other important elements including renewable and 'clean' energy sources. Therefore, a comprehensive and complete review of the energy situation in China is timely and necessary. The work presented here is intended to fill this gap by bringing the research on fossil based and renewable energy economic studies together and identifying the potential drivers behind both energy demand and supply to provide a complete picture of China's energy situation in the new millennium. This will be of interest to anyone concerned with the development of China's economy in general, and in particular with its energy economy.

This review of China's energy situation is organised as follows. Firstly, we consider the historical origins of China's current energy situation. This is followed by an investigation and analysis of China's energy resources, including renewable energy. In the third section we consider the energy industrial regulations. Section 4 focuses on capacity building in the energy sector. Sections 5 and 6 describe energy transportation (focusing on coal) and energy price information. Section 7 discusses China's energy efficiency in particular, energy intensity over time and across regions. This is followed by a discussion of energy supply, demand and trade. Section 9 discusses the potential factors driving demand and supply. The final section provides some areas for potential policy initiatives in the Chinese energy market and more widely explores issues relevant for economic development.

1.1 An historical perspective of China's energy situation

As early as 1974, Dean considered the energy situation in the People's Republic of China and argued that the discovery and initial exploration of new petroleum reserves were significant in relation to changes to energy policy and operation. In particular, he was concerned with future developments in the energy industry and the effect on the international energy market. He argued that the size of China's fossil fuel and hydroelectric resources, combining with its commitment to 'self-reliance', made it unlikely that China would become a major energy importer. Furthermore, he argued that China would likely become a major exporter in the foreseeable future. By 1992 China had, in fact, become a major energy importer.

Dorian and Clark (1987) discussed potential supply problems and implications for China's energy resources. They stated that primary energy production must increase significantly by the year 2000 if China were to achieve its current modernisation and economic objectives. To support and sustain this rapid economic growth, indigenous supplies of primary energy resources would have to be developed at rates greater than those of the time. With a specific concern for China's sustainable energy supplies, they conducted a systematic assessment of China's primary energy resources by province using the Unit Regional Production Value (URPV) technique, originally developed by Griffiths (1978). What is interesting is that they present the potential for petroleum, natural gas, coal and uranium by province.[1]. Once they had identified the potential supply of petroleum, natural gas and coal by province they considered the extent to which exploration was restricted by outdated equipment and poor management. Furthermore, they considered whether increased energy production may be limited by inadequate infrastructure combined with high capital requirements, safety and environmental issues.

Kambara (1992) investigated China's energy situation in the 1980s. He considered economic growth and energy consumption and, in turn, the energy intensity by sector and by region, observing the changing patterns of energy supply and demand. He raised a number of issues, including the unequal distribution of energy reserves, rising investment cost, limited funds and lack of technology imports which he believed have constrained China's energy supplies. He stated that his review of China's energy situation suggests that supplies of, and demand for, energy will grow in a 'balanced fashion' that will keep pace with economic development. Finally, he argued that the most important task facing China was to totally reform the energy market, particularly pricing to eliminate wasted generation caused by low energy prices. The current 'partialy liberalised' market, he argued, actually caused more confusion than benefits.

Wu and Li (1995) studied developments in China's energy situation in the 1980s and early 1990s. They described commercial energy production and consumption and stated that certain features of China's energy production and consumption have had a profound impact on the country's energy development strategies and policies. Much of their work, therefore, focused on explaining these strategies and policies in China, fuel by fuel. Overall,

[1] In the Appendix we present three figures for petroleum, natural gas and coal (see Appendix Figures 1-3) - for detailed URPV see Dorian and Clark (1987)

they present two basic characteristics of China's energy industry associated with China's policies for energy development. The first is that China's energy policy has varied over the last several decades consistent with domestic and international situation. The second is that China does not have a unified national energy development strategy as energy resources are not all substitutes and the distribution of energy resources is uneven across regions or provinces. As a result the 'national' energy policies have become de facto 'regional energy development policies' with each of the major energy industries developing their own strategies. In conclusion the authors recommend that China offer more flexible terms to attract foreign investment in the energy sector; formulate a comprehensive oil import policy; improve the legislative and business climate to support fair competition; ensure balanced growth of coal production and transportation; limit the monopoly power of railway transportation through government intervention; and finally reform electricity pricing.

There is abundance of coal and a lack of natural gas in China, where coal extraction originates from two types of enterprises: large collieries owned by the state and administrated from Beijing, and a variety of local medium and small mines run by counties, townships, collectives and individuals (Wang, 2007). In China it is common that growth in output is not accompanied by improvements in quality. Attempts to open small mines, without geological and technical evaluation, has led to a significant waste of coal resources. Primitive extraction methods and inexperienced operators have led to a very low recovery rate and often extensive destruction of arable and grazing land. Rapid economic expansion and the continuing reliance on coal can be expected to more than double China's current carbon dioxide emissions, which are forecasted to rise significantly, with a large increase in the other greenhouse gases (Smil, 1998; Liang, Fan and Wei, 2007).

It is very surprising that the reviews summarised above have not mentioned any renewable energy at all, given that renewable energy has been playing an important role in China's energy supply. China's population is over 1.2 billion of which more than 60% live in rural areas where most households use renewable energy (e.g., biomass, biogas) rather than fossil fuel based energy (Liu et al., 2008; Zhou et al., 2008). For example, since 2000 renewable energy has accounted for approximately 74% of China's total rural residential energy consumption (CESY, 2007). Meanwhile, China's urbanisation is gradually reshaping the pattern of rural energy consumption away from biomass energy based to cleaner energy sources (Cai and Jiang, 2008). This will undoubtedly lead to more pressure on non-renewable energy demand.

The energy situation in China is highly dynamic. Do the concerns raised above persist? Did China follow the policies suggested above? What does the current energy situation in China look like? Are there any new concerns that have appeared? Are there any new policies that have been proposed? The following section presents an overview of the current energy situation in China.

2 China's energy resources

The issue of China's energy reserves is of long standing interest to researchers and policy makers. Issues related to general energy reserves can be found in BP (2008) and energy potential in Dorian and Clark (1987). Here we present three figures to illustrate China's energy reserves and their distribution over provinces as it helps understand issues related to energy transportation and policies on energy exploration and regional development.

2.1 Coal reserves

China's proven reserves of anthracite and bituminous coal are 62200 million metric tonnes (mmt) and for sub-bituminous and lignite coal, 52300 mmt (BP, 2008). The total proven coal reserves are therefore 114500 mmt and account for 13.5% of total world stocks. As of the end of 2007, the ratio of reserves to production is 118 years. It is also widely known that China's distribution of coal is extremely uneven across regions. Figure 1 shows the distribution of China's coal reserves by Province in 2004. Coal is found almost everywhere in China, but the major deposits are found in the North (Shanxi and Inner Mongolia), Southwest (Guizhou and Yunnan) and Northwest (Shaanxi). Most coal reserves are located in Shanxi Province (over 100 billion metric tons).

2.2 Petroleum reserves

Statistics show a clear decline in China's proven and recoverable petroleum reserves. In 1987 there were 2377 mmt declining to 2322 mmt by the end of 1997 and 2117 mmt by 2008. Chinese petroleum reserves presently account for 1.3% of the world total (BP, 2008). As of the end 2007, the ratio of reserves to production was 11.3 years. Finding new oil fields and creating a comprehensive oil import policy package is one of the most important tasks for China to undertake. Similarly, oil reserves are not evenly distributed over provinces, see Figure 2, which shows stocks in favor of Northeast (Heilongjiang), East (Jiangsu) and Northwest (Xinjiang).

2.3 Natural gas reserves

China's confirmed reserves of natural gas are 1.9 trillion cubic meters and account for 1.1% of the world total. As of the end 2007, the ratio of reserves to production is 27.2. Natural gas reserves are mainly located in the Southwest (Sichuan and Chongqing), West (Shaanxi), North (Inner Mongolia) and Northwest (Xinjiang) provinces (see Figure 3). There are two types of natural gas reserves – are independent of oil fields and those associated with oil reserves. Natural gas development is sluggish due to the absence of production facilities, transportation pipelines and urban gas supply systems. Nevertheless, China's natural gas resources are estimated to be large and more will no doubt be confirmed and developed. The most promising fields are in the Ordos basin, the Caidam Basin, and in the Yinggehai Basin off Hainan Island (Smil, 1992).

2.4 Renewable energy

China currently uses various renewable energy sources including hydropower, biomass, solar energy, wind energy, geothermal energy and wave energy. It is currently estimated that the economically potential exploitable renewable energy resources amount to approximately 7.2 billion tonnes coal equivalent, while the current exploited renewable energy resource is only 0.1 billion tonnes coal equivalent (Zhou, 2006). Here we will consider only hydropower and biomass renewable energy as they are currently two of the most important sources of renewable energy in China.

2.4.1 Hydropower energy

China is rich in hydropower energy potential. Maximum exploitable hydropower resources are approximately 680 million KW, of which 380-400 million KW currently has economically exploitable potential. To date, there has been total installed capacity of 116 million KW. China plans to install new capacity of 165 million KW by 2010 and 290 million KW by 2020.

Of 380-400 million KW of economically exploitable hydropower, there is 128 million KW from small hydropower stations (under 50,000 KW), located in 1600 counties across the country. Total installed capacity of small hydropower stations was 47 million KW in 2006. Total generation of rural hydropower was 148 billion KWh in 2006 (CSY, 2007). China plans to install 50 million KW by 2010 and 75 million KW by 2020 for small hydropower station generation (Zhou, 2006).

Small hydropower stations play an important role in China's rural electricity supply. Currently, approximately half of the territories, one third of counties and a quarter of the total population are dependent upon small-scale hydropower for rural electricity supply.

The distribution of small-scale hydropower generation, however, is uneven. Approximately 65% of small hydropower stations are located in the west and south of the country. In 2005, total installed capacity was approximately 24.7 million KW in the western areas of the country, which generated total hydro electricity of 71.5 billion KWh.

2.4.2 Biomass energy

Potential biomass energy in China includes crop stalks, firewood, foul waste, domestic garbage, industrial organic wastes and waste water, among others. It is estimated that total potential biomass energy is approximately 70-100 mmt coal equivalent, of which 50% comes from crop stalks, i.e. 35-50 mmt coal equivalent (Zhang et al., 2008 in Press).

During the period 1995-2006, China produced approximately 620 million tons of crop stalks per year of which 50% came from the east and central south of China. Crop residues amount to 1.3 times total crop output and 2 times that of the total fodder of grassland. Crop stalks of corn, wheat and rice amounted to 189, 136 and 237 million tons respectively accounting for over 85% of all crop stalks in 2006 (CSY, 2007). At present, energy use accounts for approximately 37.5% of crop stalks, non-energy use accounts for approximately 27.5% of crop stalks, with approximately 35.0% of crop stalks either lost during the harvest or discarded in the field (Liu et al., 2008). This means that there is still 35% potential use of crop stalks as biomass energy in China's rural areas (over 50 mmt coal equivalent).

3 Energy industry decentralisation

Before proceeding with this section, we list some government departments, agencies, administrative bodies, and large energy enterprises relevant to energy industry regulation.

- SPC - State Planning Commission, since 1952 and replaced by SDPC in 1998
- SDPC - State Development and Planning Commission, replaced by SDRC in 2003
- SDRC - State Development and Reform Commission, taking place of the former SDPC and incorporating partial functions of SETC and the former State Economy and Institution Reform Office
- SETC - State Economic and Trade Commission, replaced by Ministry of Commerce (MOC) in 2003
- MOC - Ministry of Commerce, since 2003 combining the former SETC and the former Ministry of Foreign Trade and Economic Corporation
- SSTC - State Sciences and Technology Commission, since 1958 and replaced by MST in 1998
- MST - Ministry of Sciences and Technology, since March 1998 replacing the former SSTC
- CNPC - China National Petroleum Corporation
- Sinopec - China Petroleum and Chemical Corporation

- MEP - Ministry of Electric Power
- MCI - Ministry of Coal Industries
- SAPC - State Administration of Petroleum Corporation
- SACI – State Administration of Coal Industry
- CGOM - Central Government Owned Mines
- PGOM - Provincial Government Owned Mines
- LGOM - Local Government Owned Mines
- TVOM - Town- and Village Owned Mines
- SPCC – State Petroleum Corporation of China
- MLR - Ministry of Land and Resource
- MOE - Ministry of Energy
- VISOU - Vertically Integrated State-Owned Utilities
- SPC - State Power Corporation
- SPG - State Power Grid
- CSPG - China Southern Power Grid
- SERC - State Electricity Regulatory Commission
- CTCE - China Taiyuan Coal Exchange, since June 2007
- SEA - State Energy Administration, within SDRC since July 2008

3.1 Previous regulatory system

China's energy industry has experienced several significant policy and management changes. The 'old form' of the energy industry regulation system was created in 1993. Figure 4 shows the government structure and regulatory system as it was. The State Planning Commission (SPC, now called the State Development and Reform Commission - SDRC) reported to the State Council which stood at the top of the energy policy hierarchy with full responsibility for energy policy. The State Economic and Trade Commission (SETC, from which most functions have been transferred to the SDRC since 2001) and the State Sciences and Technology Commission (SSTC, now the Ministry of Sciences and Technology) played a relatively minor and subordinate role in the energy sector. Under the old system, each of the major energy industries was dominated by a single institution which was either a State Corporation or a Ministry. For example, the China National Petroleum Corporation (CNPC) dominated petroleum exploration and production, while the China Petroleum and Chemical Corporation (Sinopec) controlled oil refining and distribution. The Ministry of Electric Power (MEP) and Ministry of Coal Industries (MCI) were in charge of the power and coal sectors, respectively. These Corporations and Ministries were also involved in policy formulation, regulation and enterprise management (Andrews-Speed, Dow and Gao, 2000).

The old industrial organisation structure and regulatory system of China's energy sector have been well documented and reviewed. Energy policies prior to the 1970s were reviewed by Dean (1974). National policies and regional strategies of China's energy development were considered by Wu and Li (1995). The changes in China's power sector in the early 1990s were discussed by Li and Dorian (1995). China's energy and resource use during the first part of the 1990s were assessed by Smil (1998). China's reform of the coal industry during the 1980s and the early 1990s were reviewed by Thomson (1996) and CIAB (1999). Decentralisation of China's electricity sector in the 1980s was considered in Wirtshafter and Shih (1990). The reform of China's electric power industry and the foreign direct investment were discussed by Andrews-Speed and Dow (2000) and Blackman and Wu (1999), respectively.

3.2 The new regulatory system

The most important reform of the energy sector was implemented in 1998. These changes included a strategic reorganisation of petroleum enterprises establishing a new vertically integrated management system for the oil industry. In 2002, China's power industry involved the separation of government functions from those of enterprises and the separation of power plants from lines operation. Figure 5 illustrates the most recent government structure and regulatory system identifying the post-1998 situation (Wu, 2003). The new structure is based upon three main goals: i) removing government from the function of enterprise management; ii) extending market-orientated energy system reform; iii) improving the efficiency of the energy industry (IOSC, 2007). However, the key questions, as stressed by Andrews-Speed, Dow and Gao (2000) are the future function of the SETC, two new energy bureaus (SAPC - State Administration of Petroleum Corporation, and SACI – State Administration of Coal Industry) and the new Department for the power industry (SPCC – State Petroleum Corporation of China). According to Wu, (2003), their future functions seem unclear.

3.3 Regulation of the coal industry

The coal industry has been free of single corporation domination since the 1990s because of two natural features that constrain the development of China's coal industry. Firstly, most of China's coal reserves are in the north and far from coastal consumption regions. Secondly, there is little rainfall in the main coal producing area. These two features make it a high priority for government to improve the transportation network and to enhance transport capacity. More importantly, coal is in surplus supply. In fact, the coal industry has often suffered from oversupply. As a result, the government has often acquiescenced to coal production from various mines during periods of shortage and issued quotas during periods of excess supply (Wang, 2007).

The reform to the coal industry took a crucial step towards decentralisation and disaggregation when the MCI was dismantled and replaced by the SACI, a newly created section within the SETC. Since 1999 the ownership and operation of central government owned mines (CGOM) has been transferred to the provinces. Today, there are three main types of coal producers in China: i) approximately 100 provincial government owned mines (PGOM) which were transferred from the CGOM, all of which are large scale with an annual output of 10 mmt; ii) previously local government-owned mines (LGOM), including provincial government owned mines; and iii) town- and village-owned mines (TVOM) and private owned mines. According to Huang (2006), there were 21,000 small mines in the LGOM, TVOM and private enterprises in 2005.

