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Global Warming and Options for China: Energy and Environmental Policy Profile

Gan, L.

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Foreword

Climatic change is a topic shared by most of the scientific community. Energy systems emissions greatly contribute towards this phenomenon. This is the reason why the linkage between energy and climate is now the focus of many global and national studies. The adverse impacts of a climatic change on human activities caused by global/regional energy systems, as well as the requirements for restructuring these systems to reduce climatic impacts, are still uncertain. It is difficult to stabilize or reduce the atmospheric concentration of energy-induced emissions and, at the same time, keep energy as the driving force needed for social and economic progress in the developing world.

From this viewpoint China is the most controversial region, with an increasing population, an inevitable growth in energy demand, and ambitious plans for economic development and improvements in living standards. It lacks low-carbon fuels but is rich in coal, which, when burnt, will emit the maximum CO_2 per unit of useful energy. Today China produces more coal than any other country. Its future coal production could increase manifold and reach the level of today's coal production worldwide. Therefore the present Chinese energy policy is of great interest for the analysis of the future energy situation on a global scale and its related impacts on the climate.

Gan Lin, who participated in IIASA's 1990 Young Scientists Summer Program, analyzes in this report the energy-ecology situation of China and reviews the governmental policy toward reducing air pollution and environmental degradation, including a greenhouse gas induced climatic change. The paper fills, to some extent, the information gap on what is going on in Socialist countries, and particularly in China, with respect to energy and the environment.

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1. Introduction

Since the last few years, the issue of global climate change has evolved from a merely scientific debate into policy arenas at both national and international levels. A number of governments and international communities, particularly those in developed countries, have started looking for concrete policy options in dealing with global carbon dioxide (CO_2) emissions reduction.[1] Considering the difficulties involved in choosing workable policy options, it has been widely recognized that if any carbon reduction policies and agreements were to be made, it would be of vitally importance to include the active participation of both developed and developing countries.

Recently, there emerged a growing consciousness within climate change concerned scientific communities of the fast growing pace of energy consumption and related CO_2 emissions in the developing countries. Clearly, this trend implies the crucial fact that the increasing CO_2 emissions from the developing world may offset the potential achievements of CO_2 reduction that may be obtainable from future actions by developed countries. In such a context, it would be reasonable to assume that without active participation of the developing countries, global CO_2 combating actions would not possibly succeed in the long run. In order to stimulate positive responses from developing countries on joining the global carbon reduction movement, it is crucial to understand the present situation of the developing countries in terms of the dynamics and driving forces in their energy sector development and related CO_2 emission problems. In a broader sense, it is also important to investigate the interrelationships of economy-energy-environment policies in developing countries. A better understanding of these issues may provide valuable inputs in formulating future CO_2 eliminating strategies. It may also offer a key for further international negotiations on achieving CO_2 limit agreements between nations.

This report attempts to give a comprehensive review of current perspectives on energy/environmental problems and policies in China during the last ten years. It is assumed that China, as one of the leading countries in terms of energy production, consumption and CO_2 emissions, has an important role to play in global carbon limiting actions in the years to come. It is expected that this study may serve as an example to show how developing countries, such as China, are transforming their economies in an era that is involved with considerable complexities and uncertainties, despite the major achievements on their path toward industrialization. Particularly questionable is their practice, with China as a typical example, on developing energy intensive economies. Should developing countries necessarily repeat what the developed countries had done in the past towards a similar pattern of economic growth and energy development? What potential alternatives exist as optimum solutions to the energy/environment dilemma faced by the developing countries? What major constraints and limitations remain in developing countries, particularly on CO_2 emission related energy and global climate change issues?

This paper attempts to answer the above questions through a concrete case study of China, by focusing on policy issues as the central point of the discussion, apart from some quantitative analysis of the energy and CO_2 emission problems. Detailed analysis emphasizes the overlapping relations between energy/environmental policy-making and performance at national level. It is divided into five chapters, and the emphasis is on chapter 3, 4 and 5.

The second chapter serves as a starting point by giving a general background of the characteristics of economic development and major policy changes in China during the last ten years (1979-89). This period is particularly important in contemporary China's history because of the dramatic political changes of the late 1970s, which propelled the society into a new period of economic development and reforms. By analyzing different phases of development, it gives a survey of the driving forces behind energy sector development and the associated environmental problems.

The third chapter analyzes the characteristics and problems of energy demand and supply in China by breaking down different economic sectors (industry, agriculture, transportation and residential/commercial sectors). The problems in coal production and use are given particular attention, due to the unique resource situation in China. In addition, the problem of energy inefficiency in China's economy is the most critical topic discussed in this chapter. Through comparison with other countries in energy efficiency improvements, the reasons behind energy inefficiency in China are illustrated, not only the economic dimensions of the problem, but also the social, political and technological perspectives of energy efficiency improvement. The major achievement in energy efficiency improvement and the measures adopted in different economic sectors are discussed, such as the development of urban coal gasification, rural energy saving, etc. The main energy policies that shape the sector's development are highlighted, such as the problems of decentralization of energy production, the performance of energy conservation policy, energy price problems and energy R & D systems and organizational structure.

The fourth chapter focuses on the problems of CO_2 emissions by giving a historical review of CO_2 emissions by linking up the impact of economic policies and political development in the country during 1950-89. It also surveys the CO_2 emission problems by investigating different sources of CO_2 emissions, including fossil fuel combustion, biomass burning and deforestation. By breaking down the sectors of economy and sub-sectors in industry, the co-relations of different types of fossil fuels used in each sector are examined, which gives an insight into the most important CO_2 contributors in China. Moreover, the future trends of CO_2 emissions are projected, according to various scenarios.

The fifth chapter is mostly devoted to describing policy performance within government environmental policy-making and implementation in the last ten years. It shows how the major policy measures, such as Environmental Impact Assessment (EIA), Urban Environmental Quality Assessment and Environmental Technology Policies are formulated and implemented, particularly at regional levels. The problems of fast expansion of rural industry in relation to environmental consequences are analyzed. It also stresses the obstacles in realizing expected environmental protection objectives in China, due to bureaucratic control, poor management, economic disincentives of environmental policy and the virtual role of public participation. This chapter attempts to link the analysis with the preceding chapters by suggesting a major policy adjustment: from producing more coal to improving energy efficiency.

Finally, the report concludes by giving several policy recommendations: a major policy adjustment from "supply-oriented" energy policy to "user-oriented" energy policy with emphasis on energy efficiency improvement; energy price system reform toward market-oriented energy price mechanism; improving the performance of international clean technology transfer and information exchange on global warming issues; intensifying renewable energy sources development and eco-agriculture/afforestation as alternative strategies for energy sector development and CO_2 emissions reduction.

2. Economic Development in the Last Ten Years

Economic reform and development has witnessed more than a decade in China since it was begun in December 1978. The initial intention of the reform program, as stimulated by the relative relaxation in political systems after Mao's death in 1976, was to bring the economy out of the stagnant situation caused by the "Cultural Revolution" during a ten-year period (1966-76), and to redress sectoral imbalance, raise productivity and improve management efficiency. The original objectives of the so-called "Four Modernizations" reform program (industry, agriculture, defence and science/technology) aimed to quadruple GDP output and raise per capita income from less than $200 in 1978 to $1,000 by the year 2000 (a few years later, the target was changed to $800).

As a decade passed by, the drastic economic reform in China seems to have come to a period of stagnation again at the beginning of the 1990s. This is a clear indication of the phenomenon of "political shaping" of economy in China, marked by the Tiananmen event in June 1989. However, what are the experiences we can draw from this ten-year economic development exercise in China, particularly regarding economic development related to the energy/environment sectors? It is not an intention of this paper to give an overall economic review of the past development, but rather a brief description of the main features and existing obstacles during the economic reform period.

Characterized by the "open door' policy and the introduction of a partial market mechanism into the centrally-planned economic system, the economic reform program in China consisted of several distinctive measures as follows,

- Decentralizing economic structure by delivering more decision-making power to local governments and production units in order to encourage more active involvement in economic activities;
- Stimulating initiative and higher productivity of production units by allowing them to retain more revenues as well as the free trade of their products beyond the state planned quota;
- Introduction of a "dual price" system, consisting of the state fixed product prices and complementary free market price;
- Allowing private and collective businesses to expand on a widespread scale in both urban and rural areas with less governmental intervention; and
- Opening up the coastal areas to international economy with operations of joint ventures and foreign business, etc.

Notably, the above measures brought about substantial growth in the economy as a whole. From 1980-87, the average GDP growth marked 10.4% annually,[2] and this figure was exceptionally high among both developed and developing countries in the same period.[3] Also, per capita income increased from 315 yuan in 1978 to 853 yuan in 1987, an average annual growth 13.2%.[4]

At sectoral levels of the economy, the growth in industry was 13.2% annually between 1980-87, compared to 7.4% in agriculture and 7.6% in service sectors.[5] **Figure 2.1** shows the trend of development in agriculture and industry during 1978-88. It is obvious that heavy industry development had experienced inconsistent growth during this period, particularly in the early 1980s. This problem is mostly attributed to the economic readjustment policy effected during 1979-81, aiming at reducing sectoral imbalance.

One of the important features embodied in the past ten years' economic development is the fast expansion of small- and medium-scale rural enterprises, which are mostly owned by private and collective township and village enterprises and businesses. From 1980-87, the number of enterprises rose from 1.4 million to 1.6 million. And the number of employees increased from 30 million to 47 million, registering an absolute 57% growth.[6] In other words, small/medium-scale industries had created 2.4 million jobs in rural areas each year during this period. This is clearly one of the positive aspects of the implementation of the decentralized economic policies.

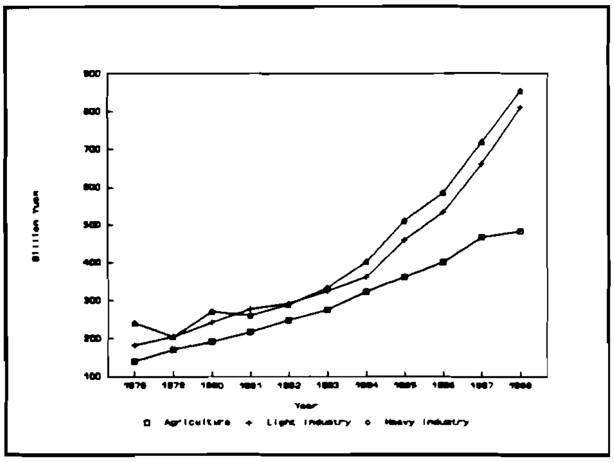


Figure 2.1 Gross Output Value of Agriculture and Industry in China*(1978-88)
Source: *China Statistical Abstract 1988*, p.8; and others
* At 1987 prices

In 1987, 71% of the employees in small-scale enterprises were involved in industrial activities. It is noteworthy that the total increase of GDP during the last decade has been very much contributed by the small- and medium-scale industries. For instance, the gross output value of industry almost tripled from 497.2 billion yuan ($105.6 billion) in 1980 to 1,380.6 billion yuan ($293.1 billion) in 1987. And the share of the output value by small- and medium-scale industries has increased from 5.9% in 1980 to 15% in 1987. By contrast, the share of output value by state-owned industries has decreased dramatically from 80% in 1980 to 60% in 1987. In terms of average annual growth rate on production output value, small-scale industries accounted for 29.7%, compared to 11% in the state-owned industries.[7] This development of fast growing small-scale collective and private industries reflects one of the important governmental policies of the economic reform. However, there remain many problems in small-scale industrial development; as given by an UNIDIO (United Nations Industrial Development Organization) report and some other sources, the problems of out-of-date technology and inefficiency in production process constitute the major bottlenecks in realizing consistent development in this sector.[8] Arguably, there are also severe problems in energy inefficiency and environmental pollution created by small-scale industrial development, which will be discussed in the following chapters.

It can be observed that the major economic growth in China during the last ten years' reform is attributed mostly to increased investment, rather than production efficiency improvement and increased productivity,[9] as indicated in **Figure 2.2**. It is clear that the investment in heavy industry has been too fast to control, which consequently created persistent contradictions in production demand/supply, due to the severe shortages of raw materials, power supply, transportation and communication capacities.

Another important feature of industrial policy is the so-called "profit-sharing" measure that allowed the large state-owned industries to retain a fixed proportion of their total profits for reproduction expansion and workers' welfare. The rates of the shared profit between enterprises and the state government depended on the production performance of the industry enterprises.[10] This policy in practice encouraged enterprises to work out their own ways toward the most profit-making measures, carelessly about by what costs and means, which in fact created a problem of "short-term behavior" in enterprise production management performance.

Having realized the shortcomings of the profit-sharing policy, another policy called "economic responsibility system" was introduced in 1981. Under this policy, enterprises negotiated for annual profit remittance quotas with their superior agencies. This policy enabled enterprises to retain 40-100% of the above quota profits. Through implementing this policy, targeting for profit-making has become a common phenomenon among industrial enterprises.[11] As one of the attempts to improve the above policy performance, another policy called "substituting taxes for profits" (ligaishui) was introduced during 1983-85. Under this scheme, all large- and medium-sized enterprises were required to pay taxes for their profits. The intention of this policy aimed to change the enterprise behavior on short-term performance for profit-making.

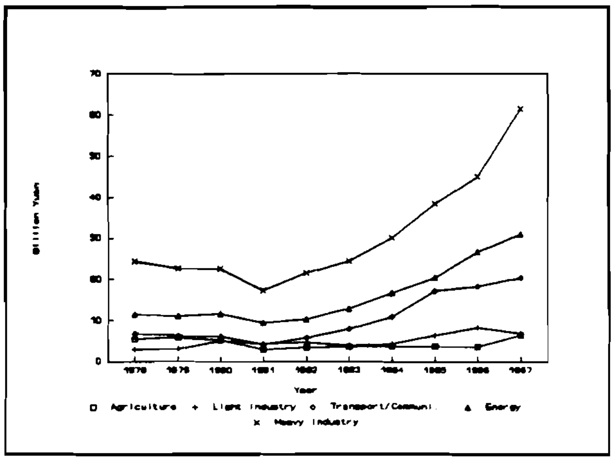


Figure 2.2 Comparison of the State Investment in Economic Sectors (1978-87)
Source: *China Statistical Abstract 1988*, 1989, p.67

It has been argued that reform in state-owned industries has failed to meet the targets of reforms, such as to raise productivity and improve efficiency.[12] However, there existed different problems in small-scale industries. In the mid-1980s, a contract system was introduced that allowed individuals and collectives to "rent" enterprises for a period of around 3 years, with the contractors responsible for production operation and profit-making. The most visible problem in implementing this policy is also the "short-term behavior" that focuses on profit as a major criterion for measuring success.

Despite the main achievements in economic growth, severe imbalances existed in different sectors. As indicated in **Figure 2.1**, the growth of agriculture output was much slower than industry. There are several reasons behind this phenomenon. The problem of inconsistent investment is one of the stimuli in creating sectoral imbalance. From 1980-87, the share of agricultural investment out of the total investment has decreased by more than 100%, and the share of investment in 1986 was less than one-third of that in 1978. By contrast, heavy industry had traditionally occupied the biggest share in industrial investment (49% in 1978). The investment in heavy industry had decreased dramatically by the end of 1981, due to the effect of structural adjustment, but it increased again afterwards, and particular fast growth shown after 1986. Obviously, the fast growth in heavy industry has and will put greater pressures on raw materials and energy supply, transportation systems, etc.[13]

The Chinese economy has experienced two readjustment periods in the last ten years, due to the "over-heating" of economic growth. One is the policy implemented between 1979-81 when major structural adjustment took place in order to reduce investment in heavy industry, and release the burden on infrastructure and raw materials supply. However, this readjustment has not been able to solve the problems fundamentally, and industry growth rose rapidly after 1984. When Industrial economy witnessed 14% growth in 1987, policy-makers had to again tighten the control of the economy by applying monetary and fiscal measures to "cool" the economy growth.

