CICERO

Center for
International Climate
and Environmental
Research - Oslo

Working Paper 1997:4

Energy Development and Environmental Constraints in China

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ISSN: 0804-452X

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ABSTRACT

This paper analyzes the inter-relationship of energy development and environmental constraints in China. It examines the effects of economic development, investment, energy trade and environmental limitations in shaping energy development. It highlights the tensions between institutions involved in energy development, energy conservation and environmental protection. It concludes that total fuel mix in China will be diversified in the future. The share of coal in primary energy production and consumption will increase in the short time span till 2020, and diminish gradually thereafter, largely replaced by gas, nuclear and renewables. China will become a big oil importer, due to increase in demand and resource limitations. Meanwhile, coal export will increase in the long run. SO_2 and CO_2 emissions will become potentially larger in the future, because of the speed of economic growth and lack of effective control measures. Institutional bottlenecks, and political preference to solving local environmental problems, will affect actions to eliminate global environmental risks. There exist huge investment potentials for energy development both from international and domestic private investment funds. Energy efficiency will continue to improve, associated with gradual decline of non-commercial energy use and increasing share of commercial energy in final consumption. Energy conservation holds the key for sustainable energy development that should be promoted at the national and local levels with demand management as a focus in policy implementation.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Swedish Council for Planning and Coordination of Research (FRN), and its support is greatly appreciated. The author is grateful to Dr. Nebojša Nakićenović, Dr. Leo Schrattenholzer, and Dr. Arnulf Grübler at the International Institute for Applied Systems Analysis (IIASA) for their comments on an early draft of the paper.

Key words: energy, environment, China

Note: The author is currently senior research fellow at the Center for International Climate and Environmental Research-Oslo (CICERO), Norway. The research work for this article was initialized at the Research Policy Institute, University of Lund, Sweden in 1995/96, and completed at the International Institute for Applied Systems Analysis (IIASA), Austria in 1997. This article has been accepted for publication in *Energy Policy* (forthcoming in 1997).

1. INTRODUCTION

Economic development in China has experienced a rapid transition and growth since the late 1970s. In 1994, total gross domestic product (GDP) accounted for US$ 522 billion, which was 1.6 times higher than that in 1980. With Hong Kong's return to China in July 1997, China's overall economic power will become even larger in the foreseeable future. The general trend is to foster economic systems reform to respond more closely to free market mechanisms. These reforms are designed to combine planning and central authoritarian regimes with the application of market instruments. Most progress achieved so far have been the result of private sector expansion, driven by rapid inflow of foreign direct investment (FDI). Majority of the public sector performance have been poor, including the state-owned energy industries. It can be expected that free market economy will eventually become a dominant force in the future, which will have profound impact on energy systems development.

China had the highest rates of GDP growth in the world with real GDP growth rate of 5.8% in 1980-1990 and 10.8% in 1990-94. The industrial sector maintained even higher rates of growth: 11.1% in 1980-1990 and 18.8% in 1990-1994 (World Bank, 1996, p.208). The potential for high rates of economic development in the coming decades is supported by the following variables. First, public policy is already in place, or is under development, to protect and promote free market competition and international trade. Second, there is a relatively good educational infrastructure that provides relatively skilled labor force for industrialization. Third, a favorable investment environment exists that has already attracted international financial inflows. Fourth, consumer demand is increasing for higher quality of life and better services, which will stimulate economic growth. Fifth, strong international competition has forced industrialized countries to reallocate their production capacities to low-cost countries in which China is a preferred choice. This massive transformation is involved with capital investment, transfer of new technologies and management know-how, which helps stimulate economic growth and market expansion, as well as rationalization of industrial structures and processes.

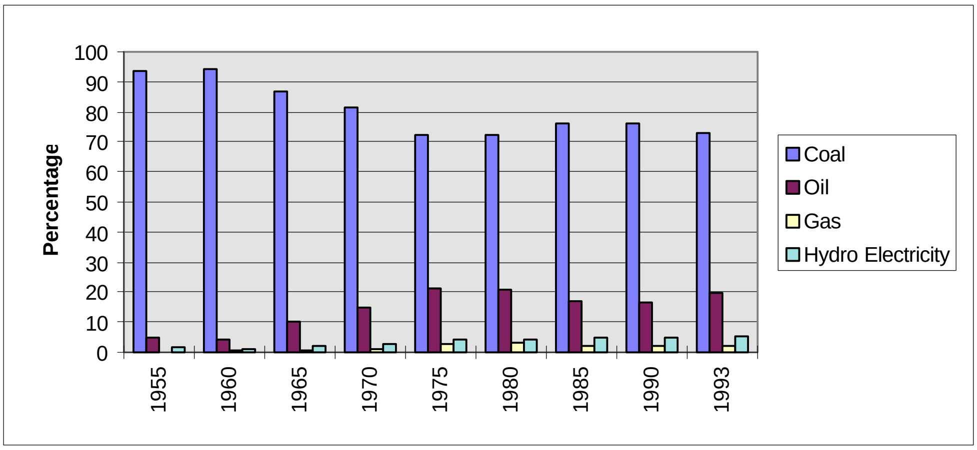
There will be structural changes in the economy: from low energy intensive agricultural production to higher energy intensive manufacturing and social services. In the long run, the transition from traditional labor intensive agricultural production towards higher dependency on mechanization and intensive use of petroleum products will push the agriculture sector on higher demand for commercial energy-oriented development. It implies the diminishing use of biomass as the final energy source, and an increasing use of commercial energy, such as electricity, oil and oil products. Therefore, higher demand for energy services is inevitable.