It is clear that under the new government structure and regulatory system there are no mines owned at the state level and all mines are owned and operated at and below the provincial level. Consequently, the SACI is left as a purely regulatory body within government (Figure 5), responsible for both policy and regulation together with its provincial equivalents. Correspondingly, the SDPC is likely to retain some control over major investment decisions and the Ministry of Land and Resource (MLR) is likely to take overall responsibility for coal licensing.

3.4 Regulation of the petroleum industry

As discussed above, prior to 1998 China's petroleum industry was controlled by two state companies: CNPC and Sinopec, both of which combined government and enterprise management. However, after the 1998 strategic reorganisation, the government functions of the petroleum sector were removed from the state companies and placed with SETC (Figure 5). The assets of both CNPC and Sinopec were redistributed to create two regional, vertically integrated companies that spanned the full range of activities in the petroleum industry. The CNPC and Sinopec have now become 'pure' companies. The CNPC's territory covers the north and west of the country, while Sinopec's territory now lies in the south and east. Their previous government functions have now been assigned to SAPC, a newly created agency within SETC.

It appears from Figure 5 that all companies in the petroleum industry are regulated directly by the SAPC within the SETC. Petroleum prices and transportation are regulated by two subdivisions, the Price Administration Division and Transportation Energy Division, within the SDPC. The MLR is responsible for issuing licenses.

3.5 Regulation of the power industry

Prior to 1985, China's electricity industry was controlled by central government (Wang, 2007). The generation, transmission, distribution and retailing of electricity were all within the administration of the Ministry of Water and Power Industry. However, the power industry has experienced a series of changes since 1985 (Xu and Chen, 2006). In 1988 the Ministry of Coal Industry, the Ministry of Oil Industry, the Ministry of Nuclear Industry and the Ministry of Water and Power were merged into a newly created Ministry of Energy (MOE), which was disbanded in 1993. This highly centralised power administration system didn't change fundamentally until 1997. However, during the interim, guidelines to separate the responsibilities of government and business were produced and provincial Bureaus of Electric Power were given some operational automony with local governmental jurisdiction over the development of the local power industry. The aim of these changes was to encourage investment in the power sector and promote the generation of electricity.

To free the sector of government intervention and create Vertically Integrated State Owned Utilities (VISOU), the State Power Corporation (SPC) was created in March 1997. One year later, the Ministry of Electric Power was dismantled and its administrative functions assigned to a new department of the SETC.

The 1997-2002 reforms were mainly focused on the separation of government and enterprise as well as the separation of ownership and operation. However, the newly created SPC became another monopolist controlling 50% of the country's generation assets and most of the technology and development assets. As a result, it became a major obstacle to developing a market-oriented power industry (Ma and He, 2008).

An important component of the market-oriented power reform process was to dismantle the SPC. In December 2002 its assets were divided into 11 new corporations, including two grid operators (the State Power Grid (SPG) and the China Southern Power Grid (CSPG))[2], five independent power plants (The Big Five: Huaneng Group, Datang Group, Huadian Corporation, Guodian Corporation and Power Investment Corporation),

[2] State Power Grid includes five regional grids: Northwestern Grid, North Grid, Northeastern Grid, Central Grid, and East Grid (also refers to Figure 7).

and four auxiliary corporations: Power Generation Consulting Group Corporation; Hydropower Engineering Consulting Group Corporation, Hydraulic and Hydroelectric Construction Consulting Group Corporation and Gezhouba Group Corporation). The generation and transmission assets were not distributed among the 11 new corporations, but were directly managed and controlled by State Power Grid until 2006. Since then, those assets have been purchased by the State Electricity Regulatory Commission (SERC). Therefore, the regulatory framework has become one where the SDRC is responsible for planning, price, investment and regulation; the SERC is an independent regulator, and at the bottom (see Figure 5) are the various enterprises. For more on the detailed reforms of China's power industry refer Wu (2003), Xu and Chen (2006), Wang (2007) and Ma and He (2008).

China Taiyuan Coal Exchange (CTCE) in Taiyuan was approved by State Council to be set up on 18 June 2007 to replace the coal ordering meeting between coal producers and power producers (CTCE, 2007). The toughest reform in China's energy industry has been settled since then. State Energy Administration (SEA), a division of State Development and Reform Commission, was established in July 2008. All these reforms likely indicate that a full competitive energy market system has started to operate in China.

4 Capacity building in the energy sector

Strong economic growth and rising income per capita have produced an increasing demand for energy. Therefore, the development of the energy industry has become an important item on the agenda of the Chinese government. Enhancing energy production is one component of meeting the demand for energy in China. Since the 1990s, China has invested significantly in increasing the capacity of the energy sector and, as a result, total new energy capacity has increased.

Table 1 shows the change in capacity building for coal, crude oil and electricity. In the 1990s, the newly increased capacity in coal extraction was, on average, only 23 mmt, which only accounted for 1.8% of the current year's raw coal production. With rapidly increasing investment, however the newly increased capacity of coal extraction reached on average 100 mmt, accounting for nearly 5.5% of current year raw coal production in the 2000s. The same pattern can be observed for crude oil extraction. For example, the newly increased capacity of crude oil extraction averaged 9.3 mmt, accounting for 5.5% of current year crude oil production in the 1990s. Both doubled in the 2000s, reaching 18.9 mmt and 10.8% respectively.

In the 1990s, newly installed capacity in coal powered plants was, on average, 11.5 million KW, being 6.4% of current year total installed capacity of coal powered plants nationwide. By the 2000s, newly installed capacity at coal powered plants reached 35.4

million KW, accounting for nearly 10% of current year total installed capacity of coal powered plants. Between 1993 and 1999, newly installed capacity at hydropowered stations was 4.9 million KW per year, while the newly installed capacity nearly doubled each year in the 2000s. Since 1992, the new capacity has been maintained at approximately 10% of current year total installed capacity for hydropower generation.

After observing the patterns of growth in capacity building in the energy industry, it can be noted that the growth of production capacity in raw coal extraction was slower than in crude oil extraction and electricity generation by coal powered plants and hydropower stations in China. Clearly the percentage of new capacity in current year total production capacity is only approximately 5% of raw coal extraction while it is closer to 10% in the other three energy sectors.

China's capacity building in the energy sector is, in general, able to meet its aggregate energy demand. However, there are significant differences across energy sources. For example, from 2000 to 2006, China's capacity for coal extraction averaged 1725 mmt, but its coal consumption only increased 179 mmt each year in the same period. Therefore, China actually ran a surplus of coal capacity building. Likewise, oil capacity building was 172 mmt each year from 2000 to 2006, but its actual increase in oil consumption was only 22 mmt in the same period.

5 Energy transportation

Uneven distribution of energy production and consumption across provinces has produced pressure on the domestic transportation sector. This is particularly true for coal, which accounts for 75% of total production where coal is consumed throughout China.

Interprovincial total shipment of coal is 2394 mmt, which amounts to 1820 billion metric tonnes km, and accounts for 75% of total rail cargo in 2006. Of total interprovincial coal shipments in 2006, outflows of coal accounted for 40% (993 mmt), and inflows 60%, (1400 mmt). Because of the uneven production and special types of coal, the total interprovincial coal shipment volumes vary significantly across provinces. Table 2 presents data on the outflows and inflows of coal and the percentage of total coal shipped in total coal consumption. Table 2 shows that Shanxi, Inner Mongolia, Henan and Shaanxi are major provinces that export coal, 432, 145, 83 and 80 mmt respectively in 2006 (column 1). Major provinces importing coal are Shandong, Hebei, Jiangsu and Zhejiang, where the total inflows were 188, 173, 158 and 112 mmt respectively (column 2). Owing to the uneven distribution of production and types of coal, total coal shipments in Shanxi Province amounted to 470 mmt being more than 150% of its total consumption within the Province in 2006 (columns 3 and 4). Total coal shipments were 200 mmt or 75% of total coal consumption within the Hebei Province. There are several other provinces where total coal shipments range from 110-160 mmt (Inner Mongolia, Jiangsu, Zhejiang and Henan).

A major feature of interprovincial coal shipments in China is that coal is shipped from West to East and from North to South. These flows are shown in Figure 6. In particular, West-East includes:

1) Datong (in Shanxi Province) to Qinhuangdao (in Hebei Province);

2) Shenmu (in Shanxi Province) to Huanghua port (in Hebei Province);

3) Taiyuan (in Shanxi Province) to Dezhou (in Shandong Province);

4) Changzhi (in Shanxin Province) by Jinan to Qingdao; and

5) Houma (in Shanxi Province) by Yueshan (in Henan Province), Xinxiang and Yanzhou (in Shandong Province) to Rizhao.

North to South includes:

1) Harbin (in Heilongjiang Province) by Shenyang (in Liaoning Province), Dalian and Shanghai to Guangzhou (in Guangdong Province), including both railway and boats;

2) Tanjing by Jinan, Xuzhou (in Jiangsu Province) and Nanjing to Shanghai, including both railway and boats;

3) Datong (in Shanxi Province) by Taiyuan, Jiaozhuo (in Henan Province), Zhicheng (Hubei) and Liuzhou (in Guangxi Province) to Zhanjiang (in Guangdong Province); and

4) Baotou (in Shanxi Province) by Xian (Shaanxi) and Ankang (in Sichuan Province) to Chengdu.

The largest coal producer in China is in Shanxi Province, from where most coal is shipped to Hebei, Shandong, Tianjin, Jiangsu, Beijing and Liaoning Provinces, which account for 90% of Shanxi's total outward shipments in 2006. The second largest is Inner Mongolia where a total of 120 mmt (accounting for 83% of total outflow shipments) was shipped to Liaoning, Tianjin, Heilongjiang, Jilin and Hebei Provinces in 2006. See Table 3 for data on other provinces.

Petroleum products are also shipped throughout China. Major provinces that export petroleum to other provinces are Tianjin, Shanghai, Liaoning, Heilongjiang, Shandong and Xinjiang. In 2006, total outflow shipments of petroleum and petroleum products was 249 mmt, of which 42 mmt was shipped from Tianjin, 36 mmt from Shanghai, 30 mmt from each of Liaoning and Heilongjiang, 24 mmt from Shandong and 17 mmt from Xinjiang, all of which account for 71% of national total outflow shipment of petroleum and petroleum products. There are six provinces that import petroleum and petroleum products of over 15 mmt from other Provinces. Of 291 mmt of inflow shipments of petroleum and petroleum products, 39 mmt was shipped to Shanghai, 35 mmt to Liaoning, 26 mmt to Tianjin, 23 mmt to Guangdong, 19 mmt to Beijing and 15 mmt to Shandong, all of which account for 54% of the national total inflow shipments of petroleum and petroleum products in the same year.

China is apparently not rich in natural gas reserves. In fact, there are only a few provinces that export natural gas. The total outflow shipments of natural gas was 18244 million cubic metres in 2006, while total transportation amounted to 8866 billion cubic meters in conjunction with an average shipment distance of 486km. The major exports come from a few provinces the largest being Xinjiang (10254 million cubic metres), followed by Sichuan and Shaanxi (5300 million cubic metres each), and finally Inner Mongolia, Chongqing and Guangdong (3870, 3100 and 2460 million cubic metres, respectively). These provinces account for 95% of the national outflow shipments of natural gas in 2006. Although gas is shipped throughout China, the variations across provinces are highly uneven. In 2006 for example, inflow shipments of natural gas were 4057 million cubic metres to Beijing, around 3000 million cubic metres to Jiangsu, approximately 2000 million cubic metres to Shanghai, and around 1000 million cubic metres to Zhejiang, Henan and Gansu. These account for approximately 70% of the national inflow shipments of natural gas in 2006.

In contrast, electricity generation is widespread with more than 80% of demand met within provinces, the exception being Beijing where only 35% of demand for electricity was met internally. As a result, only 11% of the demand for electricity is transmitted inter-provincially. The largest surplus of electricity was Inner Mongolia (coal-based) and Hubei (hydro-based), each of which exported transmission of approximately 55 billion KWh. Other exporting Provinces in 2006 included Shanxi, 43 billion KWh (coa-based); Guizhou 36 billion KWh (coal based), and Jiangsu 25 billion KWh. Most of the surplus electricity was transmitted to Guangdong (61 billion KWh), Beijing (41 billion KWh), Hebei, Shanghai and Jiangsu (around 30 billion KWh for each), which accounted for over 70% of national inflow transmission of electricity in 2006.

China has seven electricity networks: Northwest, Xizang, North China, Central China, Southern China, Northeast and East China. It has three major electricity transmission routes: Northern Route, Central Route and Southern Route. China's electricity is typically transmitted from West to East and from North to South. Figure 7 shows China's electricity networks and transmission routes.

6 Energy pricing reforms

Energy price reform is an integral part of the overall economic reform package in China. Fesharaki et al. (1994) believe that energy prices were 'irrational' and caused enormous macroeconomic and microeconomic distortions in the energy sector and throughout the economy in China. However, the most important and interesting aspect is whether energy prices are still irrational and still cause macroeconomic and microeconomic distortions: In this section we firstly review the major policies of energy price adjustment and their corresponding effects. We will then consider the trends in energy prices for the major energy components focusing on the heterogeneity of price levels across provinces. Finally, we use our new results to show how the energy market currently functions in China by considering the degree of energy market integration.

6.1 Characteristic of China's energy price reform

Since the early 1980s, China has introduced numerous measures to rationalise oil, coal, gas and electricity prices. However, many of the measures were incremental and the scale small until 1993. This is because China's energy price reform startegy was gradual. In the initial years there might have been little effort to move the economy to one in which resources and factors were allocated according to market price signals (Huang and Rozelle, 2006). As a result, there were no losers in the initial years (Lau, Qian and Roland, 2000).

Until the reforms of the late 1970s, energy prices were fully state controlled in China. During the early 1980s, China adopted a 'dual track' system of energy pricing policy, with 'in-plan' prices and 'out-plan' prices. This energy pricing system remained in place until 1993. 'In-plan' energy prices were normally lower than market prices, while 'out-plan' energy prices were typically market prices. However, in-plan energy prices were not always fixed. Most in-plan prices dramatically increased as energy price reform progressed after 1994 (Wu and Li, 1995). In-plan energy prices were gradually replaced with market-mediated prices (Hang and Tu, 2007). This prepared the sector for government motivated market-oriented energy price reform.

6.2 Evolution of energy pricing policies

6.2.1 Coal price reform

The market-oriented energy price reform varied in time and in intensity across energy types. The 'dual track' pricing system for coal was introduced in 1985. Under this policy, CGOMs were given an output quota at low price for unified allocation to those important state-owned downstream industries such as electricity, steel, metallurgy, engineering, chemical and transportation. The LGOMs and TVOMs were also given quotas. Coal within quotas was referred to as 'in-plan' and coal above quotas was referred to as 'out-plan'. The output above the quota could be priced 50% higher and the output above more could be priced 100% higher than within quotas (Cheng, 1998).

As more and more coal was sold on the free market, the deliberate low price of 'in-plan' coal was difficult to sustain. It was confronted with great pressure to recover to market level, which caused little complaint from most downstream industries because their markets and prices were gradually freed up. Therefore, price regulation on coal was completely abolished after 1994.

As electricity tariffs were still tightly controlled, some power plants could not afford coal at market price and some coal enterprises refused to sell coal to power plants. As a result, in 1996 a new policy established that the government once again would guide coal prices, which were to be announced at the end of every year. However, this policy could not be implemented perfectly because coal producers did not fully perform their contracts (Wang, 2007). In addition, contracts sometimes aborted owing to unavailable transportation. Consequently, the electricity industry could not always meet its coal demand under guided prices. Under these circumstances, there were frequent disputes and blackouts between coal producers and power plants.

The bargaining between the two parties became even more severe after 2002 when the government-guided price of coal was announced to be cancelled but electricity tariffs still remained regulated. This means that coal producers were allowed to determine coal price at their will. As a result, only 90 mmt, which was 37% of total amount of demand for coal, were contracted in 2002. This posed a dilemma for the central governement. Faced with serious power shortage, in April 2003 NDRC gave an order in which the price was just midpoint between requirements of two parties. Then in 2004 the government introduced a new coal pricing policy, which was called 'co-movement' of prices of both coal and electricity. The co-movement is not a free market adjustment but regulated and determined periodically by the SDRC to avoid extreme price fluctuation. Adjustment will only be made if fluctuation of coal price exceeds 5%, otherwise, the change will be accumulated into the next adjustment period (Ma and He, 2008).

China Taiyuan Coal Exchange (CTCE) was established on 18 June 2007 (CTCE, 2007), replacing the coal ordering meeting between coal producers and power producers. Since then, coal suppliers and consumers have more freedom, implying that the toughest reform in China's energy industry had been settled and a full competitive energy market was expected to operate in China.