The failure of the central planners to control the pace of economic development has led to another readjustment policy initiated in late 1988 and early 1989. It implied in fact a policy shift toward more centralization and governmental control, and this has been performed periodically during the forty years practice in economic development.[14] As the former party Secretary-General Zhao Ziyiang put it in march 1989, "We are prepared to spend two years or more as an expense to pay for reducing the speed of the economic development in order to solve two problems: the readjustment of economic structure and the means of readjustment at the macro-level [national level]. The purpose is to find out the ways of avoiding a situation of chaos while relaxing restrictions, and of rigidity while restricting regulations."[15] Unfortunately, this commitment was unable to come into practice, due to the "political chaos" (Tiananmen Event) in the following summer.

3. Trends in Energy Sector Development

Recently, there emerged a growing concern in industrialized countries, particularly in scientific communities, about the problems of China's energy development and the associated impacts to global environment, such as CO_2 emissions, in relation to global climate change.[16] There is a clear indication that tensions are arising rapidly in China, concerning the "co-impact" between energy development and the corresponding environmental costs, and vice versa. In this respect, there remains a need to examine carefully the problems and dynamics of energy sector development, current energy policies and performance. In particular, emphasis will be given to the roles energy efficiency and conservation may play in future energy systems development in China.

3.1. Energy Demand and Supply

Energy plays an important part in China's industrialization process. Regarded as a priority area in national economy and planning, primary energy production has been one of the slowest growing sectors in China in the last ten years, with an average annual growth rate of 4.8%, compared to the average annual GDP growth rate of 9.3% during the same period. During 1980-87, industrial sector growth was much faster at 13.2% annually, with agriculture and service sectors growth at 7.4% and 7.6% respectively.[17] By contrast, energy production has lagged very much behind. Primary commercial energy consumption increased from 443.5 Mtoe (million tons of oil equivalent) in 1979 to 664.5 Mtoe in 1989, an average growth of 4.1% annually, which marks China the third largest energy consumer in the world after the USA (1967.8 Mtoe in 1989) and the USSR (1389.4 Mtoe in 1989). In other words, China consumes about one-third of the amount of energy consumed in the USA and one-half of that in the USSR.[18]

In terms of per capita energy consumption, China ranked at moderate level as No.59 in the world with 0.6 Toe (tons of oil equivalent) in 1988. This figure was No.2 among the group of low-income developing countries (per capita GDP at below $500), which was 1.5 times higher than

India and 4 times higher than Kenya. Even compared with the group of middle-income developing countries (per capita GDP between $500-2,000), China's per capita energy consumption is higher than most of them (No.13 out of 34). It can not, of course, be compared with the advanced countries, since China only consumes per capita about 8% of the energy consumed in the USA and 17% of that in Japan.[19]

The energy balance of China in 1985 (commercial energy sources only), as shown in **Table 3.1**, may serve as a point of departure for analyzing the characters and driving forces of China's commercial energy sector development, particularly on the pattern of energy demand and supply.

Table 3.1 Commercial Energy Balance Sheet of China in 1985* (Mtoe)

Energy Product.	Coal	Oil	Gas	Hydro**	Electr.	Heat	**Total**
Production	433.6	127.1	11.0	20.6	-	-	592.4
Import	1.2	0.9	-	-	0.1	-	2.2
Export	-4.3	-36.8	-	-	-	-	-41.1
Stock Change	-16.1	2	-	-	-	-	13.7
Primary Energy Consumption	414.4	93.7	11.0	20.6	0.1	-	539.8
Electricity	-75.3	-14.7	-0.5	20.6	35.3	9.1	-66.7
Distribution & Transf. Losses	-6.7	-	-	-	-2.6	-	-9.3
Others	0.1	-9.4	-2.9	-	-3.5	-	-15.6
Final Energy Consumption	332.6	70.2	7.7	-	29.3	9.1	448.2
Industry	189.0	37.1	6.5	-	21.8	7.2	261.6
Transportation	11.9	12.0	0.02	-	0.5	-	24.4
Agriculture	19.7	9.2	-	-	3.6	-	32.4
Resid/Comme***	111.9	11.5	1.24	-	3.3	1.9	129.8
Electricity Generated(TWh)	266.3	52.0	-	92.4	-	-	410.7

Source: *World Energy Statistics and Balances 1971-1987*, 1989, Paris: OCDE/OECD, p.366
* Commercial energy sources only, and non-commercial energy consumption was estimated at 130 Mtoe in 1985;
** Primary electricity, including other renewable energy sources; *** Including public services and other end users

Energy Demand It is obvious from the above table that coal and oil are the major fossil fuels supplying China's energy demand, which accounted for 76.8% and 17.4% (all together 94%) respectively, out of the total primary energy demand in 1985.[20] In particular, coal, as a major fossil fuel, is considered as the "backbone" of China's energy system and economic infrastructure. (More detailed discussion on the role of coal will be given in **Section 3.2**)

During the last ten years, the share of coal in total primary energy consumption has been increasing gradually, while the share of oil decreasing. Comparatively, natural gas and hydroelectricity occupied only a small proportion of the total amount of primary energy consumption (altogether 6.4% in 1989), given the fact that the share of hydroelectricity has increased from 2.8% in 1979 to 4.5% in 1989, an average annual growth of 4.9%. By contrast, the share of natural gas has slightly decreased during this period (see **Table 3.2**). Notably, this trend is mostly related to the growth in the energy production sector where the total growth of coal production (71.3%) has been much faster than oil (30.3%) during the past ten years. (Reference is given in **Table 3.5**)

Table 3.2 Comparison of Primary Commercial Energy Consumption by Sources in China(%)

Year	Coal	Oil	Nat. Gas	Hydroelectr	**Total**
1979	73.8	20.5	2.7	2.8	100.0
1980	73.3	20.5	2.7	3.4	100.0
1981	73.3	20.2	2.4	3.9	100.0
1982	74.5	18.9	2.1	4.2	100.0
1983	75.0	18.0	2.2	4.6	100.0
1984	76.5	17.0	2.1	4.2	100.0
1985	76.9	16.6	2.1	4.2	100.0
1986	75.9	17.5	2.1	4.3	100.0
1987	75.8	17.8	2.2	4.2	100.0
1988	75.6	17.9	2.1	4.4	100.0
1989	76.0	17.6	1.9	4.5	100.0

Source: *BP Statistical Review of World Energy*, June 1990, London: Corporate Communications Services, pp.1-36

Notably, China has a very uneven energy consumption structure that has two main features: on the one hand, 580 million rural people (53% of the whole population in 1987) consume about 30 percent of the total energy available, including non-commercial energy sources (about 130 Mtoe in 1985).[21] 75-80% of the rural household energy consumption depends on non-commercial energy sources, namely biomass, among which firewood accounts for 40% and agricultural by-products, such as stalks and straw, for 60%.[22] For instance, 270 Mt of firewood are burnt annually, which is three times the natural reproduction rate, thus causing serious damage to forests, vegetation and ecosystems. Shortage of fuel for cooking is a common problem in rural areas, so that about 2/3 of the rural people suffer from a serious fuel shortage for 3-5 months a year.[23] Moreover, rapidly declining forest resources made the situation even worse.

Considering the problem of energy consumption in the agricultural sector, there is an imbalance between energy input and agricultural production output. As indicated in Table 3.1, energy consumed in agriculture sector only accounted for 7.2% out of the total end use energy consumption, while the share of agricultural production output was 26.1% out of the total GDP in 1985. This situation implies a fact that the Chinese agricultural production system is highly dependent on the intensive use of human labor with little mechanization. This system is provided with relatively small amount of energy resources, but supplys a huge population of 1.1 billion (one-quarter of the world population) with food, and light industry with raw materials. However, in respect of fertilizer use in grain production, China is currently using almost the same amount of fertilizer as the USA for producing one ton of grain products in 1986 (56.3 kg/ton of grain for China and 56.7/ton for the USA). But China uses about 2 times more fertilizer than the USA and 3 times more than India per hectare of arable land for grain production. Though this fact implies a common feature of "petroleum agriculture", relying on higher inputs of energy, the energy utilization rate in China is much lower than those of industrialized countries and some developing countries. (see **Table 3.3**) This fact suggests that there remains a considerable potential in improving energy efficiency during agricultural production process.

Table 3.3 Comparison of Grain Production and Fertilizer Use in the World's Four Leading Grain-Producing Countries (1986)

Country	Grain Production* (Million Tons)	Fertilizer Use (Million Tons)	Fertilizer Use Per Hectare (kg)	Grain Output Per Ton of Fertilizer (Tons)
China	300	16.9	174.0	18
India	137	8.5	57.1	16
USSR	202	25.4	118.1	15
USA	314	17.8	91.8	18

Source: Brown, Lester R., et al, (1990), *State of the World 1990*, Washington, DC: Worldwatch Institute, p.74; *World Development Report 1989*, 1989, New York: Oxford University Press, p.170
* Food products, including wheat and rice, etc.

On the other hand, more than 500 million people living in urban area, and the modern industrial sectors consume more than 90% of the total commercial energy resources, among which the residential/commercial sector accounts for 33.6% and the industrial sector for 56.8%. In urban household energy end use, about 52.5% of the energy consumed is used for cooking and water heating purposes, 46% for space heating and the remaining 1.5% for lighting and electric appliances.[24] In addition, 90% of the end use energy resources depend on coal that is most directly burnt in stoves with as low as 15-18% combustion efficiency. This mode of inefficient use of energy resources consequently creates a lot of waste, pollution, e.g., air and water pollution, and emits considerable GHGs to the atmosphere. For instance, from 1950 to 1989, carbon emissions from fossil fuels burning increased from 21 Mt to 650 Mt, an average annual growth of 9.2%.[25] (More discussions in **Section 4**)

Table 3.4 indicates the quantitative change of energy consumption in each sector of economy during the first half of the 1980s. In the residential/commercial sector, final energy consumption increased by 47.1% total (8% annually), compared to 21.1% total growth in industry, 25.6% in transportation and 19.6% in agriculture. Energy demand in household consumption has been so huge that it has "eaten" up to 63% of the increased electricity production output in 1989.[26] This trend of rapidly rising energy consumption in the residential/commercial sector suggests that China is currently undergoing a transition period that had already experienced by the developed countries and some developing countries.

Table 3.4 Trends of Commercial Energy Consumption by Sectors in China (Mtoe)

Year	Industry	Transport.	Agricult.	Resid/Comme	**Total**
1980	216.0	19.5	27.1	88.5	351.1
1982	216.8	21.0	27.6	99.6	365.3
1983	229.0	21.8	28.6	104.9	384.5
1984	244.1	23.1	31.9	115.3	414.6
1985	261.5	24.5	32.4	130.2	448.9

Source: Based on *World Energy Statistics and Balances 1971-1987*, 1989, Paris: OCDE/OECD

There also remain some obstacles in China's energy distribution systems. The energy resources in China are very unevenly distributed in terms of geographical locations. 90% of the coal reserves are located in the north, while 80% of the hydropower are situated in the west and southwest regions. More than half of the natural gas reserves are within Sichuan province of central China. However, the majority of the energy consuming industries are located in the eastern and coastal areas that are also densely populated. These regions provide 73% of the total GDP, but with only 10% energy self-sufficiency, and the rest provided by the energy "exporting" provinces, such as Shanxi, Henan, etc.[27] This situation makes energy resources distribution rather difficult, because it requires a relatively well developed infrastructure, such as transportation systems for coal transportation and long range transmission lines for power transmission, or some alternative solutions.

These prerequisites constitute the major barriers on China's path toward advancing energy sector development, since infrastructure development has long been left behind industrial and energy sector growth, particularly obvious during the 1980s, even though the transportation sector has been one of the priority areas in investment in the 1980s, as shown in **Figure 2.2**. This problem can be argued generally in two ways. On the one hand, coal shortages in China are partly due to the lack of transportation capacities. For instance, there were large quantities of coal (21 Mt) at coal mines waiting to be transported to the coastal areas in early 1989. This situation consequently caused a coal price ratio of 10:1 between coal consumption and production areas;[28] on the other hand, it is also because of the questionable energy policies that emphasize the "supply-oriented" development by producing coal as a means to satisfy energy demand, which puts more pressures on transportation systems.

However, to change this situation requires huge capital investment and great quantity of trained labor, which can certainly not be met in a short time span because the common development problems experienced in most of the developing countries, such as shortage of funds, backward education, brain drain and debt problems. China is no exception with regard to the above problems, which are particularly severe due to the fast growth of economy during the 1980s. Most fundamentally, there remains a need to reexamine the existing energy policies in relation to consistent modes of development.

Energy Supply In the energy production sector, **Table 3.5** gives an overview of the primary commercial energy production output during 1979-89. The most obvious development is the quantitative growth of coal production that registered an average annual growth of 5.5%, despite a few years' slowing-down in the early 1980s, because of the effects of economic adjustment policy during 1979-81. By contrast, the growth of oil production was not so significant, only 2.7% annually, along with a stagnation in natural gas production.

Table 3.5 Primary Commercial Energy Production in China between 1979-1989* (Mtoe)

Year	Coal	Crude Oil	Nat. Gas	Electr.**	**Total**
1979	297.9	106.1	12.5	4.2	420.7
1980	299.1	106.0	13.0	4.9	423.0
1981	300.4	101.2	11.6	5.5	418.7
1982	318.6	102.1	10.9	6.3	437.9
1983	351.1	106.1	11.3	7.4	475.9
1984	387.2	114.6	11.6	7.5	520.8
1985	414.0	124.9	12.0	7.9	558.9
1986	429.3	130.6	13.1	8.6	581.6
1987	454.7	132.9	12.5	8.7	608.8
1988	471.1	137.0	12.6	9.0	629.7
1989	510.4	138.3	12.9	9.7	671.3
1990 (target)	519.4	153.5	13.5	11.0	697.4

Source: Various, including *World Energy Statistics and Balances 1971-1987*, 1989, Paris: OCDE/OECD; *Energy Statistics Yearbook 1982 - 1986*, 1984 & 1988, New York: United Nations; *BP Statistical Review of World Energy*, June 1990, London: Corporate Communications Services; *People's Daily*, Jan.8, 1990, p.3

* Due to statistical differences, the numbers presented in this table are slightly different from **Table 3.1**.

** Hydro electricity and other renewables

The fastest growing sector in energy production was reflected in the growth of the electricity utilities industry. In 1989, the total electricity production output was 575 TWh, which made China the No.3 electricity producer in the world after the USA and the USSR.[29] As indicated in **Figure 3.1**, the total electricity production output has more than doubled from 282 TWh in 1979 to 575 TWh in 1989, with an average annual growth of 7.4%. Compared to the average growth rate of primary energy production (4.8% annually), electricity sector development has been very significant.

Comparing the share of each energy source in contributing to the total electricity production output during 1979-89, the general trend indicates as follows: coal 62%-68.5%, oil 20.2%-10.9% and hydro 17.8%-20.6%. It is clear that the share of coal and hydro has been increasing and oil decreasing substantially. Among them, hydroelectricity has been the fastest expanding sector during the last ten years with an absolute growth of 136%, with coal 126%, and oil only 9.5%.