Energy development is shaped by many interrelated factors. The following sections analyze major variables, which affect long-term energy sector development and policy-making. The analysis goes across economic, trade, environmental systems. It points out major factors that pose constraints as well as opportunities for sustainable energy sector development in China.

2. ENERGY CONSUMPTION

Figure 1 shows the historical trends in the changing patterns of primary energy consumption in China. The absolute dominance of coal in primary energy consumption from the 1950s till the early 1970s was challenged by the increased domestic oil production output in the early 1970s, supported by the discovery and exploration of huge oil fields in the Northeastern region. Coal consumption declined drastically in the 1970s, substituted largely by oil use. Oil was believed to have had abundant supply at the time and consequently stimulated demand increase. From the late 1980s, economic reform brought into a shape increase in energy consumption, particularly in the industrial sector. Oil supply was then constrained by production capacity limitations. Subsequent demands for energy would have to be met by increasing coal consumption, which was mostly sustained by production capacity increases of private- and collectively owned coal mines. From the early 1990s, the share of oil in primary energy consumption started to increase gradually, pulled by economic recovery from the 1989-1990 recession and high demand in sectors of the economy.

Figure 1. Primary Energy Consumption in China (1955-1993)

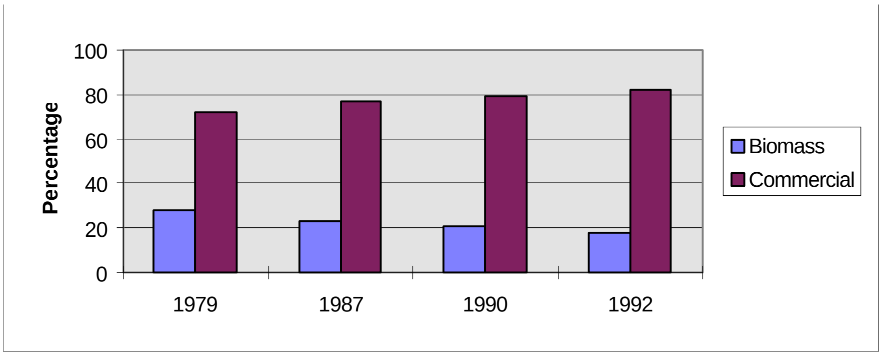


Source: Sinton, 1996, p.IV-13.

In the same period, natural gas and hydro electric power generation had been stagnating, due to lack of investment funds and adequate policy incentives. These disparities in energy consumption patterns are very much shaped by resource availability and production capacity limitations. This situation is expected to change in the future. Natural gas development has been prioritized with the build-up of new infrastructure, i.e., pipelines to transport natural gas outputs from newly developed offshore and inland fields. Hydropower development is symbolized by the Three Gorges Dam construction. The long-term trend in energy consumption tends to shift toward diversification. Natural gas, nuclear power and hydro electricity will come to take larger shares in final energy consumption. However, the share of coal in primary energy consumption may still increase in the near term till 2020, and decrease thereafter. The timing for change in consumption patterns, especially in coal use, depends, to a large extent, on how environmental externalities are incorporated into public policy-making, so are reactions of the general public to health-related coal use.

The trend in primary energy consumption indicates a continuous decrease in biomass consumption, as seen in **Figure 2**, From 1979 to 1992, consumption of biomass energy, including firewood, crop stalk and dung cake, decreased from 28% till 18% out of the total primary energy consumption. By contrast, use of commercial energy increased from 72% to 82%. This trend is consistent with the assumption made in the IIASA-WEC scenarios across regions of the world (IIASA-WEC, 1995, p.vi). In urban residential areas, population with access to gas for cooking, including natural gas and coal gas, has increased from 16.8% in 1980 to 61.7% in 1994 (State Statistical Bureau, 1995, p.314). Clearly, gas has increasingly replaced coal as a fuel for cooking in urban areas. It is an indication of the shift toward cleaner fuel in the residential sector. It can be expected that this trend is to continue in the future.

Figure 2. Commercial and Biomass Energy Consumption in China (1979-1992)



Source: Sinton, 1996, p.IV-16.

From 1980 to 1993, China had experienced a constant decline in energy intensities with an average of 4.1% annually. In the same period, primary energy consumption increased 5.1% annually, while GDP raised 9.6% per year. This trend reflects the structural and technological changes in sectors of the economy. A number of combined factors contributed to the overall improvement in energy intensities: shift in industrial structures toward less energy-intensive sectors, improvement in production efficiency and management skills. Most important, increasing international investment in industry has brought about not only financial resources, but also new technologies and devices which contribute to efficiency improvement in final energy consumption. However, the energy intensity of GDP in China is still 6 times higher than that in OECD countries, and 2 times higher than that in India (Wu, 1994, p.907). Against this background, the potentials for continued improvement in energy intensity is foreseeable, but the pace of energy intensity improvement will slow down, due to structural bottlenecks. Further decline in energy intensity depends, to a large extent, on the market adaptation and diffusion of new technological innovation, production process rationalization and end-use efficiency improvement in the industrial and commercial sectors. Diffusion of new technologies based on market competition holds the key in energy efficiency improvement in the coming decades.