6.2.2 Petroleum price reform

Petroleum price regulation has experienced four stages. Pre-1981, petroleum prices were fully state-controlled. From 1981 to 1994, a 'dual track' pricing system was adopted, while from 1994 to 1998 petroleum prices were market meditated. After 1998, domestic petroleum prices have been set in accordance with the international energy market price (Hang and Tu, 2007). Meanwhile, the central government sets the regional prices of refined oil products according to the Singaporean oil market. As a result, the 1998 reform has domestic oil prices very close to international prices (Wu, 2003).

6.2.3 Electricity price reform

Electricity pricing reform is complicated in China. As in other countries, electricity prices are not completely deregulated in China; however, the government has made significant progress to raise electricity prices to 'realistic' market levels since the beginning of these economic reforms.

In 1985, electricity tariffs were raised throughout the country. For the first time, locals were allowed to raise tariffs to cover the rising costs of coal and transportation (Hang and Tu, 2007). The State Council also encouraged investment in the power industry and created multi-tiers of electricity tariffs. In 1987, the government issued a new policy of *Fuel and Transportation Add-up*. It was used as an adjustable surcharge on catalogue prices based on fluctuations in coal and transportation costs. This pricing adjustment procedure was administered and assessed annually by the SDRC.

In 1991, a 'high-in' and 'high-out' policy was introduced, allowing electricity tariffs to fluctuate according to coal and other factor costs. In 1993 a 'new plant-new price' policy was implemented, which allowed all power plants built after 1992 to sell power to provincial power companies at debt repayment prices in order to provide sufficient revenue for the repayment of loan capital with interest. In the 1990s, a range of surcharges, such as the '*Power Construction Fund*' and the '*Three Gorge Construction Fund*', were imposed (Ma and He, 2008). With these new policies, electricity tariffs have risen rapidly (Lam, 2004). However, these new policies also resulted in a complicated price structure, leading to high regulatory, supervisory and transaction costs.

To simplify and control the price a new price scheme using 'operation-period price' and 'yardstick price', was adopted in 1997. The price under this scheme is based on an average social generation cost and a unified internal rate of return on capital over the remaining operation period. For existing electricity plants, this is indeed an 'operation-period price', while for new plants the new scheme actually specifies a unified yardstick price.

Some new policies were introduced after 2002. 'Operation-period price' and 'yardstick price' are still used in regions where the competitive regional wholesale market was not established after 2002. For regions where the competitive wholesale transaction has been introduced, the price consists of two components: the capacity price, which is determined by the government according to the average cost of all generation units in the market; and volume price, which is determined competitively in the market.

On the retail side, the catalogue was simplified to include:

i) a unit price scheme used for residential and agricultural sectors;

ii) a two-component price scheme, similar to the counterpart on generation side, used by the industrial and commercial sectors;

iii) '*tidu jiage*' prices[3] were also introduced after 2004;

vi) higher prices charged for energy-intensive industries (Ma and He, 2008). To reflect rising coal cost, the 'co-movement' price of coal and electricity is used for various electricity prices.

6.3 The changes to energy prices

China's energy prices have experienced several energy policy adjustments during the last three decades and the prices of major primary energy sources are apparently converging over time. China's energy prices appear to be rising and are increasing dependent upon those in other international markets (Hang and Tu, 2007; Wu, 2003). However, at the regional and provincial level, energy price heterogeneity appears to remain endemic for some forms of energy.

6.3.1 Historical observation

To illustrate these issues, consider Table 4, which displays the spot prices and their changes over time for four major energy fuels in China. Several features can be observed. Firstly, energy prices were very stable during the late 1990s. They rose rapidly, however, in the new millennium. For example, gasoline and diesel prices were below 2500 RMB per ton in the late 1990s, but they immediately rose to over 3600 and 3300 RMB per ton respectively in 2000. They quickly climbed to over 5400 and 4500 RMB per ton by 2005. Similar scenarios can be found for coal and electricity. Secondly, prices for coal and oil are very consistent with a similar pattern of price change over time. Thirdly, electricity prices seem to be an exception. Electricity price levels rose by nearly 55% and changed at a lower growth rate (only 4.4%) during the period. This may suggest that electricity prices were not consistent with those of the other three energy sources or that electricity prices may not be cointegrated with those of the other three energy sources, as a consequence of government control. This is an issue we will return to later.

How fast did energy prices change over time? Are energy price changes consistent with other factors of production or the consumer price index?

[3] This price is a kind of variable price decided based on current quantity consumed and used to encourage or restrain electricity consumption.

It is useful to compare Chinese energy price trends with those of the international market and to consider the degree of market integration, which is an important commitment within the WTO. As coal is the most important fuel in China, we take it as an example for comparative purposes. If we compare the cif price of Japanese steam coal imports (BP, 2008) and China's coal spot price (SDRC, 2006) for the period of 1995-2005, we find that after 1998 the coal prices in Japan and China were very consistent despite apparent differences before 1999 (see figure 8). This illustrates how China's coal price has converged to that of the international energy market this century. A similar pattern of coal price change can be observed between China-Northwest Europe and between China-Central US according to BP (2008).

6.3.2 Across provinces

It is perhaps not surprising that energy price levels and price change patterns show considerable variation across provinces given the significant variations in economic growth. Table 5 shows the spot prices in 2005 and the changes from 1995 for four major energy sources over 31 provincial (municipal or autonomous regional) capital cities in mainland China. It can be seen from Table 5 that the spot price of coal varies considerably and the price change patterns are also quite different across cities. For example, the spot price of coal is over 630 RMB per ton in the East (Shanghai and Nanjing), while it is below 200 RMB per ton in the West (Lanzhou and Urumqi). The spot price of coal rose over 3 times in Chongqing, over twice in Taiyuan, and over 1.5 times in many places from 1995 to 2005. However, the spot price of coal only increased by 25% in Haikou and Xian, and less than 50% in Nanning, Lhasa and Xining during the same period. The spot price of coal actually declined in Lanzhou and Urumqi, perhaps due to the characteristics of coal itself.

However, the opposite pattern can be found for gasoline and diesel. The spot prices across cities are at the same levels for both gasoline and diesel at around 5300 and 4300 RMB per ton, respectively. The price changes are also similar across cities. The price almost doubled in all cities during the study period. There are only a few exceptions; for example, the spot price of gasoline increased by less than 80% in Harbin, Wuhan and Changchun, but more than 140% in Lhasa. Likewise, the spot price of diesel increased by less than 75% in Chongqing, but more than 130% in Lhasa and Urumqi.

6.4 Energy price integration

Following the major reforms in energy price policy over the last two decades, can we discern evidence of energy prices convergence across regions and cointegration across energy types? The literature, to date, has been unable to address such questions.

To fill this gap, we report some new results on energy price movements using a new high frequency dataset that comprises the market prices of four energy types from 31 provincial capital cities collected at 10-day intervals over a maximum of 132 months from 1995 to 2005. We provide results for two key energy input prices, coal and electricity, whose price convergence has not yet been reported for China. Our conclusions show that the coal market is convergent as a whole in China, but that the electricity market may not be integrated as a whole based on the existing electricity network and other relevant energy market factors (Ma, Oxley and Gibson, 2007).

As discussed previously, the course of market-oriented energy price reform has differed both in time and in emphasis across the various energy types. It is possible, therefore, that energy prices may not be cointegrated as a whole. Figure 9 describes how monthly prices change over the period 01/1995 - 12/2005 for four major fuels in China. Energy prices change little for gasoline, diesel and electricity in 1995 and 1996 because their prices were highly regulated. The price of coal did rise, however, due to its early price deregulation. During 1997 and 1998, China's energy economy could be considered as being in a 'transition period' during which energy prices fluctuated considerably, especially for electricity and gasoline. Since 1999 China's energy economy might be treated as a 'new regime' period, which can also be divided into the 'early period', 1999 to 2001, and the 'development period', post 2002. It seems unclear whether China's energy economy is now experiencing a 'mature period' or is still developing. There might, therefore, be a period before China's energy economy is fully integrated and reflecting internally driven price changes.

7 China's energy efficiency

Energy intensity is an important indicator of energy efficiency that is directly related to economic growth and energy consumption. To ascertain the change in China's energy intensity over time, Figure 10 shows national aggregate GDP (in 1978 price), aggregate energy consumption, and energy intensity measured as the ratio of energy consumption to GDP, since 1978. It appears that energy intensity has generally declined since 1978; however, the trend has varied over time. This may suggest that the rates of energy intensity change frequently. It is also clear that since 2000 a different pattern has emerged.

We observe some similarities and differences when we consider energy intensity by sector since 1980 (see Table 6), one can observe some similarities and some differences. Firstly, the patterns of aggregate energy intensity shown (Figure 10) and of industrial energy intensity (Table 6) are consistent as both industrial energy consumption and output (GDP) comprise most of the aggregate economy. Similar stable yet fluctuating energy intensity can be found after 2000 for industrial energy intensity (Table 6). Similar patterns can be observed for other sectors. However, more apparent and stronger rising trends appear for the other four sectors. For example, intensity rose from 0.64 in 2001 to 0.76 in 2006 for the transportation sector and from 0.12 in 2001 to 0.19 in 2006 for the construction sector. Whether these rising trends will maintain in the long run is unclear. In part they may depend on changes to energy policy.

What might have induced the changes in China's energy intensity? Ma, Oxley and Gibson (2008) survey the literature on China's energy economy and conclude that declining industrial energy intensity plays an important role in the decline in national aggregate energy intensity before 2000 and that rising industrial energy intensity plays an important role in increasing national aggregate energy intensity after 2000. This finding, however, does not identify the factors driving the change in energy intensity. To fill this gap, Ma et al. (2008) estimate a translog cost function using a panel of provincial data for China, concluding that 'technological change' has driven the increase in energy intensity, and factor prices play little role in this process. Specifically, it is energy-using technologies that have been employed in this new millennium in China. If this finding is correct, the implications for current policies on technological and capital investment need to be seriously analysed by China's decision-makers.

The changes in energy intensity are also not homogenous across regions, territories or provinces. Table 7 shows provincial aggregate energy intensity and its changes over the period from 2001 to 2006 (based on 1978 prices) allowing comparisons to be made between Table 6, Table 7 and Figure 10.

As can be seen from Table 7, substantial variation in energy intensity, in both the levels and changes, can be seen across provinces. For example, energy intensity is low in Beijing, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan. These provinces are located in the East and South of China and are part of developed areas. On the other hand, in 2006 energy intensity is relatively high in the less developed area: It measures over 1.4 in Guizhou, Ningxia and Qinghai, and about 1.0 in Gansu and Xinjiang. These provinces are in the the less developed western region. Energy intensity is also greater than 1.0 in Shanxi and Inner Mongolia, which are in the less developed northern region. In contrast, energy intensity is less than 0.5 in the developed regions in the East and South (e.g., Beijing, Tianjin, Shanghai, Jiangsu, Guangdong and Hainan).

The trends in energy intensity also vary across provinces. Energy intensity declined by approximately 50% from 2001 to 2006 in Beijing and by 30% in Tianjin and Shanxi. However, it rose by 30% in Fujian and 20% in Shandong, Hubei and Hunan. It appears that energy intensity and economic growth are closely correlated. Therefore, national energy policies may not be suitable for provincial realities. As a result, provincial energy intensity may need to be studied and regional energy policy developed.

To improve energy efficiency, many projects have been introduced over the past 25 years. Price et al. (2001) review China's energy efficiency policies from 1949 to 2000. They explain China's energy efficiency programs, examine the development of a comprehensive energy policy and assess existing energy conservation, regulation and policies. However, China's energy efficiency is still fairly low relative to other developed countries and regions. For example, China's large and medium enterprises consumed 181 kg standard coal equivalent to produce one ton of cement in 2003, while Japan consumed only 128 kg standard coal equivalent in the same year; China consumed 890 kg standard coal equivalent to produce one ton ethylene in 2003, while Japan consumed 629 kg standard coal equivalent to produce one ton ethylene in the same year; and the loss ratio of electricity transmission and distribution in Mainland China was 6.8%, but only 4.8% in Taiwan in 2005 (CESY, 2007). As a result, energy intensity remained high at about 0.9 ton oil equivalent per thousand US$ GDP (measured in 2000 US$ price) in mainland China, whereas the world average was only 0.31 ton oil equivalent per thousand US$ GDP (measured in 2000 US$ price) post 2002. Mainland China's energy intensity is approximate 3 times higher than the world average.

8 Energy supply, demand and trade

8.1 Primary energy supply and demand

8.1.1 Fossil fuel-based energy

China's energy production and consumption has increased since 1985, owing mainly to its high economic growth rate. Table 8 shows China's energy production and consumption as well as its composition. There appear to be three distinct periods of energy production during the last two decades. During the decade 1985-1995, the growth rate of energy production is approximately 4% per annum. This is followed during the period 1995-2000 by a period of stagnation. From 2000 production soars at an annual rate of growth of approximately 9.0%. The composition of primary energy production, however, changed little. Coal continues to dominate primary energy production with a share of over 76.7% in 2006. The share of oil production has obviously declined over time and this has accelerated post- 2000. Natural gas and other primary energy production have increased, but with fluctuations. The share of natural gas in primary energy supply, for example, remained approximately constant from 1985-1995. The growth rates of natural gas share in total primary energy supply varied considerably, rising to 8.1% from 1995 to 2000, declined to 2.7% in the next five years and then rose to 9.4% post 2005 (Table 8). Other primary energy production shares increased at an average of approximately 3% annually.

As for energy consumption, a similar scenario can be found for aggregate primary energy consumption and composition. The only difference is that with a higher growth rate for aggregate primary energy consumption the role of coal has seen a decline, from over 75% in the 1980s and the 1990s approximately to 70% by 2006.

8.1.2 Hydropower and nuclear energy

Table 8 shows that China's renewable energy supply is very limited. In spite of a high growth rate, the share of renewable energy supply has remained low. In 2006 it was only 8% of the total primary energy supply. Of the renewable energies, hydropower and nuclear energy are two of the most important for China. China's hydropower production has grown rapidly during the last decade, from 1906 billion KWh in 1995 to 4829 billion KWh in 2007. This represents an annual growth rate of approximately 8%. Nuclear energy has grown even faster, from 12.8 billion KWh in 1995 to 62.9 billion KWh in 2007, representing an annual growth rate close to 15%. However, as shown previously, the shares of both hydropower and nuclear energy are very small in total electricity generation. The former is 14.7%, while the latter is less than 2% in 2007 (BP, 2008).

8.1.3 Rural biomass consumption

Biomass energy has been playing the most important role in residential energy demand for rural China and has made a great contribution to alleviating the pressure of domestic fossil energy supply. Rural biomass energy consumption (only including firewood, crop stalks and biogas) in mainland China was 206 million tonnes coal equivalent in 2000 and it rose to 280 million tonnes coal equivalent in 2006. Biomass energy accounts for an overwhelming share in total rural energy consumption. Its share in rural aggregate energy consumption was 76% in 2000 and still maintained 74% in 2006. Biomass energy crop stalk accounts for over 60% (CESY, 2007).

8.1.4 Fossil fuel based energy consumption by industry

Industry remains the nation's largest consumer of primary energy. However, as other sectors have expanded their share of primary energy consumption, it has declined from close to 80% in the 1980s to approximately 70% by 2006 (Table 9). Likewise, agriculture's share of primary energy consumption has also declined from approximately 8% in the mid-1980s to around 3.5% in 2006.

It is worth noting the sharp growth of shares in fossil fuel based energy consumption in the transportation and commercial sectors during the last two decades. Transportation was a very small consumer in 1985, consuming only 1.5%. The commercial sector consumed close to 1%. However, since 1985, their shares have grown considerably. For example, the share of primary energy consumption in the transportation sector increased to 4.5% in the 1990s and then climbed to 7.5% by 2006. At the same time, the share of primary energy consumption in the commercial sector more than doubled from barely 1% in

1985 to 2.2% by 2006. These two sectors currently account for approximately 10% of total national primary energy consumption.

Since 1990, the residential sector has become the second largest consumer of primary energy in China. Its share of primary energy consumption was only 5.4% two decades ago in 1985. Five years later, it jumped to 16.0%. Since 1995, when industrial output began to recover, the residential share of consumption has remained stable at approximately 10%.