However, China currently has a huge gap between energy supply and demand, particularly in the electricity sector. As reported by China Daily on April 21, 1990, the shortage of electricity supply is 70 billion KWh per year (electricity production output was 575 TWh in 1989), or a 12% shortage in electricity supply.

Electricity shortages are a common problem around the country. In Fuzhou, the capital of Fujian province in southeastern China, factories cound operate only four days a week. In Dec. 1988, a number of small enterprises were ordered to stop operation, due to their higher energy consumption ratio in production process. In the summer of 1988, power was switched off 15 days a month in the rural areas around Suzhou of southern China.[30] Consequently, one-third of the industrial enterprises were unable to operate at full capacity, thus it causing a loss of 200 billion yuan ($42.4 billion) per year in national economy (14.4% of the GDP in 1988).

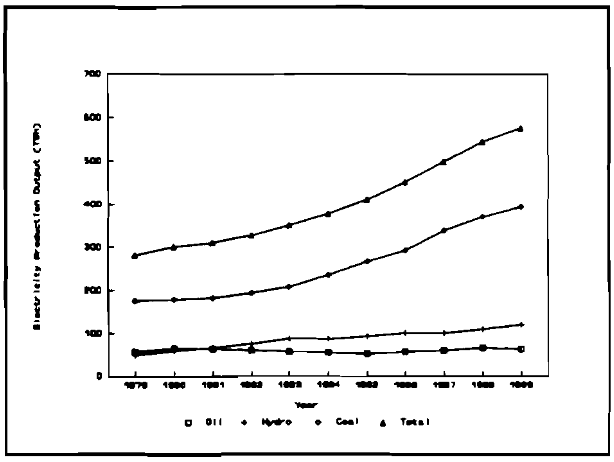


Figure 3.1 Electricity Production by Sources in China between 1979-89 (TWh)

3.2. The Role of Coal

Coal, as a major energy source in China, accounted for 76% in energy consumption and production. This share has increased by 2.2% in the last ten years. Overall demand for coal has grown from 604 Mt of raw coal in 1979 to 1,030 Mt in 1989, with an average growth at 5.5% annually. (see **Table 3.6**)

Table 3.6 Supply and Demand for Coal in China between 1979-89 (Mt)

Year	Production	Import	Export	Demand
1979	607.1	2.2	5.0	604.1
1980	595.8	2.0	6.3	591.5
1981	595.1	2.1	6.4	623.6
1982	666.3	2.2	6.4	658.7
1983	714.5	2.1	6.6	697.6
1984	798.2	2.5	7.0	767.7
1985	872.1	2.3	7.8	836.6
1986	894.0	2.5	9.8	878.9
1987	928.0	1.9	13.5	916.4
1988	960.0	1.5	14.2	949.5
1989	1,040.0	1.3	15.3	1,030.5
1990 (target)	1,060.0		16.0	1,056.8

Source: Various, Mainly based on *World Energy Statistics and Balances 1971-1987*, 1989, Paris: OCDE/OECD; and original newspapers, such as *China Daily*.

China has abundant coal resources. By the end of 1989, there reported a total of 167 billion tons of coal reserves, which accounted for 15.4% of the total world reserves. This fact places China as the third country in the world after the USA (24.1%) and the USSR (22.1%) in abundancy of coal resources.[31] China is currently the biggest coal producer in the world with 1,040 Mt of raw coal production output in 1989. By contrast, oil production, as the second largest energy source in China, may face resource depletion in about 2-3 decades, which means China may confront the situation of oil production decline in the early of the next century, in case if no significant development were achieved on exploring new oil reserves. In a more optimistic light, however, there still remains a considerable potential on discovering new oilfields in the future, if China gave more efforts to upgrading technology, supplying appropriate equipment and management personnel.[32]

Another interesting trend is the substitution of coal for oil as a major export product for earning foreign currency. Coal exports tripled since 1979, with particularly faster growth beginning in 1986. In 1989, China exported 1.5% of its total coal production output to its neighboring countries, such as Japan and South Korea, even though there existed severe fuel shortages in the domestic market. (see **Table 3.6**) This policy change implies in fact a long-term strategy that will alter substantially the whole energy system toward a more coal-oriented structure. The reasons behind this development are as folows: deceleration in oil production; possible decline of oil production in the next few decades; the increase in coal price and the decrease in oil price in the international market and so on.[33]

According to Prof. Dequan Tang's prediction in 1989, based on the indigenous energy resource conditions, coal may continue to dominate the available energy sources in China in the foreseeable future, even though the share of coal in the energy system may decrease gradually. But the total quantity of demand for coal may grow substantially from about 1 billion tons of raw coal in 1990 to 3.76 billion tons in 2050, namely a 270% net growth in 60 years, based on the assumption that the share of coal in the energy system may be at 70%-60%-50% in the years of 2000, 2020 and 2050 respectively.[34] (see **Table 3.7**) In addition, it would be interesting to note that 3.8 billion tons of coal production output is incredibly huge, since it equals 170% of the current level of the global total coal production output (2.2 billion tons by 1989).

Table 3.7 Projection of Demand for Coal in China (2000-2050)

Year	Share of Coal in Energy Sources (%)	Demand for Coal (Mtce)	Demand for Raw Coal (Mt)
2000	70.0	993.0	1,390.0
2020	60.0	1,540.0	2,150.0
2050	50.0	2,690.0	3,760.0

Source: Tang, Dequan, (1989), "Three Major Problems in the Development of Coal Mining Industry of China", in *14th Congress of the World Energy Conference*, Div.4, Ses.4.2a, Sept. p.2

Another opinion was held by Prof. Yingzhong Lu, who argued that the future structure of the energy production system in China may have to change in the near future, due to oil resource depletion.[35] Consequently, the share of coal in future energy systems will increase, even if taking into account the development of nuclear energy sources.[36] However, in principle, scientists and policy-makers are generally agreed that coal will have to be the major energy source in China in the future, though the share of coal in energy system may differ by the year 2050 (between 50-70%), mostly depending on the pace of nuclear energy development.

The point is that this tendency of energy development through heavy dependence on coal-burning as a major energy input will not only create big pressures on coal production and transportation systems in China in the foreseeable future, but will also cause additional environmental problems, such as air pollution and acid rain, etc., at local and regional levels, and CO_2 emissions at global level. (see **Section 4.** for a more detailed discussion)

Clearly, there exist boundary conditions and dynamics on the development of energy systems. China has a number of preconditions for choosing coal as a major energy source: the proven single largest energy deposit is coal; there remains in practice a lack of alternatives to substitute other energy sources for coal, due to resource limitations; the infrastructure of the existing industrial and energy systems is dominated by coal-burning boilers and thermal power plants, thus it would cost thousands of billions of yuan in investment to substitute other sources of energy for coal; lack of financial resources to import oil as a fuel substitution for coal; natural gas has its limitations to be a major energy source due to the geographical locations of reserves; and the development of large hydropower requires huge capital investments, and is also very sensitive in terms of the impacts to the sustainability of ecosystems and natural environment.

Moreover, the possible substitution of nuclear energy for coal will be a long-term process, beyond the huge initial costs of capital investments and the additional safety and waste disposal problems. Clearly, nuclear energy will not occupy a big proportion of energy supply by the middle of the next century in China. (More discussions in **Section 3.3**)

Based on the above arguments and analysis, it is crucial to realize the fact that China has its own unique indigenous situation and problems within energy sector development. It would not be likely to assume that China may follow a similar path of energy development as countries like Japan, relying entirely on external energy supplies. China has to rely on coal as a major energy source in the coming future, and the main task is to learn how to use it with maximum efficiency and least environmental impact. It is also important to look for some alternative solutions to diversify the sources of energy supply and to relieve energy shortage problems. For instance, it would be possible for China to import natural gas from the USSR in exchange for consumer goods, such as electronic products and foodstuff in the future.

3.3. Nuclear and Hydro Power

China has recently formulated a strategy for speeding up the development of nuclear energy industry. The reasons behind this policy are several: to meet the urgent energy needs of industrialization and increased domestic energy consumption in fast growing eastern regions and coastal areas; to diversify energy sources in order to reduce the heavy dependence on coal as main energy source; and to relieve the heavy burden for coal transport, since about 40% of the existing transportation capacities are occupied with coal transport.

Nuclear Power At present, there are two nuclear power plants under construction: Qinshan Nuclear Power Station, using a Chinese designed pressurized water reactor, (first phase of construction at 1x300 MW) in Zhejiang province of southeastern China. In the 1990s, Qinshan will complete its second phase of construction with two 600 MW units. The station will begin its operation in 1991, with a one year delay according to the original plan.

Daya Bay Nuclear Power Station (2x900 MW) is a joint venture with Hong Kong, British and French companies based on French design, situated in Guangdong province near to Hong Kong.

The total investments will be amount to $1.86 billion, and most of the equipment has purchased from France and the Great Britain. The station will start operation during 1992-93. For the second phase of construction, the reactor is likely to be purchased from the USSR.[37]

The future development of the nuclear power industry is in the planning process. According to a senior official from the China National Nuclear Corporation (CNNC), there are plans to build up several nuclear power stations in the southwestern and northeastern regions, such as in Guangdong and Liaoning provinces, where a heavy concentration of industry and big shortage of electrical power supply exists. Great effort will be devoted to explore and exploit uranium resources. It was estimated that by the year 2000, the total generating capacity of the nuclear power plants will reach 6 GW.[38] Most reactor designs will be based on pressurized water reactors like the one constructed in Qinshan. In the long run, the share of nuclear power in the total energy supply/demand balance sheet may reach 0.7% in 2000, 2.6% in 2020 and 20% in 2050 respectively. The highest share of the 2050 capacity may be around 563 GW installed capacity and electricity generation output at 34 TWh annually.[39]

However, there are considerable uncertainties involved in long-term nuclear energy development. It was reported by a leading mining expert that China's uranium deposit may meet the short-term needs for nuclear power generation, but is insufficient for a long-term development.[40]

Hydro Power China has abundant hydropower resources with total theoretical capacity of 680 GW, and economically exploitable capacity 378 GW, which ranks the NO.1 in the world.[41] But so far only about 3% of the total capacity has been utilized, with 20 GW output capacity. However, hydropower only accounts for a small proportion of the total electricity generating capacities in China (4.6% in 1987). The geographic locations of the hydro power resources are mostly concentrated in the western and southwestern parts of China where it is less populated and industrialized, compared to the eastern part of China. However, the industrial structure in these regions has a feature of heavy concentration on petrochemical and heavy industry development.

In 1989, China produced 575 TWh of electricity, of which 20.6% came from hydropower (118.4 TWh), in comparison with the share of 17.8% in 1979 (50.1 TWh out of the total 282 TWh). (see **Figure 3.1**) In respect of the exploitation of huge hydropower resources, the state government has recently postponed the plans for constructing huge dams, such as the Three Gorges Dam project in Yangtze River, due mostly to funds shortages and, to a less extent, political sensitivities.[42] As an alternative solution to the Three Gorges Dam, the short- and medium-term hydro development plans will focus on medium-sized hydropower projects.

For instance, the state government has recently decided on a large comprehensive development project in the Wujiang region of the southwestern part of China, which includes several provinces. The designated development project will cover a total area of 64,000 square kilometers with 14 million population. This integrated development project consists of the build-up of a number of heavy industries, supplied with an intensive exploitation of the rich hydro power and coal resources in the region. Along with the Wujiang River, ten hydropower stations will be constructed with a total generating capacity of 7.6 GW during the next 30 years. The short-term target is to reach a generating capacity of 2.4 GW in the year 2000. This hydropower development will eventually lead to an extensive regional industrialization, concentrated on coal mining and aluminum industries.[43]

The small-scale hydro power stations are considered as a very important source of electricity supply to rural areas. They are mostly constructed and managed by counties and lower level administrative bodies, or small production units at local level. Since small hydro development requires less investment and simpler technology, the state government has regarded small hydro development as an appropriate means to supply rural energy demand, by providing subsidies and soft loans to support this development. By the end of 1984, there were about 632,000 small hydro power stations in China, with the total installed capacity of 10.8 GW and total 27.9 TWh of generated electricity annually, which accounted for one-third of the total hydroelectricity production output.[44] However, the existing small hydropower only accounted for 12.8% of the total exploitable small hydro power potential of the country. In 1984, the total rural electricity consumption reached 53.5 TWh or 16% of the total electricity consumption in China, of which more than half was provided by small hydro stations.[45]

3.4. Renewable Energy Sources

As part of the decentralized energy policy, renewable energy sources development in rural areas has undergone a substantial growth in the last ten years, which includes wind power, biogas, solar energy and geothermal power, etc. The rapid development of renewable energy sources indicates the governmental efforts to fulfil the urgent energy needs of the rural people, since there are still 200 million people (25% of the total rural population) in rural areas living without electricity.

Wind Power There are more than 50,000 small wind power generators in China, of which 10,000 operate in Inner Mongolia, with the generating capacity between 0.05-3 KW each. The total installed capacity is 1.5 GW. The electricity generated is mostly used for lighting, radio and TV operation and water pumping, etc. The existing problems are low conversion efficiency and high initial costs.[46]

For instance, Inner Mongolia has the richest wind power resources in China, estimated at 540 GW potential capacity. The development of wind power for electricity generation has become one of the major energy policies of the regional government in order to meet the energy demands in remote rural areas. The regional government has adopted a series of policy measures to encourage wind power R & D and production systems development, such as:

- Economic incentives, e.g. direct government investments and low interest loans;
- Legislation enforcement, e.g., *Strengthen New Energy Resources Exploitation and Utilization*;
- Encouraging diffusion of wind power technologies, e.g., "wind power technology market"; and
- Strengthening technical training, e.g. vocational training for technicians and managers, popular education for local people in order to popularize wind power knowledge.

As a result, there emerged a combined industrial production and R & D system, with increasing cooperation between wind power industrial enterprises and R & D institutions. This system further promotes the development and diffusion of wind power generators and spare parts and technologies. In some remote areas of the region, the proportion of electrification supplied by wind power generators has reached more than 80% by 1989. Consequently, the proportion of mechanization is increasing, with more electricity-driven machines used in dairy production and water pumping for agricultural production and household use.[47]

Biogas Biogas development in China has usually been claimed as a success in rural energy development. At present, 5 million household biogas digesters were under operation, supplying 25 million rural people with biogas energy for cooking and also fertilizer as a by-product. There are 882 biogas power generating stations around the country, with installed capacity of 9 GW. As the traditional way of direct burning of biomass or firewood has a very low combustion efficiency (below 10%), the development of biogas in rural areas allows hope for solving the severe rural energy shortage problems. It was reported that the use of biogas as a fuel could double heating efficiency, so that 40% of biomass fuel can be saved accordingly.[48]

The state government has established the Leading Group for Rural Energy of the State Council in 1984, together with the Bureau of Rural Energy and Environmental Protection under the Ministry of Agriculture, Animal Husbandry and Fishery, responsible for policy issues of biogas development. At regional and local levels, biogas organizations are also formulated to strengthen the development and diffusion of biogas technology. There are now 2,000 full-time staff working at the county level, and 10,000 at district and township levels involved in biogas development projects.[49] The main strategical objectives for developing biogas energy sources are: to solve the problems of rural energy shortage; to raise the quality of fertilizer used in agricultural production system, and to retain rural ecosystem equilibrium through more efficient use of biomass resources. It has been decided that the key areas for biogas development will focus on the southern part of China, due mostly to favorable climate and water resources conditions.