The general trend is that China's energy structure will shift from the current situation of coal domination till an increasing share of hydroelectric and nuclear power, and new and renewable energy sources. According to a study from Tsinghua University, China, after 2020, the share of coal in primary energy supply will decrease from the current 75% to about 50%, and the share of hydropower and nuclear in electricity generation will increase from less than 5% to about 20%. By 2050, per capita energy consumption will be around 2-2.5 Tce (He, 1996, p.253).

3. INVESTMENTS AND FINANCIAL MECHANISMS

Gross domestic investment as percentage of GDP in China was 35% in 1980 and 42% in 1994. This is partly due to high private savings rate. China had an average gross domestic savings rate of 35% of GDP in 1980 and 44% in 1994. Hong Kong had an average savings rate of 31% in the 1980s (World Bank, 1996, p.212). This can be compared with the world average savings rate of 22% in 1993 (World Bank, 1995, p.179). Due to high savings rate, there exists a big potential to mobilize private savings from capital market for energy sector finance in the coming decades.

During 1980-1990, energy investment as a share of public sector investments in China was about 23%, of which 52% was invested in electric power generation, and the rest in oil and coal sectors (State Statistical Bureau, 1992, pp.28-29). There is a tendency that the share of energy sector investment in total public investment is declining. In 1993, it was 20%, compared with 29% in 1990. Total public energy sector investment was amounted at 85 billion yuan ($17 billion) in 1990. This figure had grown till 150 billion yuan ($26 billion) by 1993. This is a fast growth, as total investment increased 50% in just 4 years (Slinton, 1996, p.III-12). There is an indication that more capital is being allocated to the energy sector, mainly mobilized from collective- and private-owned industries. At the same time, state investment as a share of total energy sector investment is declining constantly from 65% in 1990 till 61% in 1993.

In the last decade, most energy investments came from public sector finance. Foreign private investment in the energy sector did not exist before 1990. It was only from the last few years that FDI in energy had grown substantially. This is mostly because of deregulation in the energy market and incentives provided by state investment policies. Due to public sector deficit, shortage of founds will be a major bottleneck. A shift toward mobilizing more private funds and foreign capital is inevitable. In this process, governmental policy could play a central role in shaping investment priorities. The main driving force in determining investment priorities will be the relative rates of economic returns for investment.

We have observed two diverging trends in Chinese energy sector investment the last one and a half decades: a steady decline of state investment in coal production from 26-29% in the early 1980s to about 15% in recent years; and an increasing share of investment in electric power generation from 34% in 1981 till 50% in 1993 (Sinton, 1996, III-14). Due to the high dependency of coal in electricity generation, this imbalance in development may have a long-term impact on energy supply. There may be a shortage of coal supply to electricity generation as what often happened in the 1980s when the gap was mostly filled up by the production increase from collective- and private-owned coal mines.[1]

Investment in energy conservation has been on average at 8.7% out of the total energy investment in the 1980s. More than 90% of the state investments were concentrated on building up production capacity. There is a particular favor of state planners who tend to give support to large-scale energy project development, such as the Three Gorges Dam project, which is projected to have an electricity generating capacity of 17 GW. Support for energy conservation is weak at the local and enterprise levels. Energy savings achieved through energy conservation have been insignificant.[2] This is a discouraging factor in attracting investment for small-scale, cleaner, and energy efficient technologies. Compared with

1 Coal production increase during 1990-1995 was mostly contributed by the output from collective- and private-owned rural coal mines, which accounted for 94% out of the total production increase (*People's Daily*, May 11, 1996, p.1).

2 During 1980-1988, total values of increased industrial output was amount at 715 billion yuan ($ 193 billion), to which energy production increase contributed 49%, structural adjustment (including import of energy intensive products and materials) 34%, and energy savings 17% (Yan, 1994, p.240).

investments in other sectors, such as consumer goods production and infrastructure development, which usually yield higher rates of return over investment, energy conservation is unlikely favored by most investors, unless strong policy support is in place.

It is expected that most of the energy investment will have to come from domestic sources, and the rest should be met through international finance. There is an indication that FDI is taking an increasing share in domestic investment in recent years. It has grown from 13% in 1993 to 19% in 1996. FDI is by far the main engine for economic growth. China has been particularly successful in attracting FDI, accounting for over three-quarters of the increase in investment flows into Asia and the Pacific region during 1991-1994. China has become the second largest recipient of FDI in the world since 1993, after the USA. During 1985-1996, FDI in China had grown from $ 2 billion to $ 40 billion. It is expected that FDI will increase to $ 50 billion in 1997 (UNCTAD, 1995, p.54).

Private domestic investments in energy have in practice been the main driving force in the coal-mining sector in China. From 1980-1992, output from local coal mines accounted for 67% of the total increased output nationwide. The share for the total output from collective and private mines changed from 45% in 1980 to 56% in 1992. This trend is further encouraged by deregulation in the energy sector. The general trend in the energy market is the decreasing role of the state investment, and the increasing performance of local governments and the private sector financing (Yan, 1994, p.2).[3]

We expect a freer market for energy production and trade. China currently has the share of 13% of the global capital flows (The World Bank, 1996, p.136). There will be more private investment in the oil and gas sector, such as on offshore oil and inland gas exploration projects. Coal resource exploration and production will be less attractive to private investors, due to thin profit margins by so far. In particular, we have seen a growing interest of foreign investors in building up electric power plants.[4] This disparity in investment may lead to coal shortage problem in the power sector in the long run. Rationalization of energy prices through increasing market competition will be a key factor to encourage more private investment inflows in the coming decades.