By observing growth rates one may be better able to understand how the structure of fossil fuel based energy consumption has changed over time and over sectors (Table 7, bottom section). Some observations can be made. Firstly, except for a short period of recovery (1995-2000), a sharply declining share of agricultural sector energy consumption has been evident from 1985 to 2006. Secondly, a rapidly declining rate only occurred in the 1980s and since then the growth hasn't changed much until 2006 for industry. Thirdly, the construction sector has experienced three different phases of growth with effects on its share of energy consumption. The first was a sharply declining rate of energy consumption share for the period 1985-1990 to 1990-1995. This was followed by an extreme move in the opposite direction 1995-2000. Since then the situation is one of stability. Fourthly, the transportation sector has also experienced three phases of share growth. shares grew the fastest during the period 1985-1990 (over 25%) followed by high growth 1995-2000, and then a with the third phase showing no share growth in all other periods; Fifthly, a similar share growth rate pattern can be found for the commercial sector where there was first rapid growth, then some decline and finally stability post-2000. Finally, the growth of the residential share of energy consumption is clearly related to the extraordinary economic growth (24.3%) that occurred during the period 1985-1990. This is clearly unsustainable in the longer term.

8.1.5 Fossil fuel energy supply and demand across regions

China's primary energy production and consumption varies across provinces and this causes significant domestic trade within China. Table 10 presents data for 2006 on the production and consumption of coal and oil, and the surplus by province. Firstly, note the largest coal producing province is Shanxi (North) producing approximately 580 mmt, followed by Inner Mongolia (North) with approximately 300 mmt, and the third largest are Henan (Central) and Shaanxi (West) with approximately 200 mmt. There are several other provinces including Heilongjiang (Northeast), Shandong (East) and Guizhou (Southwest), whose coal production is approximately 100 mmt. Secondly, crude oil production is very small with many provinces registering no production. The largest oil field is currently located in Heilongjiang (Northeast), with production of 43 mmt, followed by Shandong (East) with

30 mmt. Twenty mmt oil fields are found in Tianjin (East), Shaanxi (West) and Xinjiang (Northwest) while 10 mmt oil fields are found in Liaoning (Northeast) and Guangdong (South). Thirdly, coal and oil are consumed throughout China. For example, Shanxi and Shandong consume nearly 300 mmt of coal and Hebei (North), Jiangsu (East) and Henan (Central) consume approximately 200 mmt of coal. There are many provinces that consume 100 mmt of coal. However, not all provinces consume crude oil. The largest consumer of crude oil is Liaoning (55 mmt), followed by Shandong (approximate 40 mmt), and the third is Guangdong (close to 30 mmt). There are several provinces that consume 20 mmt of crude oil. Fourthly, it is clear that most, but not all, provinces run a 'deficit' of coal. For example, Shanxi, Inner Mongolia and Shaanxi run a 130-300 mmt surplus while Heilongjiang, Guizhou, Guangxi, Gansu and Xinjiang have a surplus of around 30 mmt. The large coal inflow provinces are Jiangsu, Shandong, Hebei, Zhejiang and Guangdong, with a deficit of between 150 mmt to 100 mmt respectively. Only Tianjin, Heilongjiang, Shaanxi and Xinjiang run a petroleum surplus. Liaoning runs the largest petroleum deficit (43 mmt) followed by Zhejiang, Jiangsu, Shanghai and Ningxia, each of which have a deficit of around 20 mmt.

8.2 Electricity supply and demand

Although capacity building in the electricity production sector increased rapidly in China, it remains the case that it still cannot meet the rising demand for electricity. China's total installed capacity of electricity supply reached 700 million KW in 2007, of which coal power plants accounted for nearly 80% and hydropower stations accounted for nearly 20%. However, electricity supply is still far behind demand. For example, the excess demand for electricity comes from Beijing and Tianjin who had a 1.1 million KW shortage of electricity in 2007 (Gao, 2008). China is hastening cooperation with Russia to transmit 10 million KW of electricity to the Northeast Grid from the Far East Grid, and negotiating with Inner Mongolia to transmit 12 million KW to the North China Grid from the Sino-Inner Mongolia coal powered plants (Gao, 2008). Other forms of foreign-based electricity cooperation deals are also under negotiation.

8.3 Energy trade pattern

In general, China's energy imports are quite limited. Until 1996 China was a net exporter in terms of aggregate energy. Post-1996, China's aggregate energy imports increased but with no obvious trend (Table 11). Only in recent years has a discernable, stable increase in net energy imports emerged, rising from 53 million tonnes standard coal equivalent in 2000 to over 200 million tonnes standard coal equivalent in 2006. This means China's energy import dependence has increased from 3.8% in 2000 to 8.2% in 2006. This pattern of energy trade is determined by two major characteristics of China's energy supply and demand: abundance of coal deposits and rising demand for petroleum.

China remains a net exporter of coal, but the surplus is declining. To meet the domestic demand for special types of coal, China imports some coal and since 2000 this has been increasing in volume of coal import to reach nearly 40 million tonnes standard coal equivalent in 2006. On the other hand, the volume of coal exports is still small and hasn't shown an apparent rising trend. As a result, China's net exports of coal have been limited, accounting for a small percentage of total domestic coal consumption.

When we turn to petroleum, however, the picture is reversed. China's petroleum imports have increased rapidly since 1995 from 37 mmt in 1995 to (98 mmt) in 2000 and more than doubling in 2006 to 195 mmt. Petroleum exports have been stable at approximately 25 mmt since 1995. China's reliance on imports of petroleum was only 7.6% in 1995. This increased to 33.8% in 2000, rising to almost 50% since then.

There is little reason to believe that the pattern of energy trade discussed above and presented as Table 11 will continue into the foreseeable future given the current energy market situation. Recent volatility in the oil market may lead to some changes, but the rapid growth of the residential sector and demand for private vehicles is likely to exacerbate China's reliance on imported petroleum products. China also faces some other challenges. Firstly, coal is not a good substitute for oil despite China's abundance of coal deposits. Secondly, automobiles or transportation in general is one of the largest consumers of petroleum products in the world. Thirdly, rising domestic petroleum consumption appears unavoidable. Finally, this situation will become more severe if no new oil fields are discovered and current oil fields are unable to maintain current output.

9 Looking ahead: challenges and opportunities

The factors that affect China's energy demand and supply have been well documented (Zhao and Wu, 2007; Crompton and Wu, 2005). However, what are the factors that drive energy demand and supply? We attempt to identify them below.

9.1 Factors affecting energy demand

Income growth. As per capita income grows, consumers will need more energy and potentially cleaner energy. At present per capita energy consumption in China is relatively low. For example, electricity consumption per capita in mainland China was 249 KWh in 2006. This is to be contrasted with 8365 KWh (in 2005) for the OECD (All); 11056 KWh in North America; 8482 KWh in OECD (Pacific); 6415 KWh in OECD (European); and 2596 KWh (World average) (CESY, 2007). China's consumption of electricity per capita is therefore only 25% of the world average. As this consumption raises, the demands on China's production sector will become enormous.

Urbanisation. There remains a substantial rural-urban gap in energy consumption per capita in China. For example, electricity consumption per capita in urban areas was approximately 370 KWh in 2006, while it was only 190 KWh in rural areas. In addition, the urban population proportion rose rapidly from 30% in 1996 to 44% in 2006 (CSY, 2007).

Transportation (including public and private transportation developments). The rapid expansion of the transportation sector has inevitably led to an increase in the demand for energy, especially oil products (Zhao and Wu, 2007). The total annual growth rate of total civil vehicles was 12.2% between 1995 and 2006. The growth rate for private vehicles was even higher: the total number of private vehicles rose from 4.18 million in 1995 to 26.2 million in 2006 (CSY, 2007), which is an annual growth rate of 18.2%.

Energy pricing. The impact of energy prices on energy intensity has been extensively discussed in Hang and Tu (2007). Ma et al (2008) estimate the elasticity of demand for energy. Fan, Liao and Wei (2008) report measures of the own-price elasticity at -1.236 for the period 1993-2005. The impacts of raising energy prices on energy demand are evident.

Energy-intensive exports. China's energy-intensive exports have significantly increased domestic energy consumption. Kahrl and Roland-Holst (2008) estimate that net exports accounted for 15-22% of China's total energy consumption which, since 2002, has significantly contributed to the increase in China's measured energy intensity. This suggests that the energy intensity of exports is higher than that of non-exports. The energy intensity of exports rose 8% annually, almost the same rate as national economic growth. Moreover, rising energy-intensive exports exaggerate greenhouse gas emissions and in turn China has to be blamed for having already become the second largest emitter of greenhouse gas. In fact, though within five years China's CO_2 emissions have nearly doubled, Weber et al (2008) find that in 2005 around one-third of Chinese emissions (1700Mt CO_2) were due to production of exports. It is evident that consumption in the developed world is driving a significant proportion of China's greenhouse gas emissions.

9.2 Factors affecting energy supply

Investment. Total investment in the energy industry was 521 billion RMB in 1995 (in 2006 prices) and 1751.3 billion RMB in 2006. Over the last decade, the growth rate of investment in the energy sector was 11.6% per annum. However, this growth rate could not keep in pace with overall national investment growth. The share of investment of energy industry in overall national investment was 21.4% in 1995. However, this share decreased to 14.7% in 2006, a one percent per year fall since 1995.

Innovation. Here we will consider issues related to new energy sources and energy supply initiatives. The National Plan for Medium- and Long-Term Scientific and Technological Development (2006-2010) written in 2005 raised issues relating to innovation in the sector. Dorian and Clark (1987) assessed China's potential for primary energy distribution based on the similarity of geographical structure between China and U.S. They suggest, for example, that China's Gansu, Qinghai Anhui, Sichuan and Chongqing areas are likely to be oil rich (Appendix Figure 1). However, nothing has eventuated and the statistics don't show crude oil production in these provinces (Table 10).

Renewable energy. There are various types of renewable energies. Hydropower and nuclear energy are two of the most important. As discussed previously, exploitable hydropower is approximately 400 million KW. To date 116 million KW have been developed. Nuclear energy has developed very slowly in China. It accounted for only 2.1% of total electricity supply in 2005 while world average for the same period was 15.2% (CESY, 2007). The share of nuclear electricity in total electricity generation in many countries is often as large as 40%. For example, France has 80% nuclear energy, the Ukraine has 48%, Sweden 46%, Belgium 55%, Switzerland and Bulgaria 41% (CESY, 2007). In addition, biomass energy even plays a more important role in rural household energy demand. For the potential of rural biomass resources and consumption, in particular crop residue, see Liu et al (2008).

Energy efficiency. With the introduction of many energy efficiency programs, China's energy intensity has been declining during the last two decades. However, China's energy efficiency is low relative to other developed countries and regions. As a result, energy intensity is still high in the world (see previous section). It is clear that China's energy supply would have increased by 30% had China's energy intensity been only twice as high as the world average. The potential of improving energy efficiency is huge in China.

Reforms. Reforms in the energy sector came in many forms, which have involved both supply and demand. China's energy economy has been fundamentally reshaped following the introduction and implementation of a number of reforms (referred to in previous sections). However, a completely competitive energy market hasn't yet been achieved. For example, competitive wholesale markets and retail access are still in the experimental phase. Once fully implemented these may produce a significant effect on energy efficiency. In addition, China's electricity prices are still low relative to world averages which may reduce demand side efficiencies. Hang and Tu (2007) have modelled the effects of price changes on energy intensity and conclude, not surprisingly, that higher energy prices lead to a decrease in energy intensity. Increasing energy prices will improve energy efficiency and therefore increase energy supply relatively.

Traffic congestion. China's traffic is one of the most congested in the world. The traffic regulation may be also the worst in the world. Improving traffic administration may be another way to increase the energy efficiency of the transport sector. According to research, only 15% of the energy from the fuel is used to move the car. Driving in urban areas, 17.2% of fuel is lost due to idling stop lights or traffic congestion (Sophia, 2007). Therefore, the potential to improve driving fuel efficiency is significant.

10 Policy directions in energy economic development

It should be clear that even the most desirable combination of the factors discussed above will not prevent a significant increase in China's primary energy consumption and electricity generation (Smil, 1998). China's energy policy makers are really in a dilemma (Khan, 2005). Choices are inevitable. Chinese policymakers must decide how and what to prioritise. Many studies have provided China's government with valuable policy options designed to mitigate China's energy demand pressure and ease the coal-use environmental dilemma. For example, Sinton et al (2005) present a comprehensive valuation of China's energy strategy options. Combining the contributions made from previous studies, this study proposes the following policy directions for the Chinese government to consider in the near future:

- Maintaining and increasing investment in the energy industry.
- Enhancing technical innovation. Technical innovations come in many forms, which are involved in both energy supply and demand. This also includes introducing overseas advanced energy techniques.
- Coordinating environment and resource policy. China's energy industry is confronted with dual pressures from economic development and environmental protection (Chang et al, 2003). Biomass and coal are two of the largest pollutants in China. For example, coal combustion produces 70% of China's carbon dioxide, 90% of sulphur dioxide emissions and 67% of nitrogen oxide emissions (Sinton et al, 2005). Therefore, improving biomass and coal's combustion efficiency is one of the most direct ways to reduce environmental pollution.
- Coordinating energy exploitation and conservation. To meet rising energy demand doesn't necessarily mean increasing energy supply, while to save energy is also a smarter way to meeting rising energy demand. Therefore, in the long run, China's government has to make great effort not only to increase energy supply but to save energy use as well. Prioritising investment in energy efficiency rather than pouring money into expanding energy supply should be strongly

recommended. Wang, Wang and Zhao (2008) put forward 13 main barriers to energy saving in China after reviewing literature on energy saving and expert opinions from energy industry and academia. These main barriers to energy saving are worthy of attention from China's policymakers.

- Strengthening policy-making institutions. Raising the price of energy to reflect national priorities will require strengthened institutions with the capacity to make these kinds of changes. One possible solution is to establish an independent "Ministry of Energy", which would formalise the government's commitment to energy issues and improve enforcement of energy regulations. This could integrate energy industry both over regional level and over energy sources, which would mean that energy policies are not independently implemented within each of the energy sources but considered as a whole energy industry (all of energy sources).

- Employing Kyoto Protocol for self-defense. During the past two decades, China's exports are mainly energy-intensity based. Though exports are one of the main drivers of fast economic growth in China, increasing exports has been at the expense of domestic energy resources, which means less energy for China itself. It may be impossible for China's government to choose between economic growth and resource conservation at this stage. However, China should request Kyoto parties to count the incremental cost of environment protection within the framework of the Clean Development Mechanism and allow some of the importers of China's carbon-intensive goods to invest in lowering the carbon intensity of Chinese exports. The reason is simple: importers benefit a lot. For example, Li and Hewitt (2008) find that through trade with China, the UK reduced its CO2 emissions by approximately 11% in 2004. Shui and Harriss (2006) estimate that that US CO2 emissions would have increased from 3% to 6% if the goods imported from China had been manufactured in the US, while 7%–14% of China's current CO2 emissions were a result of producing exports for US consumers during 1997-2003.

- Increasing investment in renewable energies. Renewable energies only account for less than 10% of the world's total energy consumption but nearly 20% of China's total primary energy consumption (Chang et al, 2003). The potential of renewable energies is enormous due to its unlimited supply and its cleanliness in use. Moreover, once the Kyoto Protocol is fully implemented by all the signatories, the incentive of using renewable energies will be greatly increased.

The opportunities and challenges for renewable energy policies (can refer to Zhang et al 2008).

- Improving traffic administration techniques and reforming traffic regulation.
- Increasing international energy cooperation and joint ventures.

11 Conclusion

The above discussion brings about a comprehensive overview of China's energy situation in the new millennium. As can be seen, China's energy situation is quite dynamic to some degree, which is apparently dependent upon the energy policy. Continuing fast economic growth inevitably drives energy demand increase. With coal as the major primary energy resource, there are a series of challenges the Chinese government have to meet. With increasing demand for clean energy, large quantities of funds need to be invested in generating electricity and environmental protection facilities. Increasing exports also significantly drives the rapid increase in domestic energy demand and in return drive greenhouse gas emissions.

China's industrialisation, modernisation and urbanisation have affected the way in which energy resources have been and will be used to facilitate economic growth (Dean, 1974). China's future in political, economic and human terms is of enormous importance to the world. The decisions that China makes in relation to its energy policy will present both challenges and opportunities for the world.

12 References

Andrews-Speed, Philip and Stephen Dow. Reform of China's electric power industry challenges facing the government. *Energy Policy* 2000; 28:335-347.

Andrews-Speed, Philip, Stephen Dow and Zhiguo Gao. The ongoing reforms to China's government and state sector: the case of the energy industry. *Journal of Contemporary China* 2000; 9:5-20.

Blackman, A. and Wu, X. Foreign direct investment in China's power sector: trends, benefits and barriers. *Energy Policy* 1999; 27:695-711.

BP [*British Petroleum statistical review of world energy*] 2005 and 2008.