Solar Energy In 1986, there were about 100,000 solar cooking stoves and 350,000 m^2 of solar collectors for water heating in China, particularly concentrated in northwestern China. It was estimated that the 1 KW unit can save 500 kg of firewood annually.

3.5. Energy Efficiency

China has a long-standing problem of low energy efficiency. The average conventional energy consumption rate per unit of GNP is more than twice of that in developing countries, such as India, 5 times that of the USA and 8 times that of Japan. (see **Table 3.8**)

Table 3.8 Comparison of Per Capita/GDP Commercial Energy Consumption in Selected Countries (1985)

Country/Area	Per Capita Energy Consumption(kgoe/cap/yr)	Energy Consumption Per Unit GDP (toe/$ million)
China	561	2216
Taiwan	1798	521
South Korea	1212	531
Singapore	5792	871
India	267	1083
Egypt	609	871
Brazil	1108	692
Mexico	1243	509
Canada	8589	633
USA	7280	436
Japan	3079	279
W. Germany	4477	434
France	3595	389
UK	3659	462

Source: *Energy Yearbook*, 1986/87, London: The Economist Intelligence Unit

In different sectors of the economy, China's energy conversion efficiency is much lower than those of industrialized countries, particularly inefficient in industry and household sectors. (see **Table 3.9**)

Table 3.9 Comparison of Energy Efficiency by Sectors in Selected Countries in 1984 (%)

Sector	China	Japan	USA	UK
Industry	35	78	77	67
Transportation	15	25	25	25
Household	25	70	30	70
Thermal Elec.*	24	30	30	28
Total	30	57	51	40

Source: Yuan, Guangru, (1984), "A Survey of China's Energy Industry", *China's Economic Yearbook*, Chinese Statistics Abstract, The State Statistics Bureau
* Including electricity generation and transmission

In China, there appear two trends in energy intensity analysis. One is the decrease of energy intensity in the industrial sector; the other is the increase of energy intensity in the residential/commercial sector.

Industrial Sector In the industrial sector, most of China's key industrial enterprises were constructed during the 1950s-70s. And about 23% of the equipment currently used in large- and medium-sized enterprises was installed before the 1970s. Especially, the industrial systems were adopted from the Soviet models during the 1950s, which apparently have a higher energy and material consumption ratio. For instance, the average thermal efficiency of industrial boilers is 55%, which is 25% lower than that of industrialized countries.[50] Unit energy consumption for steel production is as high as 39 GJ/ton in China, compared to 23 GJ/ton in South Korea and 18 GJ/ton in Japan.[51] Energy consumption in the cement industry is 70% higher than that of industrialized countries. The 13 large synthetic ammonia plants, most built in the 1970s, consume 15-30% more energy for producing one ton of ammonia than those of the industrialized countries.[52] In addition, the small rural synthetic ammonia plants are more energy intensive, since they consume about twice as much energy as the larger state-owned plants.(see **Table 3.10**) At the national level, it was estimated that if energy utilization efficiency could be improved up to the levels of the industrialized countries, about 40% of the total energy consumed in China could be saved accordingly.[53]

Table 3.10 Energy Consumption Intensity in Synthetic Ammonia Plants in China (Gcal/t)

Sector	1980	1981	1982	1983	1984	1985
Large Plant	10.18	10.09	9.94	9.97	9.76	9.64
Medium Plant	17.07	16.67	16.63	16.32	15.84	15.64
Small Plant	21.15	20.40	18.74	17.45	16.68	16.57
Average	17.92	17.13	16.43	15.62	15.11	14.73

Source: Qiu, D, et at., (1989), *Preliminary Report on Energy Auditing in Five Demonstrative Plants*, Beijing: Institute for Techno-Economics and Energy System Analysis

The reasons behind the decreasing energy intensity in the industrial sector are several: the effects of energy conservation policy measures, e.g. regulation enforcement, energy management improvement; technology advancement and technical innovation; structural change, e.g. adjustment between the share of heavy and light industries; imports of energy intensive products, etc. Notably, the effects of energy prices are not obvious, because of the complications of the "dual price system" in the energy market, in which free-market energy prices play a relatively marginal role. (More discussion in **Section 3.6**)

In reviewing the problems of inefficiency in energy production and consumption, particularly in the industrial sector, there are many interrelated factors, such as:

- Distortion of energy prices (prices of energy products do not reflect the real costs of producing them);
- Irrational industrial structures, locations and outdated equipment;
- Lack of technological competence and management skills;
- Lack of skilled labor and trained managers in energy efficiency improvement;
- Misformulated and implemented governmental energy and industrial policies;
- Lack of credit and financial support for technological innovation in energy conservation; and
- Lack of knowledge about energy conservation among the common people, etc.

Urban Residential/Commercial Sector On the other hand, the increase of energy intensity in the residential/commercial sector reflects some visible and invisible factors. The rise of income and living standards among the general public during the last decade has stimulated a changing lifestyle that leads to more widespread use of home electric appliances, such as TV sets, refrigerators, washing machines, even there are a considerable amount of home air conditioners used in private homes in the southeastern part of China.

Table 3.11 Ownership of Home Electric Appliances in Urban Households in China (Units Per Hundred Urban Households)

Items	1981	1985	1987	**A.A.G.R.* (%)**
Electric Fans	42.6	73.9	103.9	16.0
Washing Machines	6.3	48.3	66.8	48.2
Refrigerators	0.2	6.6	19.9	115.3
Television Sets				
Black/White	57.0	66.9	64.8	2.2
Color	0.6	17.2	34.6	196.6

Source: Liu, William T. (ed.), (1989), *China Statistical Abstract 1988*, New York: Praeger Publishers, p.106
* Average annual growth rates

In addition, the more liberal economic policy led to the opening-up of hundreds of millions of booming private and collective businesses, particularly in the commercial sector. These are obviously important factors in considering the growing trend of energy consumption in the residential/commercial sector. Moreover, the lower energy prices, e.g. electricity, compared to other consumer goods, tend to encourage "over-consumption" of energy products. For instance, energy bills, including the costs of electricity and fuel for cooking and heating, accounted for less than 3% of the average household expenditure in 1987, among which the share of fuel for cooking and heating occupied only 1.4% of the total household expenditure, and this share has decreased by 0.6% from 1981 to 1987.[54] Those who have become rich, such as the "millionaires" (by Chinese living standards), do not really care about what energy costs in their monthly spending. Heating is inexpensive, since every employee receives a "heating allowance" from either the government or his/her company before winter season comes, which may cover most of the fuel expenses.

Another "hidden" factor is that in China's situation, due to historical reasons, many residential areas are located within industrial production areas. Many dwellers who belong to factory employees are often provided with industrial electricity or fuel supply with very cheap payments. Some even illegally use electric cookers for cooking or heating. This problem is usually not reflected in the official energy statistics or social indicators. In the real situation, it can be assumed that energy consumption in the residential sector may be higher than the numbers reflected in energy balance sheet.

The above discussed problems are, to some extent, also linked to misleading governmental policies. During the mid-80s, there had been intensive propaganda in mass media, encouraging those who knew "how to make big money" to spend their money. This policy has in fact led to a tendency of "over-consumption" of consumer goods, despite the fact that there were considerable problems in supplying consumer goods in the market place, including energy products and services. This policy was later abandoned, however, it had made a long-term impact on the society at large.

Despite the existing problems, it has been reported that energy conservation and efficiency improvement have made substantial progress during the last decade. As reported by Qingyi Wang, Deputy Director of the Energy Research Society, in the past ten years the Chinese government has paid a great deal of attention to energy conservation. A number of policy measures have been implemented, concerning the enforcement of the administrative, legislative, economic and technological measures of energy policy. As a result, from 1980 to 1987, the average annual energy consumption increased by 4.4%, while the average annual increase of GDP was 10.4%. The energy elasticity was 0.42, and the energy intensity decreased by 25%.[55] (see **Figure 3.2**)

From 1980 to 1985, China invested 18 billion yuan ($3.8 billion) on energy conservation projects, which accounted for 22.2% of the total investment in energy industry during the same period.[56] The projects include district heating systems that can serve 40 million m^2 residential areas with heat supply, a processing capacity of 80 Mt of coal washing equipment, a 800 MW cogeneration power plant, combustion efficiency improvement of 16,000 industrial boilers and furnaces, etc. In addition, 400 energy conservation R & D projects were implemented in order to develop advanced energy-saving technologies.[57] The progress in energy efficiency improvement resulted from several policy measures of technological innovation, urban coal gasification and rural energy saving are briefly discussed in the following paragraphs.

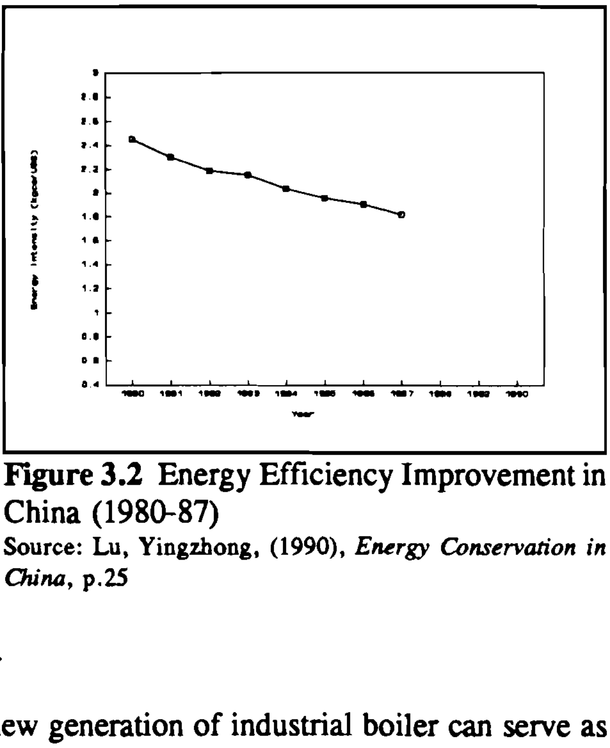


Figure 3.2 Energy Efficiency Improvement in China (1980-87)

Source: Lu, Yingzhong, (1990), *Energy Conservation in China*, p.25

Technological Innovation The development of a new generation of industrial boiler can serve as an example, indicating one of the governmental efforts on raising energy efficiency in the industrial production sector. From 1985-88, conducted as a key industrial innovation project in the Seventh Five-Year Plan (1985-90), a joint research by the Academy of Sciences, Jinan Boiler Factory and Jinan Minshui Electric Power Plant was carried out, aiming at the development of a new generation of industrial boilers. Up to now, the prototype has been put into the phase of industrial production experiment, which increased the heating efficiency up to 86%, compared with the average heating efficiency of about 55% with in-use industrial boilers. This new technological innovation will soon be introduced into the production system.[58]

Urban Coal Gasification From the early 1980s, it has been a major governmental policy to improve coal combustion efficiency and urban environmental situation by shifting traditional ways of directly burning of coal in urban areas to gaseous fuel for household cooking. Between 1984-87, the share of producer gas used in households in Tianjin, the third largest city in China (8 million inhabitants), increased from 28% to 93.7%, and coal combustion efficiency rose from

15% to 55%. In Beijing, the share of fuel gasification (including natural gas and producer gas) rose from 55% to 87% between 1980-85.

In the last few years, the pace of urban gasification and district heating development has been sped up, regarded by the central government as one of the priority areas in urban planning and development. There are now 162 cities where the inhabitants can be supplied with gaseous fuels for cooking. There are more than 200 commercial coal gas production enterprises, supplying 10.5 million households with gaseous fuels. Industrial and social welfare systems using gaseous fuel reached more than 182 thousand units. The supply sources of gaseous fuels have been developed from only producer gas in the early stage into diversified gas fuels, such as natural gas, coke oven gas, industrial waste gas, etc. In responding to the growing demands for gaseous fuel supply and consumer products, the urban gas fuel industry has emerged as a new branch of the industrial sector, currently with 114 enterprises, provided the end users with more than 1,400 different types of consumer products, such as gas cookers, gas heaters, etc.[59]

In large cities (2-10 million inhabitants), the share of fuel gasification has reached 60-70% in household cooking and in medium-sized cities (0.5-2 million inhabitants) 30-40%. In comparison, gaseous fuel development in small cities and townships is still in an initial stage. On average, the share of urban household fuel gasification increased from 15.2% in 1980 to 22.4% in 1985. The residential areas supplied with district heating systems increased from 18 million m^2 in 1980 to 55 million m^2 in 1985, an average 25% growth annually. It was estimated that the above measures can save about 4.5 million tons of coal annually.[60] However, what seems to be problematic is the rapid industrial development and population growth in small cities and townships (200,000-50,000 inhabitants), which have created considerable pressure on urban development and environment, particularly on energy-related environmental problems that may further threaten the ecosystem equilibrium in the vast areas of the country. As reported, this trend has so far not been paid adequate attention by governmental policy-makers and planners.[61]

Rural Energy Saving According to the Ministry of Agriculture's report early this year, an estimated 114 million rural households (57% of the total rural households in 1987) are currently using fuel-saving stoves, which has saved 30 million tons of firewood in 1989. The combustion efficiency of the energy-saving stoves has doubled, compared with traditional household stoves (energy efficiency at 8-10% with straw and stalk burning stoves). In the area of biogas development, it was estimated that there are 4.75 million rural households (2.4% of the total rural households in 1987) currently using biogas as a fuel for cooking and lighting. And about one billion cubic meters of biogas can be generated each year. It was predicted that these measures may lead to a energy saving of one Mtoe in 1990. In addition, 10 million yuan ($2.1 million) of low interest loans will be provided to support the rural energy industry and to develop service systems, and another 40 million yuan ($8.5 million) will be invested in energy-saving technology innovation projects in 1990.[62] By contrast, in 1988, 37 billion yuan ($7.9 billion) of the state investments have been put into energy industrial development, which accounted for 24% of the total government investments in the industrial sector.[63] Comparatively, the investments in rural energy-saving is only a very small fraction out of total energy investments.

3.6. Energy Policy Development

The present governmental policies on energy sector development have four main features: 1) heavy investments on energy production to meet energy demand; 2) restructuring energy production system with more emphasis on coal as the main energy source; 3) encouraging decentralized rural energy industry development in order to increase energy supply; 4) developing new energy sources, focusing primarily on nuclear power development. By contrast, energy conservation and end use efficiency improvement are considered in governmental policy agenda as a relatively lower priority compared to energy production growth, even though energy conservation has been officially stated as one of the central points of the current energy policy.

Supply-Oriented Policy As discussed in the above sections, with the existing strong pressure for meeting huge energy demands, China has now formulated the strategy for speeding up the development of electricity utilities industry as the central focus of energy policy. In the 1990s, medium and large thermal power stations (3-6 GW generating capacity) will be built in order to improve energy efficiency. According to the national energy development plan, there will be increases in energy production output by 25.3 Mt of raw coal, 15.2 Mt of crude oil, 700 million m^3 of natural gas in 1990. The targets for energy production in 1990 will be 1.06 billion tons of raw coal, 138.5 Mt of crude oil, 14.5 billion m^3 of natural gas, and electricity at 605 GW. The long range plan is to double the electricity generation output from 575 TWh in 1989 to 1,200 TWh in 2000.[64]

Figure 2.2 shows the trend of the state energy investment to the state-owned industries during 1978-87, in comparison to the investment in other sectors of the economy. Investment in the energy sector tripled from 11.5 billion yuan ($2.4 billion) in 1978 to 30.9 billion yuan ($6.6 billion) in 1987, an average annual growth of 11.6%. This growth rate is, by contrast, the No.2 among other sectors: transportation/communication at 13%, heavy industry 10.8%, light industry 9.7% and agriculture 1.9%.