International development assistance also plays an important role in China's industrialization. However, ODA may not be able to grow substantially in the future, due to financial constraints in the UN system and in most bilateral aid agencies. In the past decade, about 20% of ODA were invested in the energy sector, mostly in production capacity building. In the future, it can be expected that stronger support for the environment and energy conservation from ODA will be provided, and meanwhile, prospects for investment increase in the supply side will be modest (Gan, 1997).

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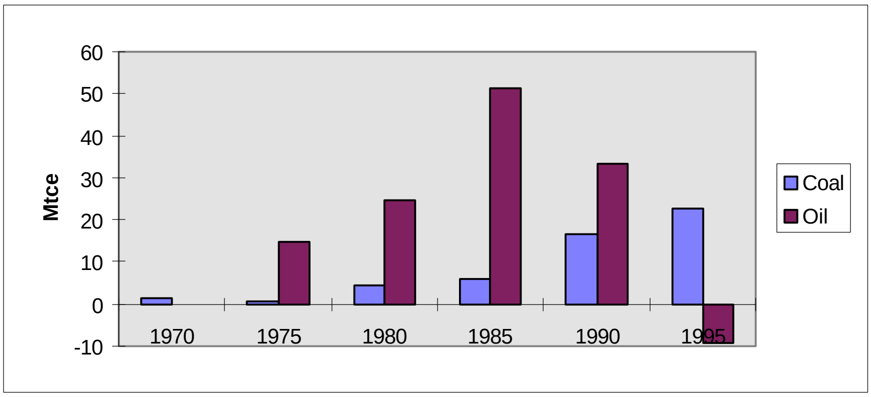
3 One example is the private fund raising for the Tree Gorges Dam Project. In 1997, $120 million bonds were issued to help finance the construction of the dam. The three-year bonds were sold out within five days (*Greenwire*, Feb.28, 1997).

4 One example is the Yangtze River basin where foreign utilities companies are attracted to invest in building up electric power plants. By 1994, total investment amounted to more than $ 1 billion with the total generating capacity of 4.1 GW (*People's Daily*, July 26, 1994, p.1).

4. ENERGY TRADE

There is a disparity in energy consumption and resource availability. In China, the coastal areas where the economy is taking off face more severe energy shortage problems than less developed inland regions. There have been two grand transitions in China's energy trade: increase in coal export, and decrease oil export. As shown in **Figure 3**, from 1970 to 1995, coal export increased from 1.3 million tons to 22.6 million tons. In oil trade, oil export increased steadily throughout the 1970s and peaked in the mid-1980s. There was a continuous decline in export thereafter. By 1993 China became a net oil importer and oil import reached 9.4 million tons in 1995. This is an important change in energy trade, indicating that China may become highly dependent on imported oil to sustain its industrialization and economic growth in the coming decades (Yan, 1994, p.154; *China News Digest*, Jan.14, 1997).

Figure 3. Net Energy Export of China (1970-1995)

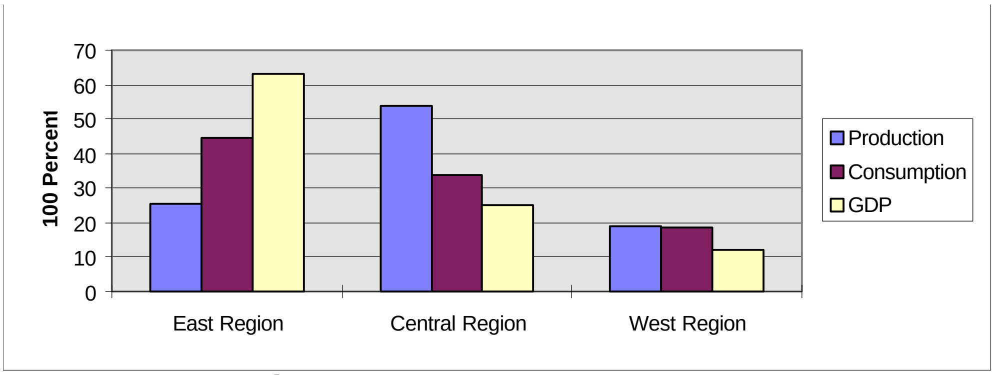


Source: Sinton, 1996, p.VII-4; BP, 1996, p.19.

There are two explanations to these changes. The first is the growth in demand. Transportation sector growth is one example. Passenger transport increased 2.5 times during 1980-1995. Road transport accounted for 65% of the total passenger transport capacities in 1980. It increased to nearly 90% by 1995. It implies an increasing dependency on automobile as means of passenger transport. The similar situation is seen in freight transport, through which 76% of goods were transported by road in 1995, increased from 69% in 1980 (State Statistical Bureau, 1996, pp.94-95). The second factor is the diminishing dependency of oil export as means of foreign currency earning, as manufactured products have replaced oil export as the major foreign currency earner. Very strong demand is pushing oil price higher in domestic markets, which has disinterested oil sells to international markets as well.

China will have to rely on imported oil and oil products in the future, because of the following limitations. China has a uneven distribution of energy resources, i.e., high energy production capacities and low energy consumption level in the Central region. By contrast, there are energy deficits in the coastal areas of the East region with higher levels of industrialization and energy consumption (see **Figure 4**). Potentials exist to import natural gas from the Far East region of the Russian Federation to the Northeast region, such as Liaoning Province, with high concentration of energy intensive industries. There are also opportunities to import liquefied natural gas from the Middle East to the Southeastern region in China.

Figure 4. Regional Comparison of Energy Production, Consumption and GDP in China in 1990



Source: State Statistical Bureau, 1992, p.17.