Cai, Jing and Zhigang Jiang. "Changing of energy consumption patterns from rural households to urban households in China: an example from Shaanxi Province of China." *Renewable and Sustainable Energy Reviews* 2008; 12:1667-1680.

Cheng, Z. *China's Price in the past 50 years (zhongguo jiage wushi nian).* China Price Publishing House, Beijing (in Chinese); 1998.

CESY [*China Energy Statistical Yearbook*]. Beijing: China Statistical Publisher; 2007.

CIAB [Coal Industry Advisory Board]. Coal in the energy supply of China - *A report of the CIAB Asia Committee*, submitted to International Energy Agency, 1999.

Chang, J., Dennis Y.C., Leung, C.Z. Wu and Z.H. Yuan. A review on the energy production, consumption, and prospect of renewable energy in China. *Renewable and Sustainable Energy Reviews* 2003; 7:453-468.

Crompton, Paul and Yanrui Wu. Energy consumption in China: past trends and future directions. *Energy Economics* 2005; 27:195-208.

CSY [*China Statistical Yearbook*] 1991-2007. Beijing: China Statistical Publisher.

CTCE [China Taiyuan Coal Exchange] 2007 http://www.ctctm.com

CTY [*China Transportation Yearbook*]. Beijing: China Statistical Publisher; 2005.

Dean, Genevieve C. Energy in the People's Republic of China. *Energy Policy* 1974; 2:33-54.

Dorian, James P and Allen L. Clark. China's energy resources - potential supply, problems, and implications. *Energy Policy* 1987; 15:73-90.

Fan, Ying, Hua Liao and Yiming Wei. Can market oriented economic reforms contribute to energy efficiency improvement? Evidence from China. *Energy Policy* 2007; 35:2287-2295.

Fesharaki, Fereidun and Wu, Kang. Energy policies in Asian-Pacific developing economies. *Asian-Pacific Economic Literature* 1992; 6:11-41.

Fesharaki, Fereidun, Tang, Chuanlong and Li, Binsheng. China's energy pricing: current situation and near term perspective. unpublished paper of the *Program on Resources: Energy and Minerals*, East-West Center, Honolulu, HI. 1994.

Gao, Yongyu. Overseas electricity purchase of State Grid to relief of electricity shortage and fastening development of Sino-Korea Yalu Jiang River. *The First Finance Daily*, Shanghai, China, August 14, 2008.

Griffiths, John C. Mineral resource assessment using the Unit Regional Value concept. *Mathematical Geology* 1978; 10:441-472.

Hang, Leiming and Meizeng Tu. The impact of energy prices on energy intensity: evidence from China. *Energy Policy* 2007; 35:2978-2988.

Huang, Y. Safety production and sustainable development of coal industry will influence national economy and energy safety. *The Ninth Peak Forum of China Energy Strategy*, May 2006 (in Chinese). http://chnes.chitec.cn/hitech/

Huang, Jikun and Scott Rozelle. The emergence of agricultural commodity markets in China. *China Economic Review* 2006; 17:266-280.

IOSC [Information Office of State Council of the People Republic of China]. *China's energy conditions and policies*; December 2007.

Kahrl, Fredrich and David Roland-Holst. Energy and exports in China. *China Economic Review* (2008). doi:10.1016/j.chieco.2008.05.004

Kambara, Tatsu. The energy situation in China. *The China Quarterly* 1992; 131: 608-636.

Khan, Haider A. China's energy dilemma. *CIRJE Discussion Papers* 2005. http://www.e.u-tokyo.ac.jp/cirje/research/03research02dp.html

Lam, Pun-Lee. Pricing of electricity in China. *Energy* 2004; 29:287-300.

Lau, Lawrence J., Yingyi Qian and Gerard Roland. Reform without Losers: An Interpretation of China's Dual-Track Approach to Transition. *Journal of Political Economy* 2000; 108:120-143.

Li, You and C.N. Hewitt. The effect of trade between China and the UK on national and global carbon dioxide emissions. *Energy Policy* 2008; 36:1907-1914.

Liang, Qiaomei, Ying Fan and Yiming Wei. Carbon taxation policy in China: How to protect energy- and trade-intensive sectors? *Journal of Policy Modeling* 2007; 29:311-333.

Liu, H., G.M. Jiang, H.Y. Zhuang and K.J. Wang. Distribution, utilization structure and potential of biomass resources in rural China: with special references of crop residues. *Renewable and Sustainable Energy Reviews* 2008; 12:1402-1418.

Ma, Chunbo and Lining He. From state monopoly to renewable portfolio: restructuring China's electric utility. *Energy Policy* 2008; 36:1697-1711.

Ma, Hengyun, Les Oxley and John Gibson. China's energy economy: A survey of the literatures. *Working Paper*, Department of Economics, University of Canterbury, July 2008.

Ma, Hengyun, Les Oxley, John Gibson and Bonggeun Kim. China's energy economy: technical change, factor demand and interfactor/interfuel substitution. *Energy Economics* 2008; 30:2167-2183.

Price, Lynn, Ernst Worrell, Jonathan Sinton and Jiang Yun. Industrial energy efficiency policy in China. A paper presented at the 2001 *ACEEE Summer Study on Energy Efficiency in Industry*.

SDRC [State Development and Reform Committee]. *China Price Information Network*. http://www.chinaprice.gov.cn/fgw/chinaprice/free/index.htm

Shi, Dan. An overview of China's energy policies and future policy priorities. *Economic Research Reference* (in Chinese) 2000; 20:20-26.

Shui, Bin and Robert C. Harriss. The role of CO2 embodiment in US–China trade. *Energy Policy* 2006; 34:4063-4068.

Sinton, Jonathan E., Rachel E. Stern, Nathaniel T. Aden and Mark D. Levine. Evaluation of China's energy strategy options. *A report prepared for and with the support of the China Sustainable Energy Program*; 16 May 2005.

Smil, Vaclav. China's energy and resource uses: continuity and change. *The China Quarterly* 1998; 156:935-951.

Sophia. Saving outweighs substituting. *China's Foreign Trade* 2007; 19:43-43.

Thomson, Elspeth. Reforming China's coal industry. *The China Quarterly* 1996; 147:726-750.

Wang, Bing. An imbalanced development of coal and electricity industries in China. *Energy Policy* 2007; 35:4959-4968.

Wang, Guohong, Yunxia Wang and Tao Zhao. Analysis of interactions among the barriers to energy saving in China. *Energy Policy* 2008; 36:1879-1889.

Wang, Haijiang. China's oil policy and its impact. *Energy Policy* 1995; 23: 627-635.

Li, B. and Dorian, J. P. Change in China's power sector. *Energy Policy* 1995; 23:619–626.

Wang, Yanzhong. Historical change and outlook of China's energy consumption policies. *China Industry Economy* (in Chinese) 2001; 4:33-38.

Weber, Christopher L., Glen P. Peters, Dabo Guan and Klaus Hubacek. The contribution of Chinese exports to climate change. *Energy Policy* 2008; 36:3572-3577.

Wirtshafter, R.M. and Shih, E. Decentralization of China's electricity sector: is small beautiful? *World Development* 1990; 18:505-512.

Wu, Kang and Binsheng Li. Energy development in China – national policies and regional strategies. *Energy Policy* 1995; 23:167-178.

Wu, Yanrui. Deregulation and growth in China's energy sector: a review of recent development. *Energy Policy* 2003; 31:1417-1425.

Xu, Shaofeng and Wenying Chen. The reform of electricity power sector in the PR of China. *Energy Policy* 2006; 34:2455-2465.

Xu, Yichong. Nuclear energy in China: contested regimes. *Energy* 2008; 33: 1197-1205.

Zhang, Peidong, Yanli Yang, Jin Shi, Yonghong Zheng, Lisheng Wang and Xinrong Li. Opportunities and challenges for renewable energy policy in China. *Renewable and Sustainable Energy Reviews* 2008: doi:10.1016/j.rser.2007.11.005

Zhao, Xingjun and Yanrui Wu. Determinants of China's energy imports: an empirical analysis. *Energy Policy* 2007; 35:4235-4246.

Zhou, Fengqi. The renewable energy development strategy in China. *Strategy and Decision Making Research* (in Chinese) 2006; 21:287-294.

Zhou, Zhongren, Wenliang Wu, Qun Chen and Shufeng Chen. Study on sustainable development of rural household energy in northern China. *Renewable and Sustainable Energy Reviews* 2008; 12:2227-2239.

Table 1. Present new installed capacity and its percentage of total capacity (million ton each year and million kw)

Year	Coal exploitation		Crude oil exploitation		Coal power plant		Hydropower station	
	Capacity	Δ %	Capacity	Δ %	Capacity	Δ %	Capacity	Δ %
1993	42.8	3.7	6.9	4.8	9.4	6.6	4.0	9.4
1994	9.5	0.8	6.2	4.3	8.1	5.2	4.2	8.3
1995	23.3	1.7	7.4	4.9	10.7	6.4	3.7	7.1
1996	16.9	1.2	9.0	5.7	13.6	7.4	3.7	7.1
1997	30.0	2.2	12.5	7.8	10.3	5.3	3.7	6.8
1998	9.7	0.8	8.4	5.2	15.4	7.9	6.2	10.8
1999	23.5	2.2	9.5	5.9	12.8	6.0	9.1	16.0
2000	22.6	1.7	9.2	5.6	13.4	5.8	4.5	7.3
2001	14.9	1.3	15.6	9.5	10.1	4.1	3.4	4.3
2002	34.2	2.5	25.4	15.2	33.2	12.0	5.2	6.5
2003	74.4	4.5	17.2	10.1	21.4	6.5	12.7	16.1
2004	154.4	7.8	24.7	14.0	37.0	9.9	11.1	11.3
2005	183.8	8.3	23.9	13.2	52.8	12.4	12.8	11.6
2006	226.5	9.5	16.0	8.7	80.2	16.2	13.0	10.7
Average:								
1990s	22.2	1.8	8.6	5.5	11.5	6.4	4.9	9.4
2000s	101.5	5.1	18.9	10.9	35.4	9.6	9.0	9.7

Note: Coal power capacity was estimated by total coal electricity generation divided by 24 (hour/day)*200 (day/year) and hydropower capacity was estimated by total hydro electricity generation divided by 24 (hour/day)*150 (day/year).

Data source: *China Statistical Yearbook* 2007. Beijing: China Statistical Publisher.

Table 2. The volume of interprovincial coal shipment in 2006, million metric tonnes

Province	Outflow shipment	Inflow shipment	Total shipment	% of total consumption
Beijing	3.9	26.9	30.8	90
Tianjin	0.0	37.8	37.8	87
Hebei	28.9	173.3	202.2	75
Shanxi	431.6	39.5	471.1	153
Inner Mongolia	145.4	17.9	163.3	95
Liaoning	5.4	77.8	83.2	51
Jilin	4.7	51.8	56.4	71
Heilongjiang	35.1	11.5	46.6	50
Shanghai	1.8	53.3	55.0	95
Jiangsu	7.1	158.1	165.2	81
Zhejiang	0.0	112.1	112.1	96
Anhui	30.8	35.5	66.2	70
Fujian	2.1	31.4	33.5	59
Jiangxi	3.0	20.9	23.9	47
Shandong	28.1	187.9	216.0	70
Henan	83.3	49.9	133.2	60
Hubei	0.0	82.9	82.9	80
Hunan	8.3	34.8	43.1	42
Guangdong	0.0	98.1	98.1	85
Guangxi	10.6	36.7	47.3	102
Hainan	0.0	2.4	2.4	68
Chongqing	5.5	3.1	8.6	21
Sichuan	19.2	20.3	39.5	41
Guizhou	29.2	0.0	29.2	28
Yunnan	6.1	8.3	14.4	16
Tibet	-	-	-	-
Shaanxi	80.0	0.0	80.0	104
Gansu	9.1	10.4	19.5	44
Qinghai	0.0	3.8	3.8	38
Ningxia	11.1	14.2	25.3	70
Xinjiang	2.5	0.4	2.9	6

Note: Physical unit. Average distance of rail shipment was 760 km in the last decade.

Data source*: China Energy Statistical Yearbook* 2007. Beijing: China Statistical Publisher.

Table 3. Major domestic railway coal shipment by origins and destinations in 2006

Origin	Coal shipment (mmt)	Of total outflow (%)	Major destinations (Provinces)
Shanxi	390	90	Hebei, Shandong,, Tianjin, Jiangsu, Beijing and Liaoning
Inner Mongolia	120	83	Liaoning, Tianjin, Heilongjiang, Jilin and Hebei
Henan	69	83	Hubei, Jiangsu, Shandong, Jiangxi and Anhui
Shaanxi	66	83	Hubei, Jiangsu, Shandong and Henan
Heilongjiang	34	99	Liaoning and Jilin
Hebei	23	81	Tianjin and Jilin
Shandong	20	74	Jiangsu and Zhejiang
Guizhou	18	64	Guangxi
Anhui	16	55	Jiangsu

Data source: *China Transportation Yearbook*, 2007. Beijing: China Statistical Publisher.

Table 4. National aggregate energy price 1995-2005

Year	Coal (¥/ton)	Electricity (¥/KWh)	Gasoline (¥/ton)	Diesel (¥/ton)
1995	214	38	2772	2293
1996	231	38	2773	2306
1997	264	40	2876	2612
1998	260	45	3240	2451
1999	247	46	2870	2530
2000	241	48	3640	3305
2001	240	50	3685	3229
2002	261	51	3571	3177
2003	283	54	4154	3516
2004	366	56	4730	3913
2005	414	58	5455	4501
1995-2005:				
% change	93	54	97	96
% growth rate	6.8	4.4	7.0	7.0

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Committee of China.

Table 5. Fuel prices and change (%) from 1995 by provincial capital cities

Provincial capital city	Coal (¥/ton)		Electricity (¥/KWh)		Gasoline (¥/ton)		Diesel (¥/ton)	
	2005	Δ%	2005	Δ%	2005	Δ%	2005	Δ%
Beijing	408	172	63	87	5345	88	4373	93
Tianjin	370	114	62	56	5486	96	4533	123
Shijiazhuang	387	165	56	33	5469	101	4533	106
Taiyuan	389	227	45	88	5534	116	4549	109
Hohhot	296	104	52	29	5491	96	4539	98
Shenyang	397	61	61	131	5357	103	4556	99
Changchun	475	147	67	86	5270	87	4323	90
Harbin	321	69	56	100	5107	79	4432	94
Shanghai	632	150	71	27	5544	102	4513	94
Nanjing	634	141	68	15	5292	118	4077	90
Hangzhou	501	75	72	30	5502	108	4430	93
Hefei	559	136	57	81	5333	90	4554	94
Fuzhou	523	87	65	6	5592	83	4435	84
Nanchang	374	58	58	95	5297	82	4489	94
Jinan	552	115	56	182	5395	109	4579	112
Zhengzhou	370	123	50	102	5330	85	4566	99
Wuhan	426	106	57	32	5210	81	4406	93
Changsha	490	87	59	36	5367	92	4411	94
Guangzhou	467	69	72	29	5422	102	4361	106
Nanning	369	41	56	135	5476	84	4517	83
Haikou	370	10	60	22	5779	109	4576	86
Chongqing	537	327	57	92	5666	99	4570	74
Chengdu	358	99	58	123	5631	119	4518	116
Guiyang	313	148	49	-32	5614	92	4606	86
Kunming	411	183	50	61	5682	97	4606	93
Lhasa	370	50	56	88	6410	143	5242	129
Xian	245	24	52	9	5390	97	4501	100
Lanzhou	168	-17	48	28	5440	96	4556	98
Xining	241	46	42	190	5099	83	4557	102
Yinchuan	270	132	47	12	5404	93	4504	108
Urumqi	135	-24	48	99	5082	99	4360	138

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Committee of China.

Table 6. The Changes of national energy intensity by sector

Year	Agriculture	Industry	Construction	Transportation	Commerce
1980	0.44	1.98	0.54	1.41	0.20
1985	0.25	1.62	0.43	1.11	0.11
1990	0.25	1.38	0.29	0.86	0.16
1991	0.25	1.27	0.28	0.81	0.15
1992	0.24	1.12	0.25	0.79	0.15
1993	0.22	1.00	0.20	0.77	0.19
1994	0.22	0.91	0.18	0.72	0.17
1995	0.23	0.87	0.16	0.67	0.17
1996	0.23	0.81	0.16	0.62	0.18
1997	0.23	0.72	0.13	0.71	0.17
1998	0.21	0.63	0.16	0.70	0.17
1999	0.21	0.55	0.13	0.70	0.18
2000	0.20	0.50	0.13	0.70	0.17
2001	0.21	0.44	0.12	0.64	0.17
2002	0.22	0.48	0.13	0.67	0.17
2003	0.21	0.49	0.12	0.72	0.18
2004	0.23	0.53	0.21	0.75	0.20
2005	0.23	0.52	0.19	0.74	0.19
2006	0.23	0.52	0.19	0.76	0.19

Note: energy intensity (ton/¥1000) = energy consumption (10k ton)/GDP (¥100 million in 1978 price).