At the regional level, particularly in the more industrialized eastern and southeastern coastal areas, growth in the energy sector will be faster, due to the serious shortages of energy supply and the fast growing pace of industrialization. Guangdong province, one of the most developed areas in China with severe electricity shortages at 30%, has set up plans for the next ten years' energy sector development at an average annual growth of 10%. It has been approved by the provincial government that more strict measures (mostly direct management measures) will be employed to save energy, including orders to ban production in those enterprises with higher energy consumption rates, lower productivity and serious pollution problems. And legislation will also be strengthened, e.g. "*Provisional Measures for Electricity-Saving Management in Guangdong Province*" will soon be stipulated.[65]

Inner Mongolia has increasingly evolved into an important energy production base in China in the last few years because of the recent discovery of huge coal reserves, accounting for 2 billion tons of deposit (22.2% of the total proven coal deposits in China). In order to speed up coal resource exploitation, the state government has invested 41 billion yuan ($8.7 billion) to build up three open coal mines. Following this development, 6 key industrial projects will be constructed in the region, with total investments of 73 billion yuan ($15.5 billion).[66]

Clearly, coal will play an increasing role in energy systems development in the future. It is planned that the increased coal production will be used mostly on thermal power plants. Taking into account the relatively slow growth in the oil industry and the prospects for future development, strategic changes are being made to transform the existing oil-burning power plants into coal-burning power plants. And further construction of oil-burning plants will not be considered in the future.[67]

China's nuclear energy development policy is basically a self-reliance policy, which means a heavy dependence on domestically developed technologies, designs and nuclear fuel supply. Nevertheless, it would be fruitful to review more critically the current nuclear energy policy. It has been widely argued that nuclear energy development has several obstacles, such as huge capital investments, longer lead time and construction period, safety and waste disposal problems, etc. At the current initiating stage, China needs experience in nuclear power plant construction and also a stable supply of financial resources, so that the prospects for future development may meet great difficulties in the coming decades, particularly in the event of a shortage of funds and fuel supply in the future. In addition, safety problems have neither been solved completely at the international level in industrialized countries nor in China.[68] In this respect, it would be useful to consider carefully the statement made by a leading nuclear energy official that "by the year 2040, nuclear energy will be the major energy source in China".[69]

Decentralized Policy Since the early 1980s, following the decentralized governmental economic policy, coal mining by small-scale rural enterprise has been encouraged. As a result, the number of small- and medium-sized coal mines operated by rural private and collective enterprises increased rapidly, e.g., from 18,000 in 1980 to 65,000 in 1989, indicating an average annual growth of 15.3%. The production output rose from 113.6 Mt in 1980 to 325 Mt in 1987, 186% net growth. The share of rural coal production output increased from 22% in 1982 to 35% in 1989 out of the total coal production in the country. By the year 2000, the production output of the small coal mines may reach 400-500 Mt each year, about the same proportion in total coal production output at that time. (Note: the planned target for coal production by the year 2000 is around 1.4 billion tons of raw coal).

The policy is backed by some distinguished energy experts. Prof. Yingzhong Lu, Institute for Techno-Economics and Energy Systems Analysis in China, argued for this policy that "the great achievements of such a decentralized policy are remarkable and encouraging", because of the low investment rates (10-70 yuan per annual ton capacity in comparison with 140 yuan average for state-owned big coal mines), even though, he agreed, there remained "imperfect safety and poor management problems".[70]

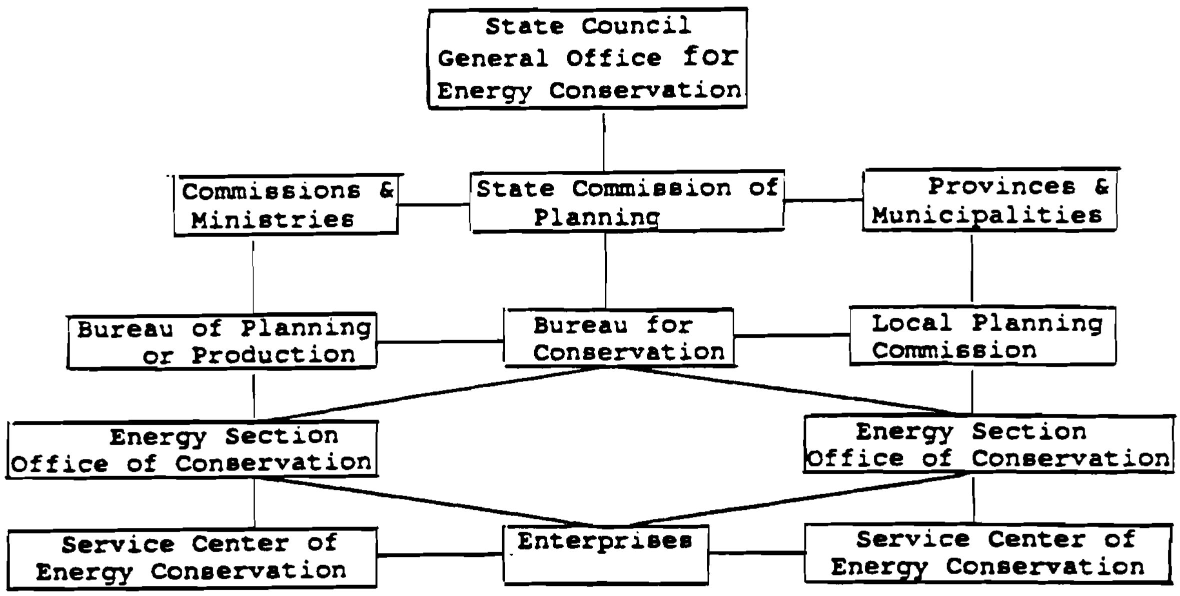
Another interesting aspect is that the small coal mines currently employ a 10 million rural labor force, which accounted for 30% of the total labor force in rural industry, or 2.6% of the total rural labor force in China.[71] It is obvious that the development of the rural coal mining industry has, to a large extent, contributed to a partial solution of some social problems, such as the release of heavy burden on the surplus labor force in rural areas and the rapid expansion of urbanization. The rural unemployment problem is mostly related to the problems of land shortage, population growth and increasing productivity in agricultural production processes, following the rapid economic reform in the agriculture sector during the last decade.

It is necessary not to ignore the negative aspects of this policy. According to another report in People's Daily, in 1989 the small-scale rural coal mines put great pressure on the rural environment. For instance, in the Inner Mongolian region, there are 2,113 small coal mines, producing coal with very low productivity and efficiency, and considerable waste of coal resources. In addition, a great deal of grassland was destroyed by coal mining, further damaging the local ecosystem.[72] (see **Section 5.3**)

Energy Conservation Policy Energy conservation is, of course, part of the national energy policy. It has been commonly stated as a "walk-on-two-legs" policy, which means the equal treatment of both energy production and energy conservation. Nevertheless, efficient use of energy resources, especially electricity, is only claimed as a "supplement" to other aspects of energy policy.[73] There is no clear evidence up to now that scientific communities have strongly urged the government to consider energy efficiency and conservation as the top priority of energy policy for environmental protection reasons. From the governmental point of view, producing more energy to meet the huge demand is unequivocally the most urgent goal to achieve in the coming future. However, reaching higher energy efficiency rates requires that effective policy measures be implemented, such as huge capital investments, substantial changes in industrial systems and structure, improvement of economic infrastructure and managemental skills, etc.

There exists an administrative structure with a hierarchy system in linking governmental bodies with lower levels of social organization to manage energy conservation activities. **Figure 3.3** gives a general view of the structure of the energy conservation administrative system in China.

Figure 3.3 The Hierarchy of Energy Conservation Administration in China



Source: Lu, Yingzhong, (1990), *Energy Conservation in China: Achievements, Potentials and Limits*, paper presented at the International Energy Workshop, Jun. Hawaii, p.16

Energy Price Energy prices are a critical factor in understanding and analyzing China's complex and overlapping energy shortage problems and inefficient use of energy. It is by its nature not only a problem in the price system, but also an interrelated issue of economic system, political constitution as well as social and cultural critique.

Energy price distortion is a critical problem existed in energy system for a long time. China has been practically operating an irrational energy price system with the state-fixed energy price for energy products since the early 1950s. Before 1978, it was entirely a centrally-planned system with the energy prices (including coal, crude oil, natural gas, electricity, etc.) determined by the state government, according to plans and regulations. After 1978, a mixed economic system emerged with a "planning-dominated and market-complemented" mechanism; however, the price of energy was considered as strategically important for the maintenance of the "stable" economic, social and political order. Any change in energy prices has to be made by the state. Due to the economic and political situation, the basic energy price has not been able to change according to market mechanisms for nearly 40 years, even though there were some small price adjustments after 1978. For instance, electricity prices for urban domestic consumers is 0.17 yuan ($0.03) per KWh, which is below the real costs of electricity generation, since many thermal power plants are currently facing deficit problems.

In consequence, this price system is apparently causing two interrelated problems: over-consumption and waste of energy resources, since energy prices are too low to be taken into account in the production and consumption processes; the huge deficit for energy producers, because the costs for producing energy exceed profits from selling energy products. Pursued by the fast growing inflation (over 17% since 1985), the state-owned coal mines have been facing deficits since 1985, with a deficit of 6 billion yuan ($1.27 billion) in 1989.[74]

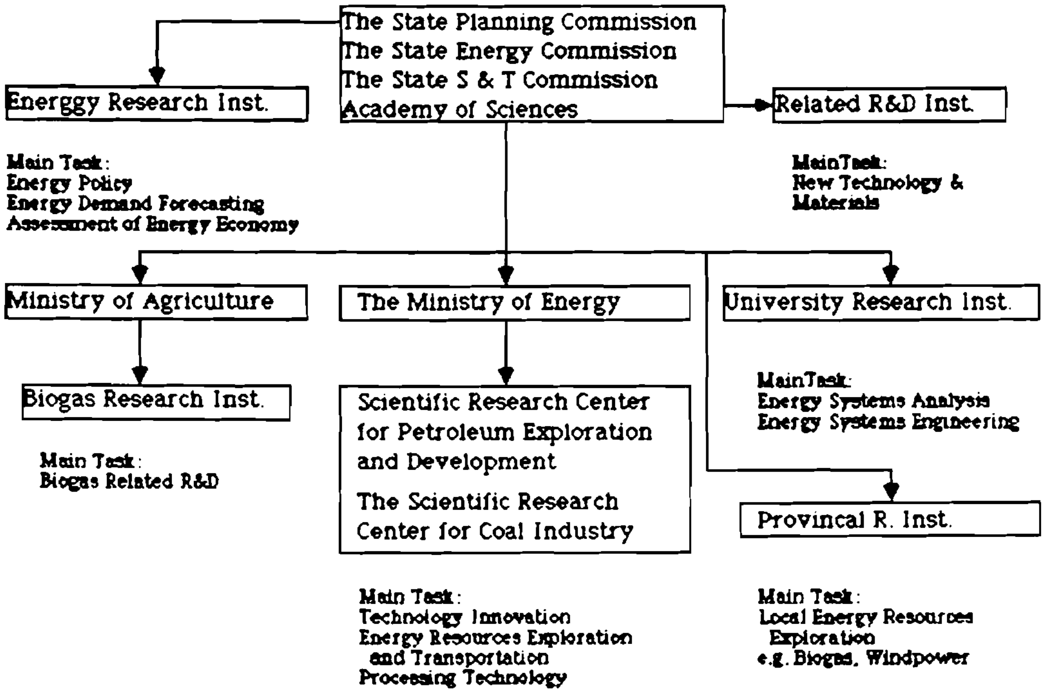
In the middle of the 1980s, a "dual-price system" was adopted in the energy sector as part of governmental efforts to rationalize energy prices. It implies that the government decides a fixed price for planned quota of energy producers and consumers, which is relatively low and heavily subsidized. The energy producers and consumers are allowed to trade energy products beyond the quota system with free market prices, depending on the market supply and demand mechanisms. However, the introduction of this price system has been controversial, and it generated additional problems. It seems that this price system stimulates more energy production than rationalized energy consumption, since the overall costs of energy account for only 3% of the total production costs. By contrast, the small rural energy producers are very much stimulated by this policy, and almost tripled their energy output during the last ten years.

Liaohe oilfield, the third largest oilfield in China, had its first deficit of 150 million yuan ($32 million) in 1988. The production costs have been increasing from 79 yuan for per ton of petrol in 1987 to 107 yuan in 1988, a 35% annual growth rate; however, the officially fixed price was 100 yuan per ton of petrol in 1987 and 110 yuan in 1988. While the production exceeding the planned quotas could be sold at 485 yuan per ton. It was estimated that Liaohe oilfield would have a huge deficit of 430 million yuan in 1989 and 670 million yuan in 1990. And a similar situation occurred at other oilfields, and the total deficit could reach as high as 1.2 billion yuan ($250 million) in 1988.[75]

The prospects for improving this situation has now been overshadowed by the uncertainties regarding economic and political systems. Economic growth has slowed down (only 2% in the last fiscal year), and price reform postponed, due to political sensitivity of possibly raising "social unrest". However, as an essential step to rationalize the energy system and structure, to a broad sense, economic structure, energy price reform will have to take place sooner or later in the next decades, depending, to a large extent, on political developments in the country.

Energy R & D systems and organizations The governmental agencies in charge of energy research and development (R & D) and energy policy-making are the State Planning Commission, the State Energy Commission, the State Science and Technology Commission and the Academy of Sciences. The State Energy Commission (SEC) is the main governmental body responsible for coordinating and organizing energy R & D as well as energy policy-making. It is also in charge of energy-related science and technology (S & T) research activities in cooperation with other foreign countries. Under these governmental bureaucratic hierarchies, there are different Ministries and research institutions responsible for energy-related R & D activities. (see **Figure 3.4**)

Figure 3.4 Energy R & D Systems in China



A recent institutional development in the energy sector is the establishment of the Ministry of Energy in 1988, which had previously been several separate ministries, such as oil, coal, electricity, hydropower ministries, etc. The reform is essential in terms of concentration of power and authority, but it also stimulates more effective communication and cooperation between different sectors of energy production, distribution, consumption and management at the governmental level. In the production sector, there are several state-owned large companies in charge of energy production, trade and distribution. Their operations are allowed to change depending on market situation. This policy measure intends to introduce more market incentives into energy systems in order to raise efficiency and productivity.

<u>Energy Forecast</u> Concerning the long-term energy development and policy in China, there are a number of scientific predictions based on demand/supply modelling.[76] **Table 3.12** shows one of the of energy supply and demand forecasts in a long-term period by Prof. Yingzhong Lu. It is crucial to be aware of the probability that the total energy demand in China may increase by 2.5 times during the first half of the next century. The major energy sources in the next century will mostly depend on coal and nuclear, and the share of oil may decrease substantially, due to resource depletion. It was estimated that oil production may reach its peak time by 2020, then may drop more than 50% by the middle of the next century. On the other hand, nuclear energy may account for more than 20% of the total energy supply. As for energy consumption level,

per capita energy consumption may reach as much as 2.6 Toe by the middle of the next century, which will be roughly at the Japanese level of 1985 (2.58 Toe).[77] However, it was estimated that per capita GDP in China by the year 2050 may reach as much as $8,000. Based on the above estimated energy consumption level, this is only about half of the Japanese per capita GDP in 1987. In such a situation, it may take China more than a century to catch up to the current level of Japanese energy efficiency per unit of production.