China's growth in GDP per capita and foreign-exchange reserves are likely to continue,[5] which could enable China to import more oil to meet high energy demand and substitute for coal use. From the environmental point of view, fuel substitution will permit China to reduce carbon dioxide (CO_2) emissions, as well as sulfur oxide (SO_2) emissions, so to reduce health effects and potential conflicts between nations in the Southeast Asian region.

[5] China's foreign-exchange reserves reached a record high by January 1997 with a total $ 110.6 billion, which was the second largest in the world after Japan. See: *The Economist*, April 12-18th, 1997, p.120.

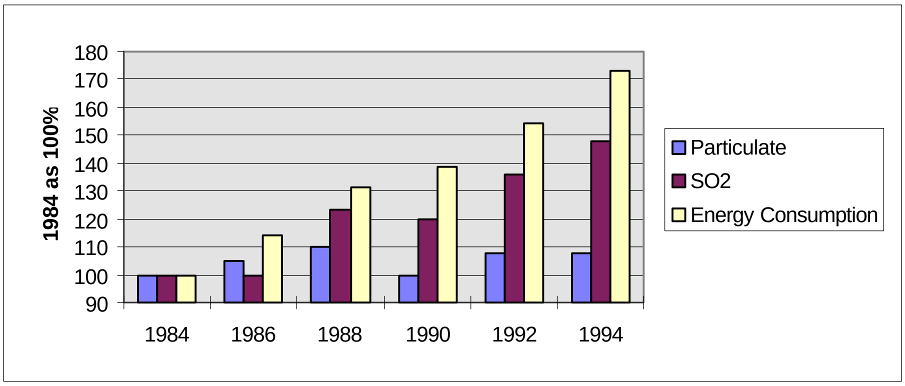
5. ENVIRONMENTAL CONSTRAINTS

Environment protection is evolving into a critical factor in determining the rates of economic growth and energy sector expansion. Energy consumption is increasingly shaped by environmental regulations. So is behavioral change of consumers with growing environmental consciousness. There will be an increasing influence of non-governmental organizations (NGOs) on environmental protection, supported by the emerging middle-class people who tend to care more for the environment. It can be expected that severe environmental damages in ecosystems and the human health will lead to stronger environmental regulations (*China Environmental Yearbook*, 1995, p.94), which is already happening with the increasing control of environmental pollution from small-scale rural *industries (China Environmental Reporter*, Vol.1, No.1, March 1997).

The most troublesome issue is, and will be, the extensive use of coal as the main energy resource. Pollution problems caused by direct use of coal, such as SO_2 emissions, might reach the critical levels that could go beyond the acceptability of the general public. Health effects of pollution may evolve into a strong social critique, and generate public protest. By so far, environmentally related public hearth problems have already drawn attention of the government, as indicated in an official report from the National Environmental Protection Agency (NEPA), National Environmental Protection Agency (*People's Daily*, June 1st, 1996, p.1). There are also potential regional and international conflicts, concerning long-rang transport of pollutants (Liu, 1993). In this respect, environment pollution will become an important limiting factor in determining future policies that might be undertaken in economic and energy spheres. In many respects, local environmental pollution problems could be weighted more than global environmental problems from the point of public concern. Therefore, measures to reduce local and regional environmental pressures, such as reduction of SO_2 emissions, may gain stronger public support than global environmental issues, e.g., CO_2 emissions reduction.

Another issue is air pollution, e.g., SO_2 and particulate emissions, associated with growing energy production and consumption. **Figure 5** indicates the trend of emissions increase in China during 1984-1994. Clearly, particulate deposition has been more or less under control with slower increase in early 1990s. It reflects the fact that more control measures are undertaken in industry to reduce particulate emissions. It also indicates the relatively low costs of reducing particulate emissions, especially for particulates removed during non-combustion processes. Further improvement may become more difficult, due to financial constraints and enforcement of the existing emissions standards, especially in small-scale rural industries. In residential areas, particulate emissions reduction related to direct-use of coal in households depends largely on fuel switching, i.e., from raw coal to coal briquettes, and from coal to gas and electricity. This will be the main transition in the future.

Figure 5. Energy Consumption, SO_2 and Particulate Emissions in China (1984-1994)



Meanwhile, SO_2 emissions have closely followed the trend in energy consumption. The main reason to explain the high growth rates in SO_2 emissions can be attributed to the relatively high costs of emissions control technologies and equipment. Coal washing is an important measure of removing sulfur dioxide (SO_2) from coal. Currently, only 14% of raw coal are washed and there was a decline of investment in coal washing capacities in the past decade. In addition, stack removal of SO_2 has been little practiced. These are the major causes to the increasing SO_2 emissions. Therefore, the general trend of SO_2 emissions is expected to follow coal-use patterns closely in the coming decades, if no radical policies are introduced to regulate SO_2 emissions.[6] Compared with eliminating particulates from coal use, reduction of SO_2 emissions will turn out to be more difficult to implement. In 1990, SO_2 Emissions in China already reached 15 Mt (Sinton, 1996, p.VIII-11), and increased to 18.3 Mt in 1994 (*China Environmental Yearbook* 1995, p.426). According to the Chinese scenarios, without controlling measures, SO_2 emissions will reach 44.6 Mt (high scenario), or 33.5 Mt (low scenario) by 2010. If control measures were implemented, SO_2 emissions would be at 36.2 Mt (high) or 25.2 Mt (low) by 2010 (Zhou, 1993, p.44-45). It is anticipated that growing investments on the environment in the future will help offset some environmental side-effects at the regional level,[7] but sustainable management of the environment will be more difficult than what is expected. According to Professor Zhou Fengqi, Director of the China Energy Research Institute, China will be able to stabilize its SO_2 emissions at the 2000 level only until 2010.[8] In this context, environmental conflicts related to SO_2 emissions and associated acid rain will be bound to increase in the future.