Data source: *China Statistical Yearbook* 1996-2007, *China Energy Statistical Yearbook* 2007. Beijing: China Statistical Publisher.

Table 7. Aggregate energy intensity over Provinces in 1996, 2001 and 2006 and change

Province	1996	2001	2006	% Change	
				1996-2001	2001-2006
Beijing	0.97	0.66	0.35	-32.0	-46.7
Tianjin	0.97	0.69	0.49	-28.9	-29.4
Hebei	1.11	0.81	0.88	**-26.8**	7.6
Shanxi	2.26	1.96	1.34	-13.3	-31.6
Inner Mongolia	1.23	1.15	1.10	-6.5	-4.7
Liaoning	1.33	0.93	0.81	**-30.2**	-12.6
Jilin	1.34	0.83	0.73	**-38.1**	-12.2
Heilongjiang	1.05	0.74	0.66	**-29.5**	-10.3
Shanghai	0.71	0.51	0.41	-27.5	-20.7
Jiangsu	0.58	0.41	0.41	**-29.7**	0.0
Zhejiang	0.50	0.42	0.40	**-16.0**	-6.5
Anhui	0.83	0.68	0.54	-18.1	-20.0
Fujian	0.40	0.32	0.42	**-19.6**	30.2
Jiangxi	0.61	0.47	0.47	**-23.4**	0.5
Shandong	0.66	0.46	0.56	**-30.3**	21.1
Henan	0.78	0.64	0.61	-17.8	-4.2
Hubei	0.87	0.57	0.67	**-34.7**	18.2
Hunan	0.89	0.51	0.61	**-42.9**	21.2
Guangdong	0.51	0.42	0.36	**-18.2**	-15.0
Guangxi	0.56	0.52	0.54	-6.1	2.9
Hainan	0.38	0.42	0.41	9.3	-2.1
Chongqing	0.00	0.75	0.64	-	-15.4
Sichuan	0.96	0.67	0.68	**-30.1**	1.6
Guizhou	2.20	1.79	1.45	-18.9	-18.7
Yunnan	0.80	0.74	0.78	**-7.9**	6.2
Tibet	0.00	0.00	0.00	-	-
Shaanxi	1.29	0.77	0.61	**-40.1**	-20.3
Gansu	1.69	1.18	0.98	**-29.8**	-17.1
Qinghai	1.63	1.35	1.40	**-17.4**	3.5
Ningxia	1.78	0.00	1.86	**-100.0**	-
Xinjiang	1.52	1.03	0.94	**-32.3**	-9.1

Note: calculated based on 1978 price, ton/¥1000.

Data source: *China Statistical Yearbook* and *China Energy Statistical Yearbook*. Beijing: China Statistical Publisher.

Table 8. China's energy production and consumption (million ton standard coal)

Year	Aggregate	Of which %			
	Production	Coal	Oil	Natural gas	Others
1985	855.5	72.8	20.9	2.0	4.3
1990	1039.2	74.2	19.0	2.0	4.8
1995	1290.3	75.3	16.6	1.9	6.2
2000	1289.8	72.0	18.1	2.8	7.2
2005	2058.8	76.5	12.6	3.2	7.7
2006	2210.6	76.7	11.9	3.5	7.9
Growth rate annually (%)					
1985-1990	4.0	0.4	-1.9	0.0	2.2
1990-1995	4.4	0.3	-2.7	-1.0	5.3
1995-2000	0.0	-0.9	1.7	8.1	3.0
2000-2005	9.8	1.2	-7.0	2.7	1.4
2005-2006	7.4	0.3	-5.6	9.4	2.6
	Consumption	Coal	Oil	Natural gas	Others
1985	766.8	75.8	17.1	2.2	4.9
1990	987.0	76.2	16.6	2.1	5.1
1995	1311.8	74.6	17.5	1.8	6.1
2000	1385.5	67.8	23.2	2.4	6.7
2005	2246.8	69.1	21.0	2.8	7.1
2006	2462.7	69.4	20.4	3.0	7.2
Growth rate annually (%)					
1985-1990	5.2	0.1	-0.6	-0.9	0.8
1990-1995	5.9	-0.4	1.1	-3.0	3.6
1995-2000	1.1	-1.9	5.8	5.9	1.9
2000-2005	10.2	0.4	-2.0	3.1	1.2
2005-2006	9.6	0.4	-2.9	7.1	1.4

Data source: *China Statistical Yearbook*, 1996-2007. Beijing: China Statistical Publisher.

Table 9. Shares of aggregate energy consumption by sector in China

Year	Agriculture	Industry	Construction	Transportation	Commerce	Others	Resident
1985	7.7	79.7	1.7	1.5	0.9	3.0	5.4
1990	4.9	68.5	1.2	4.6	1.3	3.5	16.0
1995	4.2	73.3	1.0	4.5	1.5	3.4	12.0
2000	4.4	68.9	1.5	7.3	2.2	4.2	11.5
2004	3.8	70.5	1.6	7.4	2.4	3.9	10.5
2005	3.6	71.0	1.5	7.4	2.2	3.9	10.4
2006	3.4	71.1	1.5	7.5	2.2	3.9	10.3
Growth rate annually (%)							
1985-1990	-8.6	-3.0	-6.7	25.1	7.6	3.1	24.3
1990-1995	-3.0	1.4	-3.6	-0.4	2.9	-0.6	-5.6
1995-2000	0.9	-1.2	8.4	10.2	8.0	4.3	-0.8
2000-2005	-3.9	0.6	0.0	0.3	0.0	-1.5	-2.0
2005-2006	-5.6	0.1	0.0	1.4	0.0	0.0	-1.0

Data source: *China Statistical Yearbook*, 1996-2007. Beijing: China Statistical Publisher.

Table 10. Provincial balance of coal and oil in 2006, million ton

Province	Production		Consumption		Surplus	
	Coal	Crude oil	Coal	Crude oil	Coal	Crude oil
Beijing	6.5	-	30.6	8.0	-24.1	-8
Tianjin	-	19.4	38.1	9.0	-38.1	**10.4**
Hebei	83.6	6.1	213.5	10.5	-129.9	-4.4
Shanxi	581.4	-	283.5	-	**297.9**	-
Inner Mongolia	297.6	-	161.9	1.4	**135.7**	-1.4
Liaoning	73.7	12.3	142.1	55.6	-68.4	-43.3
Jilin	30.0	6.8	75.5	9.5	-45.5	-2.7
Heilongjiang	102.8	43.4	90.3	18.5	**12.5**	**24.9**
Shanghai	-	0.2	51.4	18.3	-51.4	-18.1
Jiangsu	30.5	1.9	184.3	23.0	-153.8	-21.1
Zhejiang	0.2	-	113.3	21.1	-113.1	-21.1
Anhui	83.3	-	88.3	4.5	-5	-4.5
Fujian	19.3	-	54.0	3.8	-34.7	-3.8
Jiangxi	27.8	-	45.9	4.2	-18.1	-4.2
Shandong	140.7	27.6	290.0	38.8	-149.3	-11.2
Henan	195.3	4.9	210.0	7.0	-14.7	-2.1
Hubei	11.2	0.8	96.5	8.5	-85.3	-7.7
Hunan	59.5	-	94.4	5.7	-34.9	-5.7
Guangdong	-	13.4	111.3	28.1	-111.3	-14.7
Guangxi	6.8	-	41.7	1.2	-34.9	-1.2
Hainan	-	0.1	3.3	2.3	-3.3	-2.2
Chongqing	39.9	-	37.3	-	**2.6**	-
Sichuan	86.0	0.2	85.3	1.7	0.7	-1.5
Guizhou	118.2	-	99.4	-	**18.8**	-
Yunnan	73.4	-	74.8	-	-1.4	-
Tibet	-	-	74.0	14.9	-74	-14.9
Shaanxi	182.6	19.9	39.6	13.2	**143**	**6.7**
Gansu	39.5	0.8	9.1	1.1	**30.4**	-0.3
Qinghai	6.9	2.2	34.9	1.7	-28	0.5
Ningxia	32.7	-	44.4	18.1	-11.7	-18.1
Xinjiang	43.2	24.7	30.6	8.0	**12.6**	**16.7**

Data source: *China Energy Yearbook* 2007. Beijing: China Statistical Publisher.

Table 11. Export and imports and trade reliance of China's energy, million metric tonnes and %

Year	Aggregate trade and reliance				Coal trade and reliance				Petroleum trade and reliance			
	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance
1980	2.6	30.6	-28.0	-4.6	2.0	6.3	-4.3	-0.7	0.8	18.1	-17.2	-19.7
1985	3.4	57.7	-54.3	-7.1	2.3	7.8	-5.5	-0.7	0.9	36.3	-35.4	-38.6
1990	13.1	58.8	-45.7	-4.6	2.0	17.3	-15.3	-1.4	7.6	31.1	-23.5	-20.5
1995	54.6	67.8	-13.2	-1.0	1.6	28.6	-27.0	-2.0	36.7	24.5	12.2	7.6
1996	68.4	75.3	-6.9	-0.5	3.2	36.5	-33.3	-2.3	45.4	27.0	18.4	10.6
1997	99.6	76.6	23.0	1.7	2.0	30.7	-28.7	-2.1	67.9	28.2	39.7	20.2
2000	143.3	90.3	53.1	3.8	2.2	55.1	-52.9	-4.0	97.5	21.7	75.8	33.8
2004	265.9	116.5	149.5	7.4	18.6	86.7	-68.1	-3.5	172.9	22.4	150.5	47.5
2005	269.5	114.5	155.1	6.9	26.2	71.7	-45.6	-2.1	171.6	28.9	142.8	43.9
2006	310.6	109.3	201.3	8.2	38.3	63.3	-25.0	-1.0	194.5	26.3	168.3	48.2
Growth rate annually:												
1980-1990	17.6	6.7	-	-	0.0	10.6	-	-	25.2	5.6	-	-
1990-2000	27.0	4.4	-	-	1.0	12.3	-	-	29.1	-3.5	-	-
2000-2006	13.8	3.2	24.9	13.7	61.0	2.3	-11.7	-20.6	12.2	3.3	14.2	6.1
1997-2006	15.6	4.4	27.3	19.3	38.7	8.4	-1.5	-7.7	14.6	0.1	17.4	10.2

Note: Aggregate energy is measured in million ton standard coal and reliance is the percentage of net import in total domestic consumption.

Data source: *China Statistical Yearbooks*. Beijing: China Statistical Publisher.

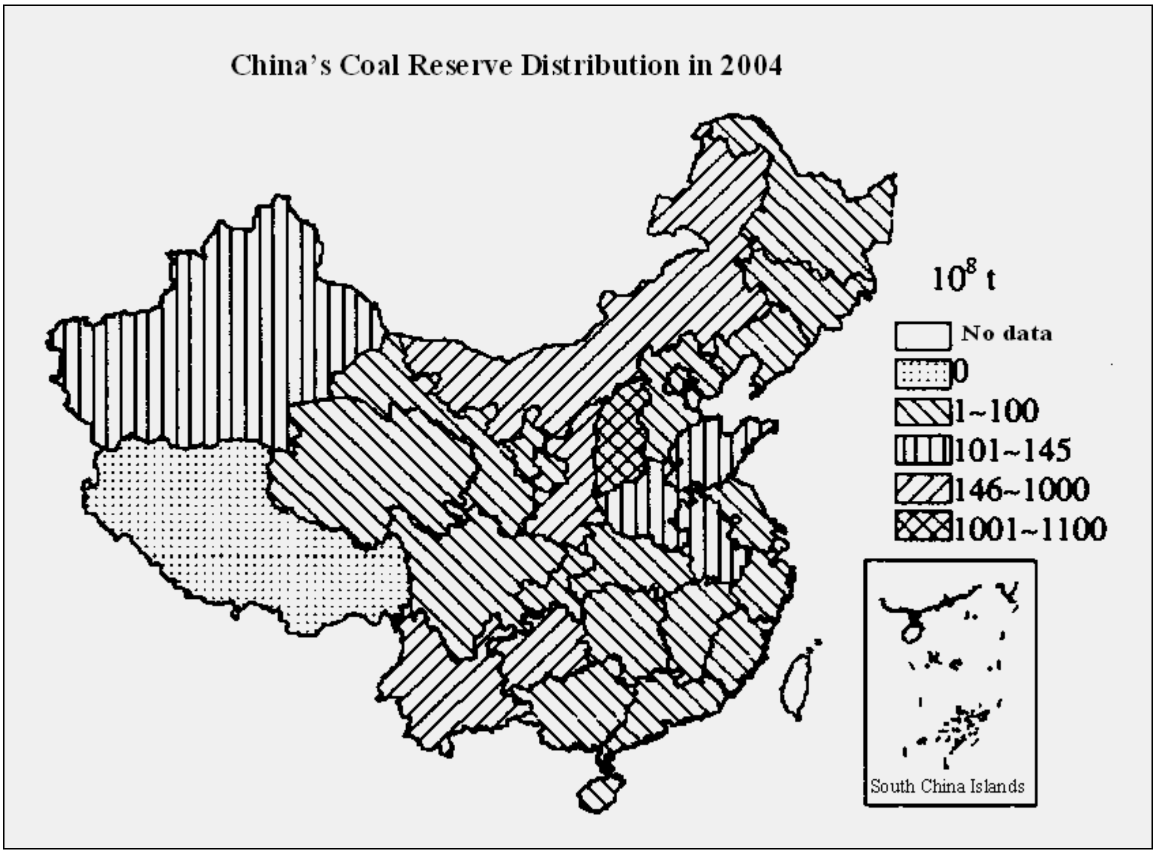


Figure 1. China's coal reserve distribution in 2004

Data source: *China Statistical Yearbook* 2005, Beijing: China Statistical Publisher.

Note: According to BP (2008), China's proved reserve of anthracite and bituminous coal is 62200 million tonnes, and proved reserve of sub-bituminous and lignite coal is 52300 million ones. The total proved coal reserve is 114500 million tones and accounts for 13.5% of world total. The ratio of reserves to production is 118 at the end of 2007.

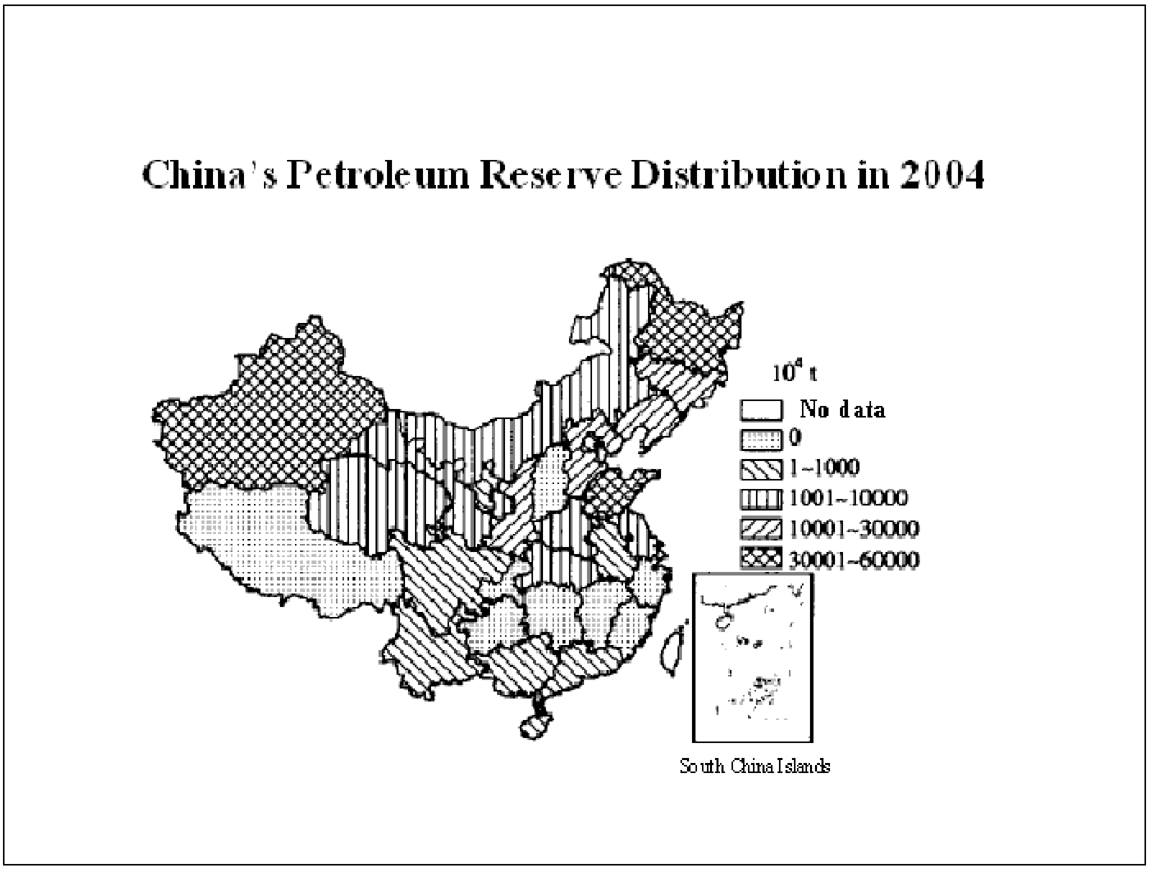


Figure 2. China's petroleum reserve distribution in 2004

Data source: *China Statistical Yearbook* 2005. Beijing: China Statistical Publisher.