Table 3.12 Long-Term Commercial Energy Demand/Supply Forecast of China

	2000		2020		2050	
Sector	Mtoe	%	Mtoe	%	Mtoe	%
Coal	740	70.1	1140	67.7	2200	60.0
Nuclear	7	0.7	44	2.6	755	20.7
Oil	200	19.0	250	14.9	115	3.2
Nat. Gas	37	3.5	94	5.6	185	5.1
Hydro	70	6.7	147	8.8	225	6.2
Renewable	0	0.0	7	0.4	175	4.8
Total(rough)	900-1100	100.0	1400-1700	100.0	3000-3600	100.0

Source: Based on Lu, Yingzhong, (1990), *Comparison of Energy Consumption, Supply and Policy of the People's Republic of China and Some Other Developing Countries*, Washington, D. C.: The Washington Institute for Values in Public Policy, p.94

4. Environmental Problems and CO_2 Emissions

4.1. Present Situation

Recently, environmental problems in China have attracted a great deal of attention among scientists and politicians. Associated with rapid economic development, particularly during the last ten years, which is mostly reflected in the growth rate of industry and agriculture, the seriousness of environmental destruction or crises has become evident. There has been considerable criticism from some distinguished Chinese and foreign scholars about the existing environmental problems and related policies (such as energy policy) in China and the consequent impact on the global environment, particularly concerned with GHGs emissions in relation to global climate change.[78]

However, in reviewing the government attitude toward environmental problems, there have been a number of conflicting reports regarding the environmental situation in China in the last few years. For instance, on the one hand, some leading government officials have warned of the serious environmental situation in China in a number of newspaper reports.[79] According to a recent research report entitled *"Improving Ecological Environment"*, which was published by the State Science and Technology Commission in 1988, the overall environmental situation in China is characterized by "some improvements in part; deterioration as a whole; and the future is in doubt."[80] Another report entitled *"Forecast of China's Environment and Countermeasures by the Year 2000"*, which was conducted by more than 1,000 scientists during a four-year period

(1984-88), predicted that environmental pollution in China will become worse by the year 2000, if it continues to grow at the present rate;[81] on the other hand, a recent announcement made by the National Environmental Protection Agency (NEPA) says that "the quality of air and water in China is generally good due to tight environmental management and pollution control".[82]

Doubtless, the alarming environmental problems have generated increasing concern in governmental policy agenda, and also attracted considerable research interests among academia. However, there is clear evidence that the majority of the environmental concerns focus on local or regional environmental issues, such as air pollution, acid rain, water pollution and so on, which are mainly connected to the problems of flying ash, SO_2 emission, etc., while not very much attention has so far been paid to the problems of GHGs emissions, such as CO_2 emissions, and the associated global climate change, except for several responses from scientific communities and the National Environmental Protection Agency (NEPA). (see **Section 5.1**)

In recent years, there have been a number of press reports concerning energy sector development in China, particularly focusing on the growth of energy production and the plans for future development, while relatively little information is given on energy-related environmental problems, and on the debates over the problems of GHGs emission and the consequent global warming.[83] Therefore, it is reasonable to assume that the general public in China is not well informed about the environmental consequences of their economic development and the potential impacts of the GHGs emissions to the global environment. What people are concerned about is, to a large extent, the pollution problems that influence directly their everyday life.[84]

One of the key factors in understanding the greenhouse issue in China is to look at the rate of CO_2 emissions into the atmosphere as a consequence of fossil fuel burning. **Table 4.1** shows the situation of the global carbon emissions divided by countries between 1960-87. China ranked the third behind the USA and the USSR. China's share of the global CO_2 emissions increased from 8.4% in 1960 to 10.6% in 1987. It is impressive that CO_2 emissions in China have more than doubled during this period. And the carbon emissions per dollar of GNP ranked the No.1 in the world. In comparison with other countries, China's carbon emissions per dollar of GNP produced in 1987 was 3 times of that in India, 4.6 times of the USSR, 7.3 times of the USA and 13 times of Japan, even though China's per capita CO_2 emissions are quite low, due to the share of its huge population (1.1 billion).

Table 4.1 Carbon Emissions from Fossil Fuels Consumption in Selected Countries (1960-87)

Country	CO_2 Emissions 1960 (Mt)	1987	CO_2 Per US$ GDP 1960 (grams)	1987	CO_2 Per Capita 1960 (tons)	1987
United States	791	1,224	420	276	4.38	5.03
Canada	52	110	373	247	2.89	4.24
Australia	24	65	334	320	2.33	4.00
USSR	396	1,035	416	436	1.85	3.68
Saudi Arabia	1	45	41	565	0.18	3.60
Poland	55	128	470	492	1.86	3.38
West Germany	149	182	410	223	2.68	2.98
United Kingdom	161	156	430	224	3.05	2.73
Japan	64	251	219	156	0.69	2.12
Italy	30	102	118	147	0.60	1.78
France	75	95	290	113	1.64	1.70
South Korea	3	44	247	374	0.14	1.14
Mexico	15	80	446	609	0.39	0.96
China	215	594	---	2,024	0.33	0.56
Egypt	4	21	688	801	0.17	0.41
Brazil	13	53	228	170	0.17	0.38
India	33	151	388	655	0.08	0.19
Indonesia	6	28	337	403	0.06	0.16
Nigeria	1	9	78	359	0.02	0.09
Zaire	1	1	---	183	0.04	0.03
R.O.W	458	1,225				
World	2,547	5,599	411	327	0.82	1.08

Source: Flavin, Christopher, (1989), *Slowing Global Warming: A Worldwide Strategy*, Worldwatch Paper 91, Washington, D.C.: Worldwatch Institute, p.26

4.2. Trend of CO_2 Emissions

In a historical perspective, China has experienced a steady growth of CO_2 emissions (see **Figure 4.1**). During the past four decades, the amount of CO_2 emissions from burning fossil fuels has increased from 21 Mt of carbon in 1950 to 650 Mt in 1989, a thirtyfold absolute growth. However, there have been different rates of CO_2 emissions growth between decades. During 1950-59, the average annual growth rate of CO_2 emissions was 27.9%. By contrast, there was a relative decline of CO_2 emissions in the 1960s with -3.3% annually. Despite the misleading economic policies in the late 1950s (see the following paragraph), the growth of population also had a substantial impact on the rate of CO_2 emissions. For instance, the population growth rate was 1.9% annually during the 1950s.[85]

In the 1970s, the average annual CO_2 emissions growth accounted for 7.6%, while during the 1980s it slowed down to 5.7% annually. One of the reasons for the slower increase of CO_2 emissions in the 1980s should be attributed to the improvement of energy efficiency and the decrease of energy intensity, particularly in the industrial sector. (See **Section 3.5**) However, in comparison with the average annual growth of the energy consumption rate in the 1980s (4.1% annually), the increase of CO_2 emissions has been faster, which may be related to some social and policy aspects of development, such as the fast expansion of urbanization (11% between 1980-87),[86] decentralized economic and industrial structures, improvement of living standards of the people, the booming service sector, and also the absolute growth of population (16 million yearly), despite the fact of faster growth in residential/commercial sector energy consumption.

It seems surprising to see the several ups-and-downs on the total CO_2 emissions indicator, as shown in **Figure 4.1**. These changes in CO_2 emissions are mostly attributed to the strong impacts of economic development and associated policy adjustment. The sudden growth of CO_2 emissions in the late 1950s has a virtual connection with the massive social movement "the Great Leap Forward" (1958-60) when intensive efforts were devoted to develop iron and steel industry and exploit energy and mineral resources, particularly at regional and local levels. This social movement failed, but its impact has been vast and widespread in terms of inefficient use of energy resources, irrational industrial structure and locations. The following decrease of CO_2 emissions in the early 1960s was the result of economic adjustment policy after the "Great Leap Forward", which restricted the fast expansion of heavy industry and brought the economy into a relatively steady period of development.

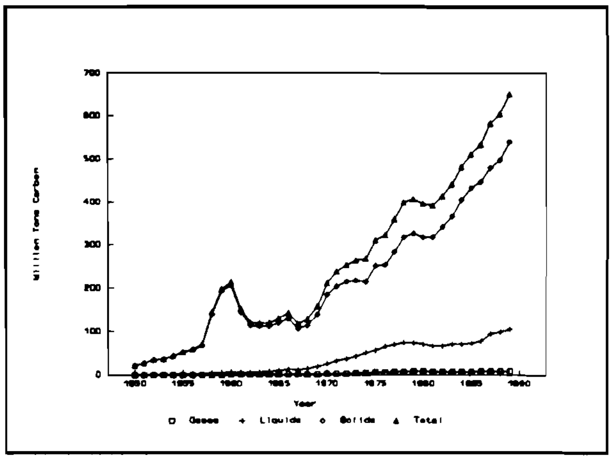


Figure 4.1 CO_2 Emissions from Fossil Fuel Consumption in China (1950-89)
Source: Oak Ridge National Laboratory data; and others.

Another decline of CO_2 emissions in the late 1960s was clearly due to the impacts of the "Cultural Revolution" (1966-76), which slowed down the pace of industrial activities and brought down the economy into a period of stagnation.[87] And the latest level-off on CO_2 emissions in the late 1970s until the early 1980s coincided with another economic adjustment policy during 1979-81, which restricted, again by governmental policy, the booming industrial growth and energy consumption.

During the past decade, per capita CO_2 emission in China has been growing at a rate of 3.7% annually. In 1989, per capita CO_2 emission in China was 0.6 ton, which was about half of the world average (1.12 tone in 1987). By contrast, per capita GDP in China is under the category of the lowest group of countries. In addition, considering per capita energy consumption vs. per capita CO_2 emissions among a similar group of developing countries, China emits considerably more CO_2 than the other countries. (See **Table 4.2**) This fact is mostly attributed to the dominant use of coal as a major energy source and the inefficient production and use of energy.

Table 4.2 Comparison of Per Capita Energy Consumption/Per Capita CO_2 Emissions in Developing Countries (1986/87)

Country	Per Capita Energy Consumption* (kg.oe)	Per Capita CO_2 Emissions** (kg. Carbon)
China	525	527
Brazil	825	379
Egypt	588	414
India	208	187
Peru	485	288
Tunisia	496	457
Zambia	380	116
Zimbabwe	512	388

Source: *World Development Report 1989*, 1989, Washington, DC: Oxford University Press, p.172; Marlan, G. et al, (1989), *Estimates of CO_2 Emissions from Fossil Fuel Burning and Cement Manufacturing*, Tennessee: Oak Ridge National Laboratory

* Based on 1987 data; ** Based on 1986 data

4.3. Sources of CO_2 Emissions

There are three major CO_2 emission sources in China: the burning of fossil fuels, excessive burning of biomass resources (firewood, grassroots, agricultural wastes, etc), and deforestation. **Figure 4.2** shows a general structure of the share of CO_2 emissions by different sources. Fossil fuel consumption as energy source in China has been the main contributor to CO_2 emissions (over 75%). Despite CO_2 emissions from fossil fuels combustion, land use change is a considerable source of CO_2 emissions, which emitted 69 Mt of carbon in 1980 (about 9% out of the total emissions). Notably, most of the emissions from changing land use come from deforestation.

Apparently, coal constitutes more than 80% of CO_2 emissions from fossil fuel combustion, and this share is the highest in the world. Oil accounted for 16.1% and natural gas 1.2%. The general trend during 1980-85 was the share of coal gradually increasing, and oil/natural gas decreasing slightly, even though there had been no dramatic changes. As discussed in **Chapter 3**, The increasing proportion of the production and consumption of coal has had a considerable impact on CO_2 emissions in the 1980s. And the higher CO_2 emissions also has interlinkages with end-use energy inefficiency, particularly in the industrial production sector.

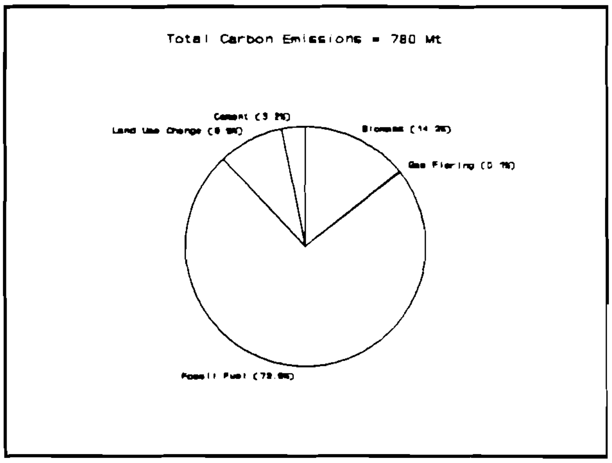


Figure 4.2 CO_2 Emissions from Different Sources in China* (1987)

Source: Oak National Laboratory data, 1987;

* Land use change data from 1980, biomass from 1979

Biomass consumption as a contributor to CO_2 emissions is currently an under-developed research theme, since little reliable data are available on the consumption rates of biomass resources in China. However, a general estimation may be based on the annual burning of 220 Mtce biomass (1979) in rural areas, among which about two-third was "over-consumed", exceeding the capacity of natural reproduction rate.[88] Thus, annual CO_2 emissions from biomass burning may be calculated as much as 110 Mt carbon each year, which amounts to 19% of the total CO_2 emissions from fossil fuels burning in China. Based on such an estimation, the total annual CO_2 emissions in China may have reached as much as 780 Mt in 1987, including CO_2 emissions caused by deforestation.

It is necessary to analyze the share of CO_2 emissions by breaking down the major economic sectors, as shown in **Figure 4.3**. It is clear that industry contributed about half of the total CO_2 emissions in 1985 (239 Mt carbon), even though this share has decreased by 3.1% from 49.8% in 1980 to 46.7% in 1985, due mostly to the decrease of energy intensity and the effects of energy-saving measures adopted in the same period. Moreover, the second biggest CO_2 emitter is the residential/commercial sector that has increased its share from 20.6% in 1980 to 24.8% in 1985, an average annual growth of 3.8%. However, the total CO_2 emissions in the residential/commercial sector has been the most substantial from 85 Mt in 1980 to 128 Mt in 1985, with an average annual growth of 8.5%, surpassing the average energy consumption growth of 5% in the same period. In the electricity utilities industry sector, the third biggest CO_2 emitter with a share of CO_2 emissions at 18.2%, the situation has been consistent over this period, and the same in other two sectors. However, taking into account the average annual growth of 7.4% in electricity utilities production in the past decade, the slower growth of CO_2 emissions at 4.8% annually implied the considerable progress achieved by energy conservation in this sector.

Within the industrial sector, as indicated in **Table 4.3**, three energy intensive industrial branches emitted about two-third of the total industrial CO_2 emissions in 1985, among which the iron and steel industry accounted for nearly 30%. CO_2 emissions in the iron and steel industry had been growing at a rate of 2.5% annually during 1980-85, consistent with the annual growth of energy consumption in the same period. It is also obvious that the major fuel in contributing to CO_2 emissions in the industrial sector is the intensive use of coal with a share of 85%.