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6 From 1993, SO_2 emissions tax was introduced in 2 provinces and 9 cities in China, regulated by the Environmental Protection Committee of the State Council, which equaled to 20% of the total costs for SO_2 removal (*People's Daily*, June 3rd, 1993, p.3).

7 By 1994, China received $ 2.5 billion loans and grants from multilateral and bilateral sources for environmental protection projects. NEPA has announced plans to tackle pollution problems. A total amount of $ 22 billion will be put on pollution control by the year 2000. In addition, more than 50,000 polluting factories had been ordered by NEPA to close down in late 1996 (*China News Digest*, Jan.12, 1997).

8 Based on a discussion with Professor Zhou Fengqi in March 1997.

6. THE ROLE OF INSTITUTIONS IN ENERGY CONSERVATION

Institutional aspects of energy policy-making can be understood from an actor-network perspective, which perceives institutions as functional actors within policy domains. The role of institutions is different, depending on their identities, conflicts of interest, as well as power relations. Each institutional actor plays a particular role in shaping decision-making processes. Policies made are the accumulated results of agreements and compromises between sectoral institutions. **Table 1** gives an overview of the characteristics of the institutional actors involved in energy policy-making and implementation in China. They include four types: government bureaucratic organizations, the scientific community, the energy industry, and environmental protection bodies.

Table 1. Characteristics of Institutional Actors in China

	Institutional		Actors	
Organizations	Bureaucratic	Scientific	Industrial*	Environmental
Character	Authoritarian & Hierarchial	Scientism	Technocratic	Environmentalism
Interests	Political Control Management liability	Prestige in S & T Achievements	Profit-making Large-scale Development	Environmental Protection & Natural Resource Conservation
Institutional Goals	Economic Growth Political Stability	Scientific Awards Publications Technology Innovation	Meet State Planning Targets & fulfill Market Demands	Pollution Control & Prevention
Instruments	Planning, State Intervention & Policy Adjustment	Peer Review Research Evaluation Tech. Assessment	Command Management	Regulation Pollution Charge EIA**

* Including governmental ministries and associated state-owned industrial corporations
** Environmental Impact Assessment

There exist conflicts of interest between two types of organizations: energy industrial enterprises and environmental protection agencies. These conflicts reflect in different objectives for energy production and environmental protection, as they represent two seemingly conflicting, according to conventional wisdom, social values. Industrial organizations tend to see their values being realized through increase in production capacities, resulted from their investments in the supply side of development, which, in return, provide them with opportunities to monopolize the industry, and affect the behavior of other industrial institutions. They tend to believe that energy conservation serves little in this end. By contrast, environmental protection agencies tend to perceive their roles in energy conservation as serving more of their interests than clean-up measures. They also see the opportunity of increasing their influence through regulating industrial behavior, as environmental agencies have been less capable of dealing with cross-sector issues, because of barriers between sectors.

In between lies the governmental bureaucratic organizations and the scientific community. The former set up the energy conservation policy as an alternative solution to the crisis caused by conventional development modes. They understand the uncertainties and risks of not applying conservation measures. Under the current trend of declining central governmental control, they perceive energy conservation as a means to increase their influence and coordinating power. The scientific community functions as a mediator to influence decision-making. Their purposes can be realized through coordination in the development of energy conservation technologies, and they also benefit from the allocation of R & D resources in this field.

During 1985-90, 300 billion yuan ($62.7 billion in 1990 dollar) was invested in energy sector development. In energy conservation, only some 4.7 billion yuan ($1 billion) was invested in technical innovation, and 11.4 billion yuan ($2.4 billion) for capital construction (1.6% and 3.3% of the total investment, respectively). The overwhelming majority of the capital was used for increasing energy production outputs (Mao, 1992, p.91). In clean coal sector, for example, recent years have seen a drastic decline in capital investments in coal washing and separation development.[9] From 1987 to 1990, capital investment in coal washing and separation dropped from 4.2% to 1.3%, i.e., from 253 million yuan ($52.9 million) to 100 million yuan ($20.9 million), as a proportion to the total investment in the coal industry. Meanwhile, investment in coal production increased by 71% from 5.7 billion yuan to 9.8 billion yuan (State Statistical Bureau, 1991, p.27).

The main problem is related to energy policy. The coal production plans set up by the former Ministry of Energy took little account about the quality of the coal produced, but taking quantity as the main parameter of production output. Due partly to this problem, coal washing capacities cannot be fully utilized. The large quantity of SO_2 contained in raw coal is emitted into the air through direct coal burning, which has led to widespread acid rain, particularly in the Southwestern region, and increasingly in the Northeastern regions, such as Beijing.[10] Meanwhile, China had to import large quantities of sulfur from abroad for use in medical and chemical production (Qu, 1989, p.197). Clearly, this policy reflects a conflict of interest between production and environmental institutions.