Note: China's proved reserve of oil is 2116.6 million tonnes and accounts for 1.3% of world total; the ratio of reserves to production is 11.3 at the end of 2007 (BP, 2008).

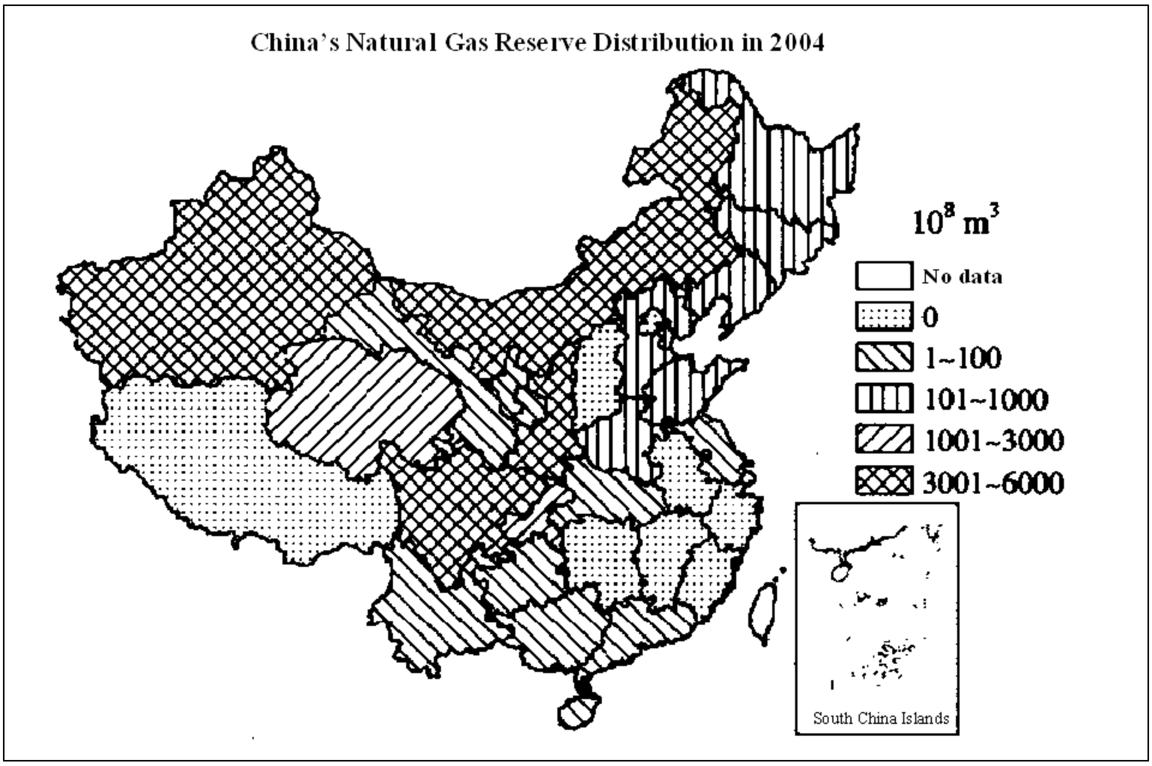


Figure 3. China's natural gas reserve distribution in 2004

Data source: *China Statistical Yearbook* 2005. Beijing: China Statistical Publisher.

Note: China's proved reserve of natural gas is 1.9 trillion cubic meters and accounts for 1.1% of world total. The ratio of reserves to production is 27.2 at the end of 2007 (BP, 2008).

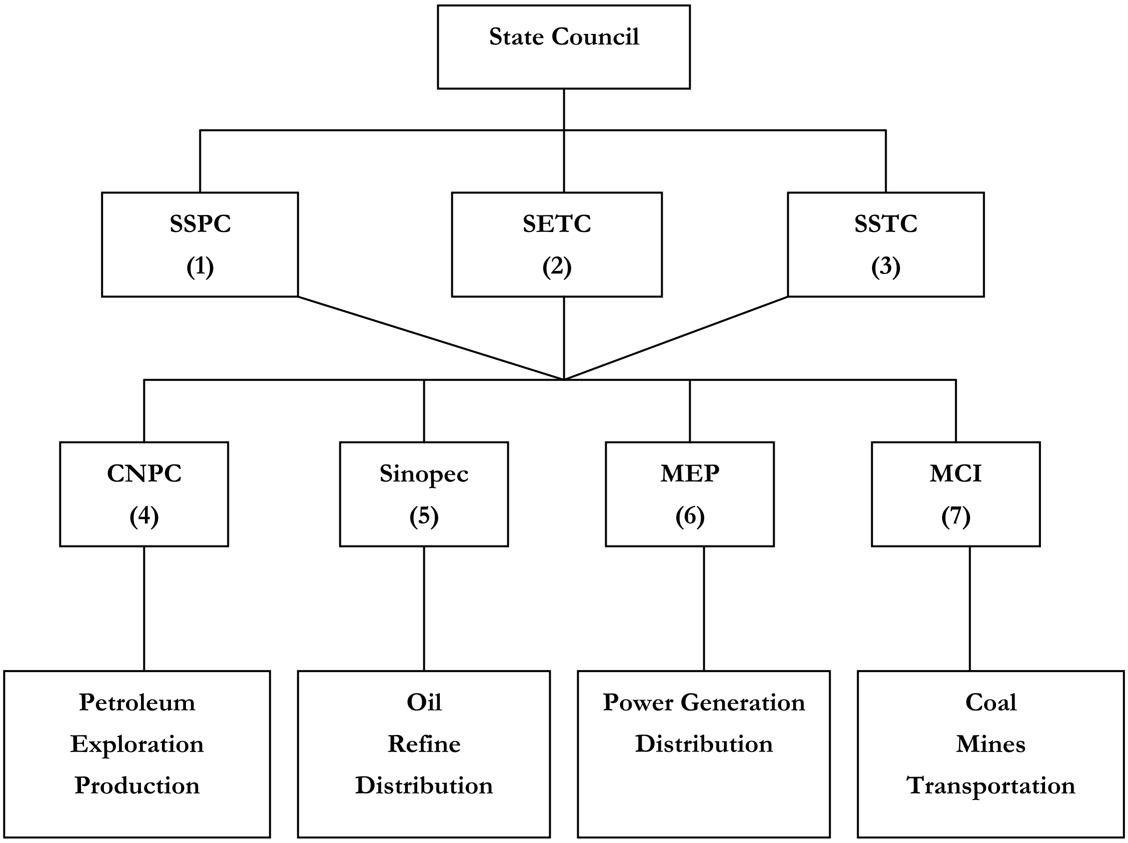


Figure 4. Old government structure and regulatory system for energy sector setup in 1993

Note:
(1) SSPC - State Planning Commission
(2) SETC - State Economic Trade Commission
(3) SSTC - State Science Technology Commission
(4) CNPC – China National Petroleum Corporation
(5) Sinopec - China Petroleum and Chemical Corporation
(6) MEP – Ministry of Electric Power
(7) MCI – Ministry of Coal Industry

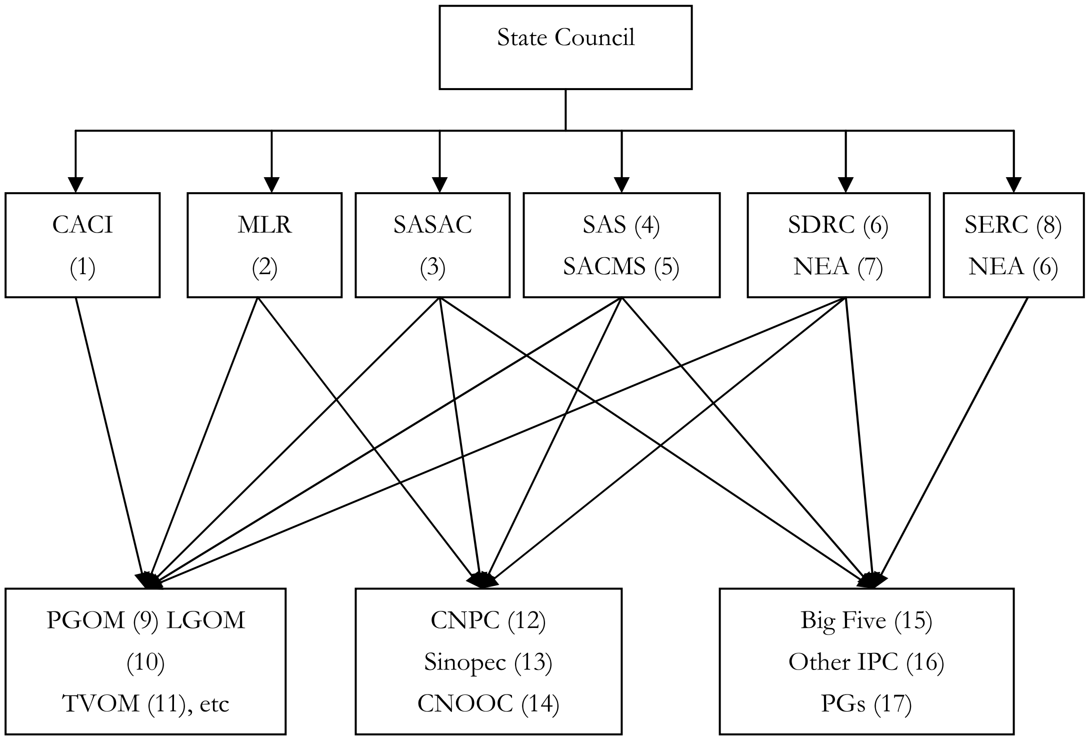


Figure 5. New government structure and regulatory system for energy sector in 2008

Note:

(1) CACI - China Association of Coal Industry

(2) MLR – Ministry of Land and Resources

(3) SASAC - State-owned Assets Supervision and Administration Commission of State Council

(4) SAWS - State Administration of Work Safety

(5) SACMS - State Administration of Coal Mine Safety

(6) SDRC - State Development and Reform Commission

(7) NEA – National Energy Administration in SDRC set up at August 8, 2008.

(8) SERC - State Electricity Regulatory Commission

(9) PGOM – Provincial Government Owned Mines

(10) LGOM – Local Government Owned Mines

(11) TVOM – Township and Village Owned Mine enterprises

(12) CNPC – China National Petroleum Corporation

(13) Sinopec – China Petroleum and Chemical Corporation

(14) CNOOC – China National Offshore Oil Corporation

(15) Big Five - Huaneng Group, Datang Group, Huadian Corporation, Guodian Co. and Power Investment Co.

(16) IPP – Independent Power Plant

(17) PGs – Power Grids

Figure 6. China's coal transportation routes

Note: Horizontal (red) lines represent raw coal transported from West to East.

Vertical (blue) lines represent raw coal transported from North to South.

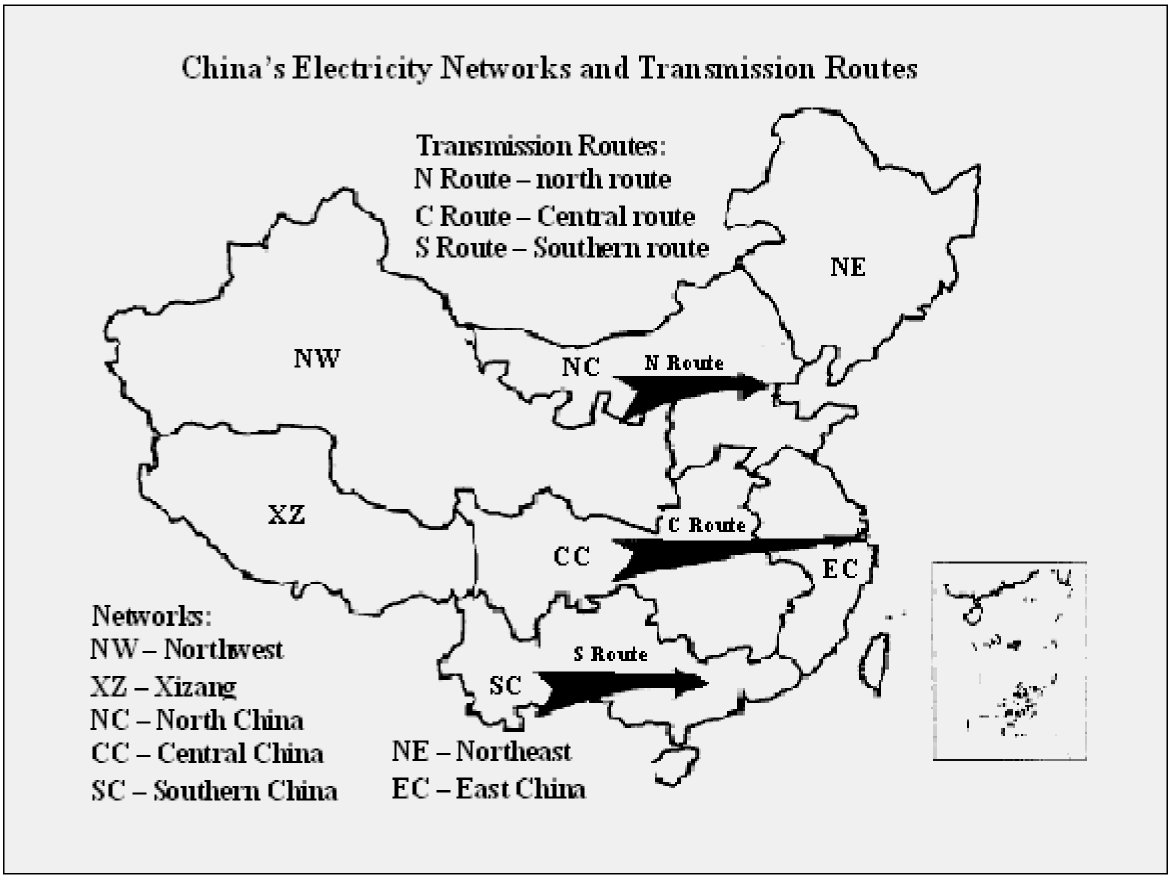


Figure 7. China's three major electricity transmission routes

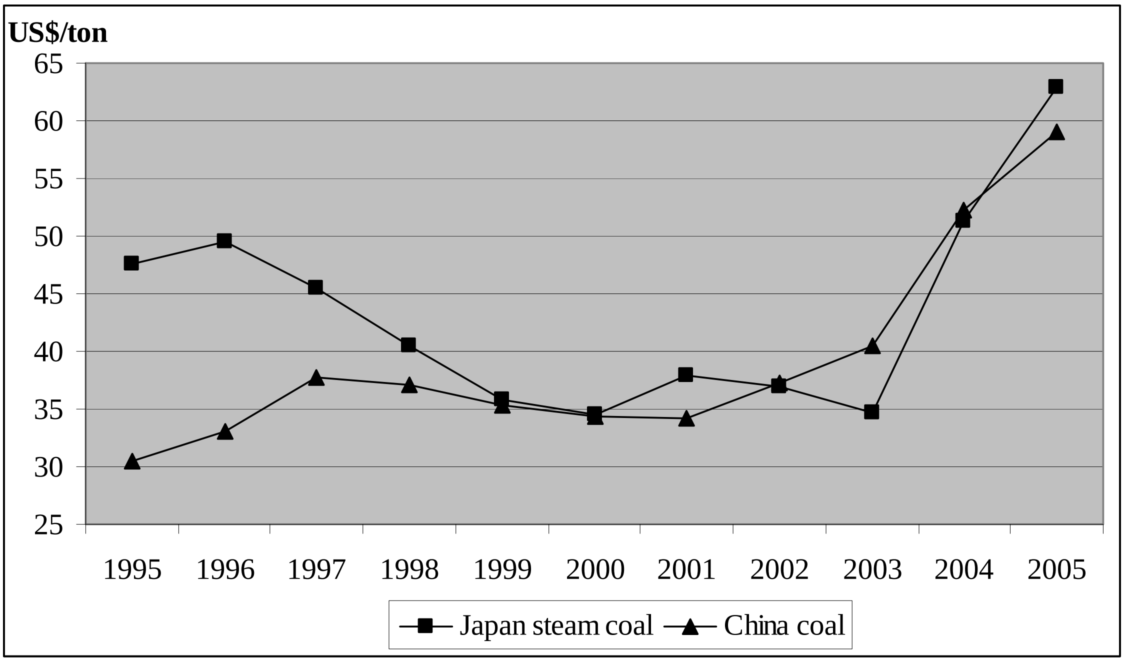


Figure 8. Japan steam coal import cif price and China's coal spot price 1995-2005

Note: exchange rate of US$ to RMB is 7.0

Data source: BP 2008 and National Development and Reform Committee, PRC.