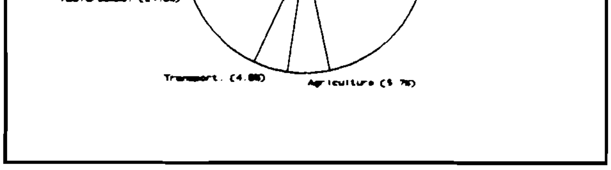


Figure 4.3 CO_2 Emissions from Fossil Fuel Consumption by Sectors in China (1985)
Source: *World Energy Statistics and Balances 1971-87*, 1989, Paris: OCDE/OECD

Another important source of CO_2 emissions is from cement production process, which emitted about 25 Mt carbon in 1987. In a historical perspective, this figure has increased by 200 times over the past 40 years. During 1978-87, cement production output almost tripled from 65 Mt to 181 Mt.[89] From 1979-87, the average annual growth of CO_2 emissions from cement production was 11.7%. Considering such a pace of growing CO_2 emissions, it should be necessary to take into account the future growth of CO_2 emissions in this sector with effective policy countermeasures to eliminate its greenhouse impact.

Table 4.3 CO_2 Emissions by Industrial Sub-Sectors in China in 1985 (Mt Carbon)

Sub-Sectors	Coal	Oil	Gas	**Total**
Iron & Steel	62.9 (94%)	3.7 (3.7%)	0.3 (0.5%)	66.9 (100%)
Chem/Petroleum	36.7 (69%)	14.3 (26.9%)	2.2 (4.1%)	53.2 (100%)
Non-Metallic Minerals	38.5 (94.6%)	2.1 (5.2%)	0.1 (0.2%)	40.7 (100%)
Cement	-	-	-	19.4 (100%)
Total	138.1 (85.9%)	20.1 (12.5%)	2.6 (1.6%)	180.2*(100%)
Total Industry	201.7 (84.5%)	33.2 (13.9%)	3.8 (1.6%)	258.1*(100%)

Source: *World Energy Statistics and Balances 1971-87*, 1989, Paris: OCDE/OECD, p.366
* Including CO_2 emissions from cement production

In the electricity utilities industry, the total CO_2 emission has reached 108 Mt in 1987 (equivalent to 18.2% of the total CO_2 emissions from fossil fuel combustion). It is crucial to realize that coal burning contributed to almost 90% of the CO_2 emitted by the power industry, and this share has grown from 78.2% in 1979 to 88.2% in 1987. By contrast, the decreased use of oil in electricity generation substantially reduced the amount of CO_2 emissions from oil burning. (see **Figure 4.4**) Taking into account the pace of 7.4% of average annual growth in the electricity production sector in the 1980s, the future growth of CO_2 emissions in this sector would be enormous.

4.4. Projection of Future Emissions

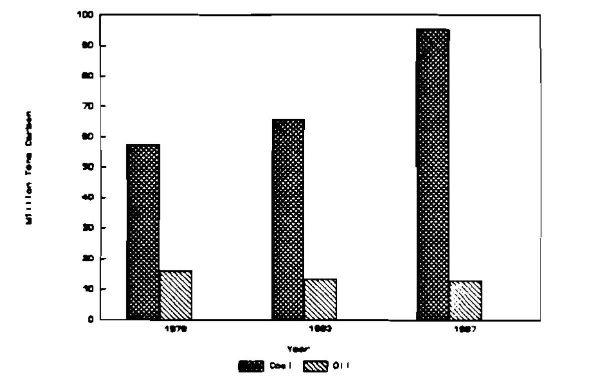


Figure 4.4 CO_2 Emissions from Thermal Electricity Generation by Sources in China
Source: *World Energy Statistics and Balances 1971-87*, 1989, Paris: OCDE/OECD

From a historical point of view, China's responsibility for contributing to global CO_2 emissions has been increasing dramatically. China's share of global carbon emissions has increased from 1.3% in 1950 to 10% in 1986. The average annual growth of CO_2 emissions from fossil fuel consumption was 9.3% during 1950-86. It almost tripled in comparison with the global average annual growth of 3.5% in the same period.[90] Per capita CO_2 emissions have observed an average annual growth of 7.4% between 1950-86. By contrast, per capita CO_2 emissions at the global level only increased by 1.5% annually in the same period. In such a context, per capita CO_2 emissions in China were 5 times that of the global average. Even though CO_2 emissions in China during the 1980s had slowed down relative to previous decades, the magnitude of emissions has been enormous, compared to the rest of the developing world. With China's economy progressing and energy demand growing, it is crucial to predict the future trend of carbon emissions based on minute investigation. This has, however, been a weak point in global climate change studies, both from the domestic and the international point of view.

Nevertheless, a number of existing studies will serve as a point of departure in the following discussion.

According to the projection given by Alan S. Manne and Richard G. Rechels, China's share of global carbon emissions may account for as much as 22% by the year 2100, under the assumption that no carbon limit policy will be adopted, namely, a "business as usual" scenario. In such circumstances, China may become the single largest CO_2 emitter in the world by the end of the next century, releasing about 50% more carbon than the USA, and 80% more than the USSR and Eastern Europe together.[91]

It is a difficult task to predict the long-term trend of CO_2 emissions in China, since it involves not only energy demand/supply modelling, but also more complicated issues, such as social, political and cultural dimensions of energy production and consumption, as well as environmental and ecosystems constraints and limitations. Issues like modifying patterns of development, altering political constitutions and changing lifestyle are all marked with a sense of uncertainty. However, a general estimation can be made, based on available data and existing studies on energy forecasting. According to Prof. Lu's projection, for instance, energy demand on conventional fossil fuel sources may reach as much as 1,480 Mtoe by the year 2020 and 2,500 Mtoe by the year 2050. (see **Section 3.6**) These figures imply an absolute increase of fossil fuel consumption in China by 130% and 280% respectively. In such circumstances, the total amount of CO_2 emissions from fossil fuel consumption may increase up to the level of 1,550 Mt carbon by 2020 (16% of the global total) and 2,560 Mt by 2050 (18% of the global total). This projection was based on the assumption that nuclear energy may substitute about 3% of energy supply for coal by 2020 and 20% by 2050. In case nuclear energy substitution were not employed, the magnitude of carbon release would have a much greater share in the global CO_2 emissions sheet. If the above calculations can be justified, it would be difficult for China to be accepted by international communities on such a magnitude of carbon release into the atmosphere for a single country, which will, to a large extent, offset most of the potential gains from global collective carbon reduction actions.

Table 4.4 gives two scenarios based on assumptions with or without the adoption of nuclear energy as a coal substitution. Taking into account the adoption of nuclear energy, the share of nuclear energy is projected at 3.3%-13.9%-19.4% in the years of 2000, 2025 and 2050 respectively (base case scenario). It is crucial to note that the choice of nuclear energy in China's energy system will be a decisive factor in determining the rate of CO_2 emissions in China in the future.

Table 4.4 Projection of China's Share on Global Carbon Emissions in 21th Century (%)

Scenarios*	2000	2025	2050	2075
A	9.0-12.0	11.0-17.8	10.8-21.9	10.5-24.0
B	9.2-11.7	9.4-15.9	8.3-19.0	7.5-20.9

Source: Lu, Yingzhong, (1989), "Carbon Dioxide Issues and Energy Policy in the People's Republic of China", *Int. Journal of Global Energy Issues*, Vol.1, Nos.1/2, p.50

* A: without nuclear energy; B: With nuclear energy

Another important factor that should be taken into account in future CO_2 emissions forecasting is the growth of population. According to the World Bank's projection, the total level of population in China may reach as much as 1,500-1,700 million by the end of the next century, depending on different scenarios.[92] It implies a net population growth between 35-55% in the next century. If this projection can be justified, the energy demand required by such a huge population will certainly put great pressures on energy systems, the resource base and the environment in China, and may offset any effort to mitigate carbon emissions and climate warming. As estimated by experts, the maximum carrying capacities of land and natural resources in China can support a population of 1.6 billion on average, though there remain imbalances between different regions of the country.[93] However, the previous projection of population growth in China was mostly dependent on the past trend of population growth rates. There is a recent report that population growth in China has gone out of control in the last few years, so that it is very likely that the total population may reach as much as 1.345 billion by the year 2000, which would greatly exceed the original target for keeping the population under 1.2 billion.[94]

It should be noted that the above estimations about the future trend of CO_2 emissions in China only gives a basis for further discussion and argument. It is by no means a solid scientific study, due to the uncertainties involved, such as the problems of inconsistent data and the underdeveloped nature of the research. In considering the status of China's energy development in relation to global climate change, it should be crucial to devote more efforts to this subject subject of China's energy system and its contributions to global climate change in the future.

5. Governmental Responses and Policies toward Environmental Problems

5.1. Attitudes and Strategies

From a historical perspective, the origin of environmental problems and the development of corresponding environmental policies in China has undergone four distinctive phases since 1949 when the People's Republic of China was established.

In the first phase of industrialization between 1949-57, pollution control policy was almost absent. Borrowed from the Stalinist "big push" development strategy of the Soviet Union, China emphasized on the development of heavy industry, which had "over-consumed" energy and raw materials. In addition, the location of industries was not taken into account by planners, resulting in the mix of residential areas with factories, which created considerable environmental problems in the following years.

The second phase coincided with the period of the Great Leap Forward and the following economic adjustment up to the eve of the Cultural Revolution (1958-65). During the mass movement of the Great Leap Forward (1958-60), encouraged by decentralized economic policies, the development of steel industry became the top priority of industrial policy. The over-simplified small-scale rural iron and steel industries expanded from 170,000 in 1957 to 310,000 in 1959, a 35% growth rate annually. Consequently, environmental quality declined without proper protective measures. The most massive state-organized environmental movement during this period was the so-called "eliminating the four pests" (flies, mosquitoes, rats and sparrows) movement.

The third phase was during the time of the Cultural Revolution (1966-77). It was not only the national economy that almost collapsed, but also environmental pollution and ecological destruction reached very serious levels. On the one hand, urban environmental pollution emitted from 130,000 factories constructed during the Cultural Revolution caused many environmental problems, such as air and water pollution; on the other, ecological problems such as deforestation, soil erosion and decertification also became worse, due mostly to irrational use of land, population growth, deforestation and over-consumption of biomass resources.[95]

The fourth phase was the period of modernization spanning from 1978 until 1989. Under the drive of economic reforms and the "open door" policy, the development of environmental policies has undergone a fundamental change, and substantial progress is being made. As a result, energy efficiency rose and some environmental problems are partly improved. Also a series of environmental laws and regulations were stipulated and implemented, as shown in **Table 5.1**.

Table 5.1 Major Environmental Protection Laws and Regulations in China (1977-89)

1977	Some Regulations on Controlling the "Three Industrial Wastes" and Developing Comprehensive Utilization
1979	Circular Related to Procedures Governing the Retention of Profits from Products Derived from Multiple Use of the "Three Wastes" in Industrial and Mining Enterprises
	Environmental Protection Law of the People Republic of China (for trial implementation)
1981	State Council Decision on Strengthening Environmental Protection Work in the Period of National Economic Readjustment
	The State Planning Commission, the State Capital Construction Commission, the State Economic Commission and the State Council Leading Group on Environmental Protection: Procedures Regarding the Management of Environmental Protection in Capital Construction Projects
1982	Marine Environmental Protection Law
	Provisional Measures for the Assessment of Effluent Fees
	Regulation on Soil Conservation Work
1983	Regulations of the People's Republic of China on Marine Environmental Protection from Oil Exploration and Exploitation
	Regulations of the People's Republic of China on the Prevention of Marine Pollution from Vessels
	The State Council Circular on the Stringent Protection of the Endangered Wildlife
1984	Forest Law
	Water Pollution Prevention and Control Law
1985	Regulation of the People's Republic of China on the Control of Marine Dumping
	The Sate Economic Commission Provisional Regulation on Issues Concerning Multiple Use of Resources
1986	Fishery Law
	Grassland Law
	Land Management Law
	Mineral Resources Law
	Provisional Regulations for Environmental Management in Special Economic Development Zones
1987	Prevention of Air Pollution Act
1989	Environmental Protection Law of the People's Republic of China

Recently, there has emerged a new awareness of the impact of CO_2 emissions and other greenhouse gases emissions on the global climate change within scientific communities in China, particularly about the impacts China may have to meet in the future. Several groups of scientists have been organized within the Chinese Academy of Sciences, as well as in the R & D systems of the National Environmental Protection Agency (NEPA), to initiate corresponding interdisciplinary studies about global climate change. China will also participate more actively in the on-going international research activities on GHSs emission.[96] For instance, in 1987, U.S. Department of Energy (DOE) and the Academy of Sciences of the PRC signed a five-year collaborative research agreement on studying the effects of the increasing atmospheric CO_2 emissions on global, hemispheric, regional and local scales of climate change.[97]

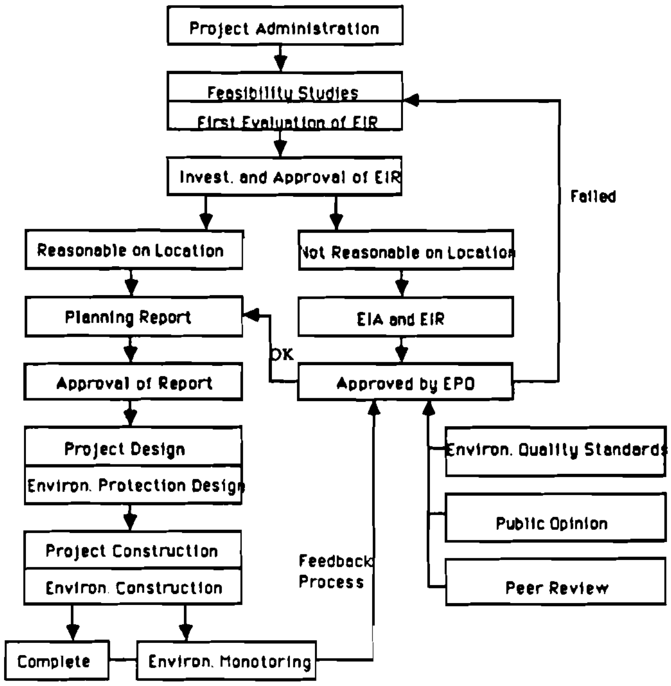
Since 1970 until the end of 1980s, China has experienced a number of severe floods, droughts and uneven climatic changes. In May, 1990, a warning was again being given that Yangtze River (Chang Jiang) is this year likely to meet the worst flood in 36 years, which is a very dangerous situation for the whole southern part of China.[98] In such a context, China's research interest in the GHSs issue is very much concerned about global climate change and its impacts on the agricultural production systems and ecosystems in China in the next 20 years or so, since agricultural production is the "life line" of China's whole economic base.

Early in this year, the State Council decided to establish a Climate Change Coordinating Group (CCCG) under the Environmental Protection Commission of the State Council. The main task for this leading group is to coordinate research, assessment, policy and foreign relations on global climate change. The members of the CCCG are representatives from different governmental agencies, such as the State Planing Commission, the Ministry of Energy, the Ministry of Education, the Ministry of Chemistry, the Ministry of Transportation, etc.[99]

5.2. Major Policy Measures

Environmental Impact Assessment Among the major Chinese environmental policies, one of the important measures is devoted to the development of Environment Impact Assessment (EIA) in the process of environmental policy implementation. In recent years, EIA has been recognized as an important policy instrument in combating the environmental problems. It was stipulated in 1979 in the Environmental Protection Law of the People's Republic of China that EIA should be conducted in every development project, and the construction design of the project should not be carried out until the Environmental Impact Report (EIR) of the project is approved by governmental environmental protection bodies.[100] By applying this legislation, governmental sectors dealing with planning, economic development and environmental protection have conducted large project feasibility studies and development planning. **Figure 5.1** shows the general administrative procedure of EIA in China.

Figure 5.1 Administrative Procedure of Environmental Impact Assessment (EIA) in China



Since the early 1980s, EIA has been pursued mainly in three interrelated areas: individual development projects, urban planning and regional development.