Energy conservation in the early 1990s has evolved higher in policy agenda, and become the top priority in energy policy, partly as a result of increasing environmental awareness and pressure. Environmental agenda also become more complex in implementation, compared with the beginning of the 1980s. The issue of energy conservation has transformed the values and attitudes of many policymakers, and the behavior of governmental institutions. The government has developed a long-term vision of conservation objectives and the potential measures to be reinforced, including reinforced regulatory and financial instruments (*China Macro-economy*, April 25, 1997). The policies developed have covered almost every sector of the economy and affect the daily lives of the general public. The inception of global environmental protection in national policy-making has given rise to a new dimension in energy conservation, and the energy policy in general.

The Chinese government has devoted substantial attention on energy conservation. Policies were formulated and implemented simultaneously, although there were dissatisfactions over policy performance (Zhu, 1992, pp.133-39). The factors that have limited the energy conservation policies being implemented effectively, and slowed down sector response to important technological innovations for energy conservation are related to institutional barriers that constitute the development of energy conservation policies (see **Table 2**).

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9 Technical processes to reduce the ash content of coal which can subsequently lessen the burden on transportation systems and increase coal combustion efficiency. Thus coal washing and separation can serve two objectives of energy efficiency improvement and environmental protection.

10 According to an interview with a governmental official at the SSTC, conducted by the author in April 1994.

Table 2. Institutional Barriers for Energy Conservation Implementation in China

Institutions	Barriers
Government Bureaucratic Organizations	Misleading in Macroeconomic Policy Distortion of Energy Prices
The Scientific Community	Lack of R & D Capacity Slow Response to Market Demands
The Energy Industry	Lack of Economic Incentives and Disincentives, Sectoral Bias
Environmental Protection Agencies	Lack of Regulatory Measures and Bargaining Power

The two bottlenecks - energy shortage and the environmental pollution problems - have shaped the behavior and attitudes of those institutions, which are involved in the development of energy conservation policies. Although, energy conservation policies have been developed and implemented for more a decade, there are still on-going debates about how to balance the production and the conservation objectives. This is very much related to the conflicting institutional interests, served by representatives of each group. One example is the conflict between state planners and the scientific community, such as the Energy Research Society, as each represents different values and preferences.[11]

The problems that often block the development of energy conservation policies and the emergence of new technology alternatives are, in part, related to sector interests and their preference in priorities. The implementation of energy conservation policy requires closer inter-sector cooperation. However, there has been a lack of incentives or disincentives available for energy conservation policies to be implemented effectively across institutions, due to the lack of coordinating mechanisms. The NEPA (National Environmental Protection Agency) has the mandate in environmental affairs, but with limited power to intervene in energy matters. By contrast, state-owned industrial organizations could care less about the environment, because of the lack of environmental regulations, e.g., solid fuel combustion standards for electric power plants. Due to the inertia that favor large-scale projects supported by the public finance, the SPC (State Planning Commission) was very much preoccupied by the economic-growth dilemma, and disturbed by energy shortage problems. Energy conservation was often regarded as a complementary solution to energy supply development.

The scientific community has a different set of problems in dealing with energy conservation policies. In general, the current capacities of R & D institutions are less capable in developing new and competitive technologies and reliable products that can satisfy the growing market demand (Shi & Chen, 1992, p.145), which consequently forces many enterprises to turn to import expensive foreign technologies for more energy efficient equipment. This problem is partly related to the traditional institutional culture that tends to ignore the market value of R & D products. In addition, the existing institutional structure provides little incentives for R & D personnel to devote themselves to new innovations, as results of energy conservation are difficult to measure, compared with supply-oriented options. This situation is currently changing, due to the rapid transition toward market-oriented reform.

State-owned energy industrial enterprises have different sets of problems. Their primary intention is to fulfill government planned production quotas and targeted rates of growth. It

[11] Commented by Wang Qingyi, Executive Director of the China Energy Research Society in an interview by the author conducted in April 1994.

also becomes urgent for them to learn how to respond to market demand and consider more about rates of economic returns for their investments. For those managers in energy-related ministries and corporations, their main concern is to solve energy shortage problems. Little efforts would be undertaken for energy conservation, unless there were certain economic incentives available for value creation, or regulatory disincentives for environmental protection. However, both governmental bureaucratic organizations and environmental institutions have not been able to provide cost-effective incentives, e.g., through macroeconomic policy, and disincentives, e.g., environmental regulations, to encourage energy conservation policies being implemented effectively. Moreover, energy ministries and corporations tend to preserve their sector interests through monopoly in power supply. The higher the production outputs they achieve the stronger the institutional power they could hold. Energy conservation cannot serve this need in large-scale and short-term span, because it requires higher capital investments and longer R & D periods.

Environmental organizations have for a long time been preoccupied by the task of cleaning up the environmental problems caused by rapid economic development and the wasteful use of energy resources. It seems that the influence of the NEPA in energy conservation has not been as strong as it should be, due to the lack of legislative power on the environment, and also the degree of its influence upon industrial organizations. Throughout the 1980s, efforts to reduce environmental destruction focused mainly on enforcing environmental management capacities, i.e., command management as a major enforcement instrument. This instrument is useful, only when complemented by other instruments such as economic and regulatory measures. The slow development of the regulatory measures on the environment has contributed to the reluctance of moving to an environmental-oriented technological development path in industrial sectors, despite the progress made in this field. Although, the power of the NEPA has been increasing, the overall influence of the NEPA on sector policies is still limited. This is especially visible when cross-sector bargains are involved and sector matters are beyond the traditional mandates of the NEPA. Compared with the State Science and Technology Commission (SSTC), the NEPA seems less capable of intervening or coordinating energy R & D activities conducted in industrial organizations (Gan, 1997).