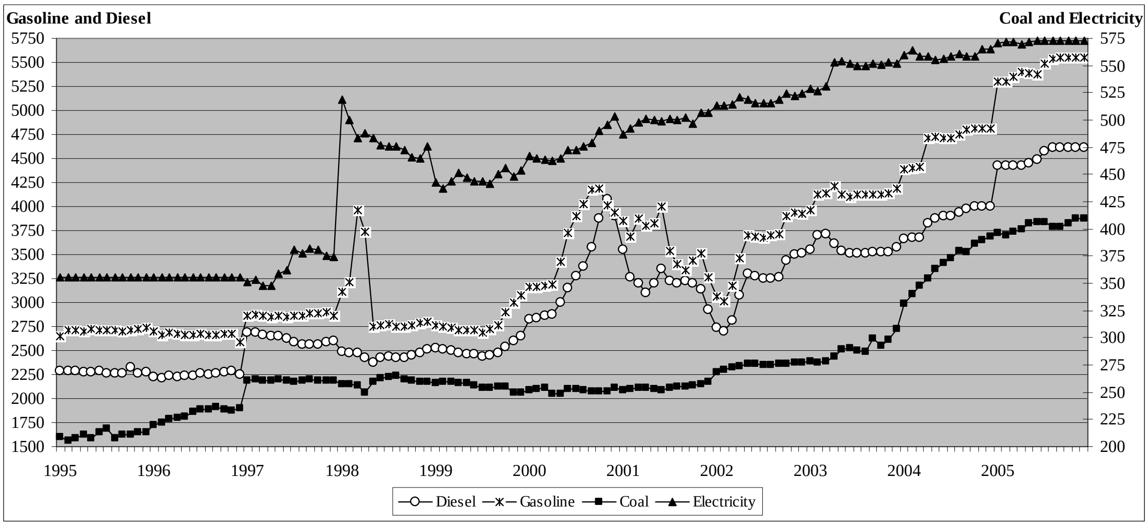


Figure 9. Monthly price change patterns of four major fuels 01/1995-12/2005.

Note: Price unit for coal, gasoline and diesel is RMB/ton and price unit for electricity is RMB/1000 KWh.

Data source: calculated by taking the average of 10-day interval spot prices of 35 major cities published by State Development and Reform Committee of China.

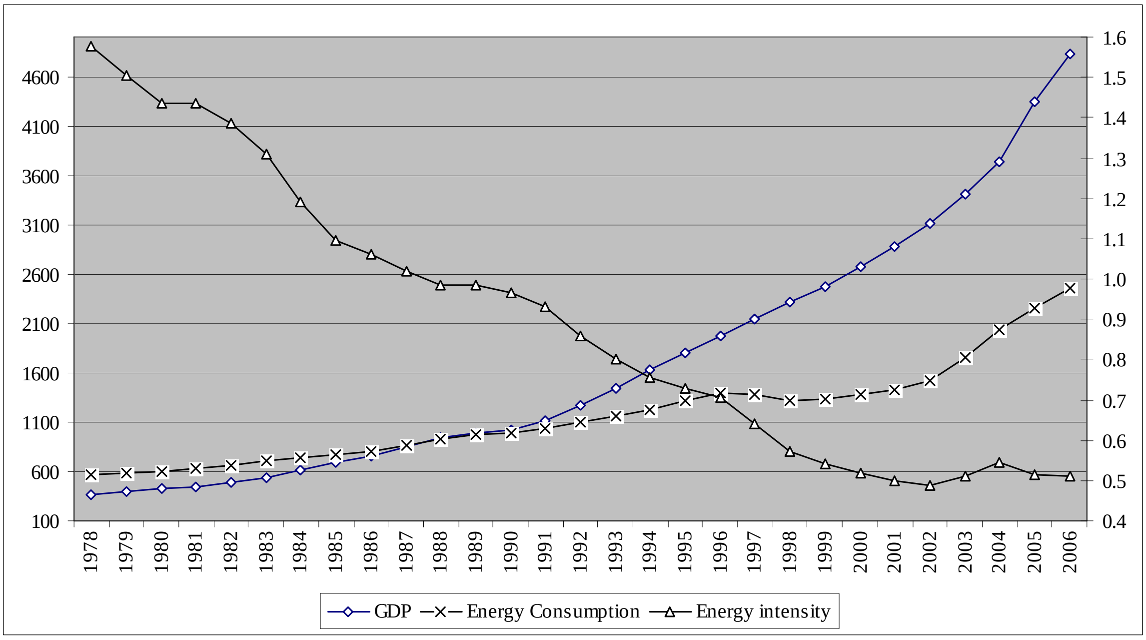
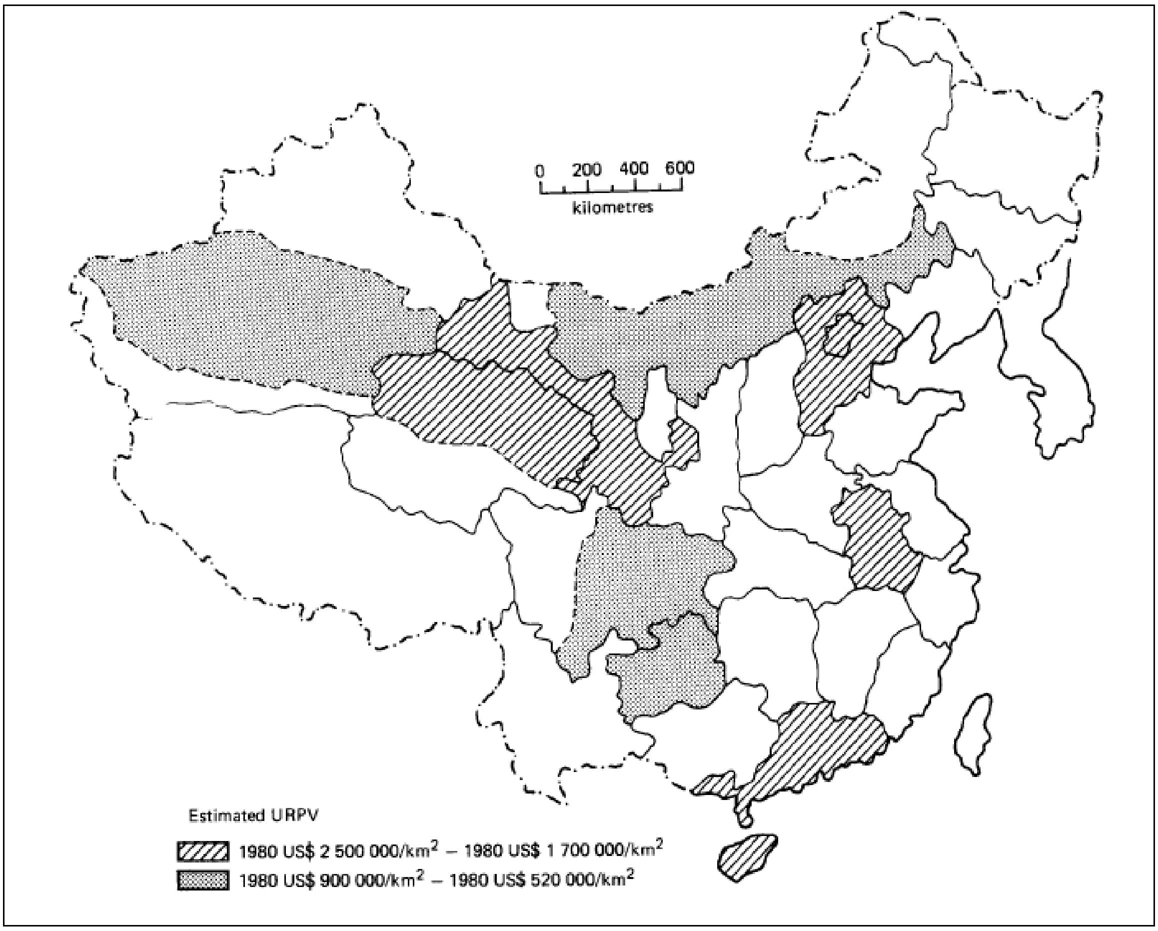


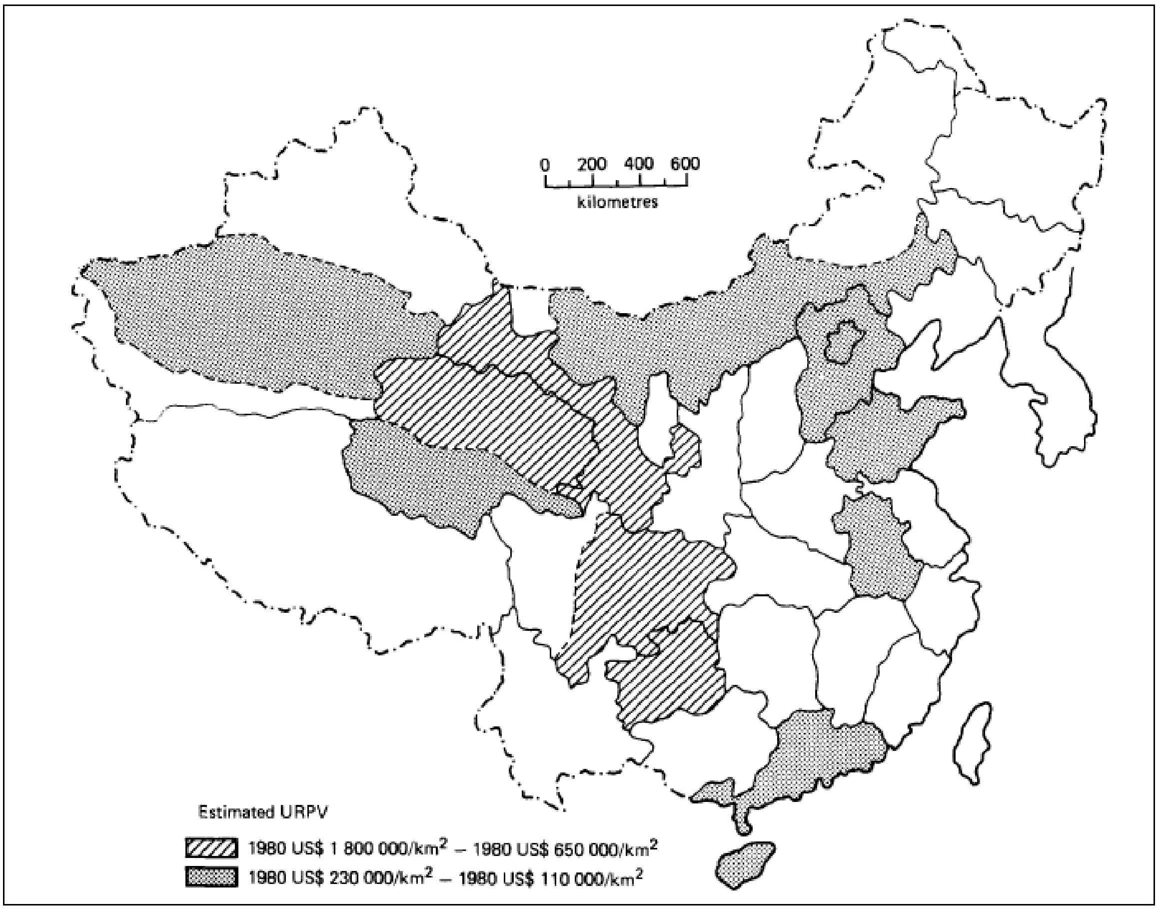
Figure 10. National GDP (billion, 1978 price), aggregate energy consumption (million ton standard coal), and aggregate energy intensity (ton/1000 yuan)

Note: left hand y axis is for GDP and energy consumption, and right hand y axis is for aggregate energy intensity.

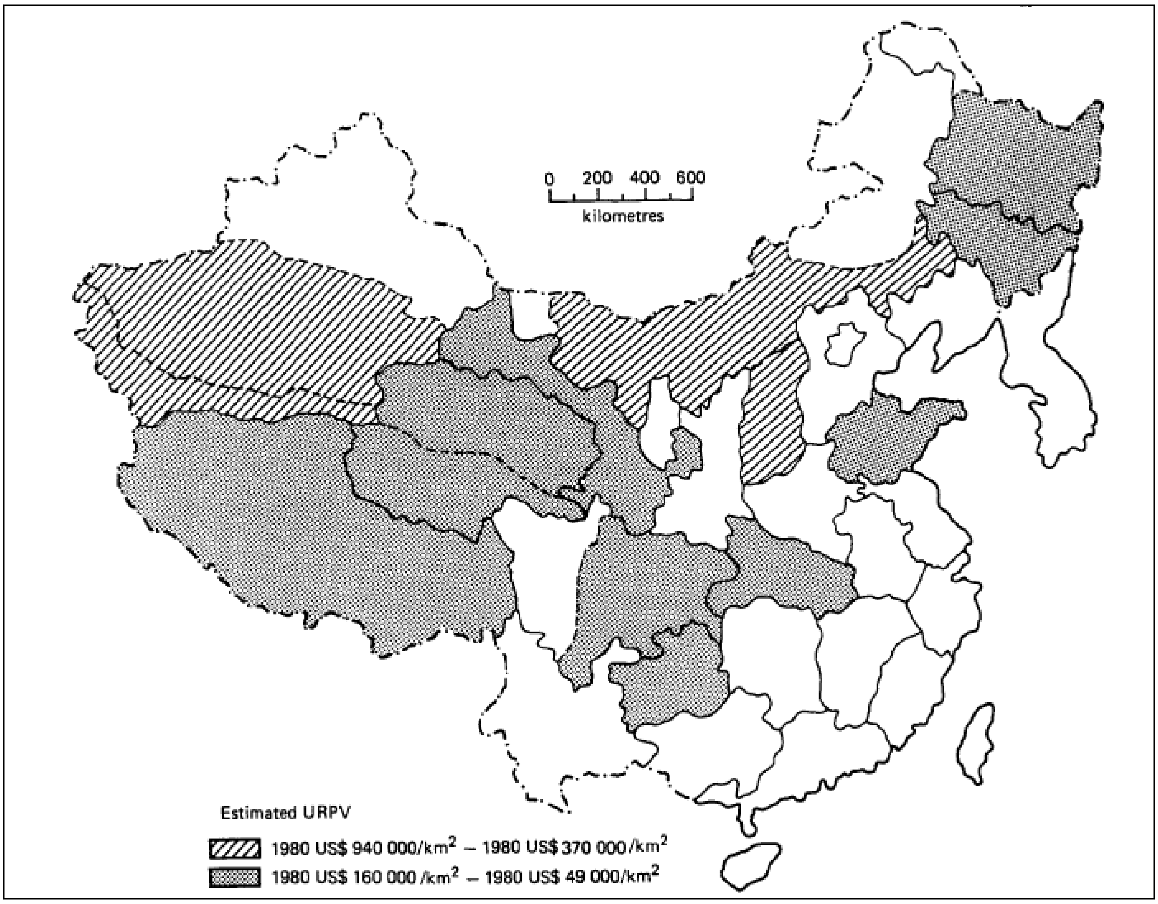
Data source: *China Statistical Yearbook*. Beijing: China Statistical Publisher.



Appendix Figure 1. China's Provinces with high petroleum potential.
Extracted from Dorian and Clark (1987), Figure 2.



Appendix Figure 2. China's Provinces with high natural gas potential.
Extracted from Dorian and Clark (1987), Figure 3.



Appendix Figure 3. China's Provinces with high coal potential.
Extracted from Dorian and Clark (1987), Figure 4.

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