Strengthening management control has been the most commonly used tool to promote energy conservation. It includes:

1. Integrating energy conservation projects and programs into national and regional plans, to ensure funding and key resources needed for project implementation.
2. Establishing personal responsibility systems at different levels to ensure project implementation.
3. Introducing corresponding industrial policies to restrict high energy intensive small-scale industrial development.
4. Organizing demonstration projects to disseminate energy conservation technologies at the local level. There have been efforts to strengthen regulatory measures. In 1979-90, 28 regulations were stipulated by the State Council, the State Planning Commission (SPC), and various ministries. And more than 600 energy standards were introduced and enforced, simultaneously. Energy conservation standards for 25 sectors were also set up.

Financial sectors were mobilized to provide resources for energy conservation projects. This includes soft loans, tax deduction or exemption for producing energy saving equipment and products and for importing energy efficient technologies. During 1980-90, investments in energy conservation totaled some 20 billion yuan ($4.2 billion), which led to an annual 50 Mtce (million tons of coal equivalent) in energy saving capacity.

In the early 1980s, energy conservation policies focused on those projects that could provide quick economic returns. Mature technologies, mostly domestically developed and manufactured, were adopted in such areas as lower energy efficient industrial boiler upgrading, and comprehensive waste heat utilization, etc. These projects had relatively good rates of economic return (1-2 years). Meanwhile, investments also aimed at higher energy efficiency improvement, such as co-generation, district heating, coal gasification in urban areas, and coal washing and separation.

In the mid-1980s, energy conservation policies were strengthened and evolved in five directions:

1. To disseminate key energy conservation technologies such as co-generation in power production, small cement industrial energy technology innovation.
2. To import advanced energy technologies from industrialized countries (more than 70 state-organized key technology transfer projects were involved).
3. To shift from single technology innovation to systems innovation to improve energy efficiency of the entire energy systems and the infrastructure.
4. To investigate higher energy intensive industrial enterprises and equipment.
5. To monitor energy production and consumption patterns nationwide.

From the late 1980s to the early 1990s, new energy technology R & D were emphasized and demonstration projects conducted, aiming at innovative technologies to be disseminated at the enterprise level. As part of the shift toward a market oriented economy, from 1992, policies were formulated to rationalize energy prices and to make them closer to the market value, at the realization that distorted energy prices in the 1980s were the main obstacle for achieving energy conservation objectives (Pu, 1992, p.71).

In this period, substantial energy efficiency improvement was achieved with the energy consumption of per 10,000 yuan of the generated GNP reduced by 30% from 13.4 tce (tons of coal equivalent) in 1980 to 9.3 tce in 1990. And some 280 million tons of coal (standard coal) were saved. The average annual rate of energy savings reached 3.6% (Shen, 1992, p.28). The majority of the 25 industrial sectors experienced a decline in energy consumption per unit of GNP produced (tce/100 million yuan) during 1985-90 (State Statistical Bureau, 1991, p.246).

From 1981-90, the implementation of energy conservation policies, through the support for R & D projects, led to substantial industrial technology innovation and advancement. More than 1,000 large projects were completed, among which 300 were state sponsored projects. Large-scale industrial technology innovation took place in a number of energy intensive industrial sectors. Projects on district heating and industrial waste heat utilization in urban areas have had widespread social and environmental benefits.

Science and technology (S & T) are having important impacts on China's policy systems than ever before. At the State Council, an important decision was made to respond to the international pledge for sustainable development. In 1992, ten policy measures were stipulated by the State Council, in which cleaner energy technology development was given a high priority. Although measures have already been taken in the past, lack of economic incentives and relevant regulatory measures has handicapped technological research and development (R & D), and diffusion of technologies in society.

Another impact of energy conservation policy is on industrial behavior. Many industrial enterprises, particularly large state-owned companies, have for a long time been reluctant to technological change, due to the lack of incentives, disincentives, and market competition. Pushed by energy conservation policies, industries have come to realize, though still slowly, the rational for investing in energy saving technologies and end-use efficiency (Ministry of Energy, 1992). Many structural changes are currently underway, which will have a profound impact on the industrial sector in the years to come.

7. CONCLUSIONS

China is in a period of rapid transition in its development. Although uncertainties and tensions are perceived, there are positive signs of development. Main issues in the energy sector in the future will be how to balance energy development with environmental protection and resource redistribution. Several issues are important in energy policymaking and implementation. First, total fuel mix will be diversified in the future. The share of coal in primary energy production and consumption will increase by 2020 and diminish gradually thereafter, to be replaced largely by gas, nuclear and renewables. Second, China will become a potentially big oil importer, due to growing market demands and resource limitations. Export of coal will increase in the long run. Third, SO_2 emissions will become potentially larger in the near future, because of the speed of economic growth and lack of effective control measures and investments. Fourth, CO_2 emissions will increase to a large extent, however, measures to reduce CO_2 emissions are unlikely to be effective in the near future, because of economic and institutional bottlenecks, and political preference to solving local environmental problems. Fifth, there exist huge investment potentials for energy development both from international and domestic private investment funds and, meanwhile, the role of official development assistance will not be substantial. Sixth, energy efficiency will continue to improve, associated with gradual decline in non-commercial energy use and increasing share of commercial energy in final consumption. Finally, energy conservation holds the key for sustainable energy development, which should be promoted at the national and local levels with a focus on demand-side management. To achieve conservation objectives, financial and regulatory instruments need to be further developed.

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