(1) Individual Development Project EIA is, to a large extent, conducted in large- and medium-sized projects, such as huge dam, nuclear power plant, hydropower plants and the chemical industry, etc. The main features of EIR are as follows:

- A comprehensive review of the project, including the size of the project, technological process, pattern and quantity of pollutant emissions;
- Potential environmental impacts of the project, e.g., the potential impacts to atmosphere, surface and underground water, soil, plant and animal species;
- Social impact of the project, e.g., social, economic and cultural side-effects;
- Qualitative and quantitative analysis, cost-benefit analysis;
- Alternative resolutions; and
- Optional remedial policy measures, etc.

According to this policy, location of the development project is emphasized, particularly in the first evaluation process of EIR. In addition, the Chinese governments have made considerable efforts to enhance environmental economic measures in EIA processes. Notably, the most widely adopted policy measure is to include cost-benefit analyses in the majority of the development projects, provided with feasibility studies concerning the optimum utilization of environmental protection investments.[101]

Another aspect is the role of public participation in EIA. As shown in **Figure 5.1**, it indicates that public participation is usually not taken into account during the process of EIA and EIR until the later stage of governmental approval, even though the importance of the public participation has been repeatedly talked about by governmental officials and stipulated in various environmental laws, such as in *Prevention of Air Pollution Act* introduced in 1987.[102]

(2) Urban Environmental Quality Assessment From the late 1970s to the early 1980s, several large- and medium-sized cities (population: 8 - 2 million), such as Beijing, Tianjin, Shenyang, Zhenzhou, had conducted Environmental Quality Assessment (EQA) in different scopes. It was approved by the Chinese government, both at national and local levels, that EQA would provide EIA with a reliable scientific and analytical basis. It has been confirmed by the NEPA in 1983 that the EQA pursued in Beijing, Nanjing and Shenyang represents the main features of the Chinese EQA.[103]

For instance, the EQA carried out in the southeastern and western suburbs of Beijing in the early 1980s contains four major steps:

- Identify the major pollutants and the sources of pollution;
- Assessment of individual and comprehensive environmental pollution;
- Investigate the interrelations between environmental quality and public health;
- Build up relevant mathematical models in order to formulate regional environmental planning and pollution control measures. Particularly, systems analysis models are adopted, identifying the relations between, e.g., energy and air pollution, organic pollution in the water basin, etc.[104]

(3) Regional EIA The most notable work in EIA that has been done in a broad scale includes comprehensive development planning in a large region consisting of Beijing, Tianjin and Tangshan (all of these three cities are relatively highly industrialized and densely populated).[105] The EIA conducted in Shenzhen Special Economic Zone can serve as an example.

Shenzhen Special Economic Zone (327 km.^{2}) is located in Guangdong province of southeastern China. Under the incentives of special economic and social policies, which are mostly based on market-oriented mechanism, Shenzhen Special Economic Zone has since 1980 developed into a fast growing industrial region with an export-oriented industrial structure. From 1979 to 1986, the output value of industrial products has increased for 57.8 times. Because of its heavy dependence upon the electronics and petrochemical industries, plus tourism and intensive farming, environmental protection has become particularly important in the regional development planning in order to ensure its development prospects. In 1981, the local government made a decision to integrate EIA into regional development planning and environmental protection practice. In 1986, this policy was approved by the State Council in a law entitled *Provisional Regulations in Environmental Management at Special Economic Zones.*

In such a context, environmental monitoring and investigation were conducted in Shenzhen, considering such issues as: atmosphere, ground water, soil, plantlife, human health, potential impacts of industrial development projects, etc. In this way, EIA provided the regional policy-makers with detailed information about the possible environmental consequences of the economic development of the region, and respectively the policy countermeasures for future development and environmental protection. Therefore, no development project was conducted without environmental protection countermeasures. As the result of strengthening and implementing this policy of environmental management, the environmental quality in Shenzhen maintains currently a level above state environmental quality standards.[106]

However, the problem is that this policy of environmental management did not distinguish large- and medium-sized construction projects from the small ones. In practice, there remains a need for setting up different criteria in EIA, depending on the size of the project. In addition, different requirements should also be set up, according to the diversified situations between regions and groups of industries.

It was reported that between 1981-85, 76% out of the total number of large- and medium-sized construction projects were conducted with EIR; between 1986-87, 100% of the projects were carried out with EIR.[107] But this situation did not apply to small-scale industries, especially those of rural enterprises, which had exceeded 18 million units in 1988.[108] In such a situation, not surprisingly, the pollution caused by the small-scale industries is running out of control.

Effects of Technology Policy The mitigation and control of CO_2 emissions in China involves many difficulties of transforming the traditional coal-based pattern of energy consumption into the use of more energy-efficient devices or some alternative technologies, such as gas or electricity for cooking and heating, within a short-time span. The problems generated are in part related to the economic and technological constraints existing in China. On the one hand, tens of billions of yuan in investments on industry and infrastructureare needed, which may not possibly be met in the current financial difficulties; on the other hand, there exist corresponding obstacles in the present economic structure and price system as well as in the political system, which require substantial reform and readjustment.

It is not fair to assume that the Chinese government is not aware of the important role technology can play in combating environmental problems. However, during the past decade, the government mostly devoted its efforts to enforcing environmental management instruments and institutional structures, aiming at the improvement of the effectiveness of environmental management with limited technical capabilities and restricted financial means.[109]

However, some arguments concerning the implementation of this policy have arisen. As pointed by an environmentalist, Zhenhua Chen,

> For many years, we followed the idea of '70% management plus 30% technology' to deal with environmental problems. This policy has been suitable to our country's situation and proved progressive during the past ten years. This is mainly because, on the one hand, the government couldn't spend more money on environmental protection; on the other hand, 30-50% of our environmental problems were caused by mismanagement, and may not be too difficult to solve by improving managemental skills. In such a context, it is not only necessary, but also possible to treat environmental problems with enforced management during that time. Nevertheless, the situation is apparently changing. We are now confronting some very serious environmental problems caused by the existing technological bottlenecks, so that they must be solved by technological means. Moreover, the increasing expenditure on environmental protection in recent years has made it possible to solve some difficult environmental problems by adopting technical means. Under such circumstances, we should adjust management and technology measures, namely through balancing technology with management. In short, it means putting them in an equal position.[110]

Notably, this point of view is also shared by some other scholars. "During the interim period of the construction of China's modern cities, it will be necessary to closely integrate prevention and control of air pollution with technical innovation that is being carried out in the fields of energy conservation and multi-utilization."[111]

It is interesting to view how much technology can help improve environmental quality. For instance, some local governments, such as Shenyang Municipality in Liaoning province, have made considerable progress in improving urban environmental quality by employing and implementing technical innovations to change the pattern of coal consumption. Shenyang Municipality is the capital of Liaoning province, and is also an industrial and economic center with a population of three million. The extent of air pollution in Shenyang is considered as the highest in China. The high density of air pollution is closely linked to the annual combustion of four million tons of coal - the main source of energy in Shenyang. Since 1979, the city municipality has made considerable efforts to implement comprehensive environmental quality control measures, along with "spot source pollution" control and renovation of the existing equipment.

As a result, cogeneration district heating systems were developed, which supply heating to 156 residential districts with a total of 2.52 million m^2 of residential space. The policy measures have led to a total energy saving of 19,000 tons of coal annually. Simultaneously, heat produced from the Shenyang thermal power plant was used for heating purposes. As a result, 100,000 tons of coal have been saved during each heating season. When the Shenyang pressurized-gasification plant is completed, the gas supply for the whole city will extend to more than 90 percent of the city's dwelling areas.[112] **Figure 5.2** indicates the development trend of air pollution control in Shenyang from 1978-83.

The problem of inefficiency of investments forms another barrier on the path to pollution control and environmental protection in China. For instance, between 1983-87, the state invested about one-third of its total environmental protection expenditure on air pollution control, which accounted for about 3.7 billion yuan ($785 million) each year, but only 30 percent of the money was properly spent, with the rest wasted mostly due to technological problems, such as the lack of know-how and qualified labor force, poor design, bad equipment quality and so on.[113]

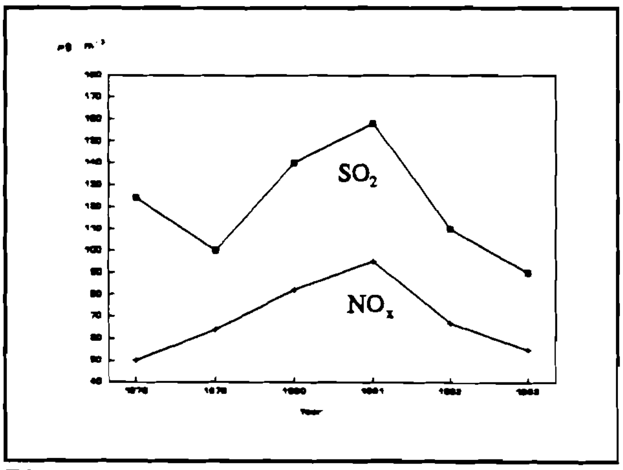


Figure 5.2 Annual Average Air Concentration of SO_2 and NO_x in Shenyang Municipality in China (1978-83)
Source: *AMBIO*, Vol.16, No.5, 1987, p.26

Moreover, the lack of legislative measures contributes indirectly to the insignificant performance of existing environmental protection devices. For instance, the environmental protection industry has grown rapidly into a multi-billion yuan business (investments at 2.5 billion yuan in 1988), but operating in a situstion without any unified product standards and quality control regulations. Consequently, inefficient, highly energy-consuming equipment is being manufactured.[114]

Clearly, technological problems have become a key factor in the performance of environmental protection measures. How this problem will be solved depends, to a large extent, on properly formulated and effectively implemented government environmental policies, and in part technology policies. In 1986, the first State Environmental Technology Policy was promulgated by the State Council, which indicated a step forward in the governmental attitude toward environmental policy in relation to the performance of technology policies, even though there exist some dissatisfaction regarding the contents of the policy as well as the problems of policy implementation.[115]

How do we measure the performance of the existing environmental technology policies? First of all, in the field of environmental protection and environmental quality control, there is a tendency to neglect the development of energy-saving technologies and devices. For instance, solar technology, energy-saving building technology and energy-saving household stoves in urban areas are particularly relevant to environment protection, because they create no or less pollution and CO_2 emissions in the course of operation. They are also relevant to decentralized rural development and beneficial to the low income groups of citizens. With the reality of the combustion efficiency of small household stoves averaging 10%, and most of the industrial boilers not surpassing 30-50% efficiency levels, there remains a great potential for improving energy efficiency in the coming decades.[116]

The point is that by increasing energy efficiency, one of the positive results will be the elimination of CO_2 emissions. One of the success stories is the development of biogas project mostly implemented in the rural areas. As reported by the World Bank, the development and production of biogas in China has been viewed as a particularly appropriate and clean technology, because it provides not only a clean fuel that can be used more efficiently than traditionally used solid fuel, but it also provides a relatively high quality of organic fertilizer to improve rural sanitation. However, despite the positive aspects of the performance of the current technology policy, some shortcomings and constraints remain, for instance, the efficiency of the improved household stoves in rural areas is still low, due mostly to problems in production design and the lack of convenience in everyday use, according to the same report.

5.3. Problems in Rural Industry

During the past decade, industrialization in rural areas in China has been sped up, under the encouragement of governmental policies, particularly in the energy and chemistry sectors.[117] From 1980-88, the industrial output value of small rural township and village enterprises increased from 51 billion yuan ($10.8 billion) to 650 billion yuan ($138 billion), an average annual growth of 37.4%. In 1988, small rural industries contributed almost half of the total industrial output value and 31 billion yuan in tax revenue, and earned 6.5 billion yuan in foreign exchange for the country.[118] The background for this trend is evident: the pressing unemployment problems and the rising living standards with higher demands for more industrial products and energy supplies in rural areas. The most problematic is the present governmental policy of transferring some heavily polluted urban industries into rural areas under the principle of reducing urban pollution problems. Clearly, this policy leads to three consequences: 1) diffusion of pollution in remote rural areas; 2) decreased energy efficiency in rural industries (50% lower than the state-owned industries); 3) increased raw materials consumption rates during production and distribution processes. For instance, only 7% of the rural enterprises (26 out of 349) in Liaoning province have installed environmental protection equipment, and the managers have no "concept of environmental protection". Furthermore, the old equipment and technologies used in these enterprises have created sizable health and safety problems.[119]

It is arguable that the current economic and environmental policies tend to neglect the serious pollution problems caused by small-scale rural industries, which not only put stress on the overall environmental situation in the rural areas, but also create increasing carbon emissions problems; on the other hand, it is not correct to assume that the governments, both at national and local levels, are not aware of the rural environmental problems, since there have been numerous reports on this issue as early as the beginning of the 1980s. Moreover, new awareness has emerged, reflected in the recent attempts of the central government to control the "over-heating" development of the rural industries.[120]

5.4. Policy Implementation: The Bottleneck

The problem of policy implementation should be regarded as a big barrier to achieving environmental protection objectives in China. It is obvious that, on the one hand, China has up to now devoted considerable efforts on enforcement of its environmental protection mechanisms and instruments since the end of the 1970s. And some progress, particularly in environmental legislation and management, have been achieved accordingly; on the other hand, the efforts in legislation do not necessarily guarantee an automatic reversal of environmental quality. The overall environmental protection objectives can only be met, to a large extent, through effectively implemented policy measures (not only environmental policy, but combined with other policies, such as technological policy, economic policy, etc.) and legal procedures, under the condition that the general public is actively involved in policy-making and implementation process.

There have been reported cases concerning ineffective implementation of environmental policies, due mostly to the inability of governmental organs and the obstacles in bureaucratic systems. One of the examples illustrates the problems of the mismanagement of natural resources and the failure of pollution control policy in Baiyangdian Lake of Hebei province in northern China.[121]

Another article entitled *The Weakness of Environmental Policy* says the environmental protection officials have been complaining that pollution control laws in Hebei province are only "empty talk", since neither the local governments nor industrial enterprises have paid enough attention to pollution problems. Consequently, all 37 major rivers in Hebei province are polluted by industrial waste water. However, under the present policy and constitution, the polluters will, of course, be charged with effluent fee, but the rate of effluent fee is only 0.1 yuan ($0.02) for discharging one ton of polluted water, while the cost of purifying the same volume of water is two or three times higher.[122]

Under the present constitution, the problems of bureaucracy, poor management and the conflicts of interests between institutions will be difficult to solve in the near future, which poses a great challenge to the successful implementation of environmental policies. The theoretical explanations to the above problems are suggested by Prof. Lester Ross as a "Bureaucratic-Authoritative Implementation Approach". He argued that "Bureaucratic planning and moral suasion [in China] have failed to solve environmental problems, despite major investments in political and other sources. Conversely, it demonstrates that markets have a considerable potential to enhance the environment".[123]

5.5. Public Participation: A Prerequisite

It seems that China has up to now not been able to achieve its environmental protection objectives through applying bureaucratic "top-down" administrative approaches and measures. In this respect, it is necessary to review the role the public can play in the processes of environmental policy-making and policy implementation. Unfortunately, little attention has been paid at the governmental level to encourage active public involvement in environmental protection practice, despite several large mass campaigns mobilized for environmental protection issues, such as the sanitation campaign and waste utilization movement during the 1960s-70s. In 1980, a nationwide environmental protection propaganda effort was launched and it achieved some positive responses from the general public, but the problem is that little was retained after the one-month propaganda. By contrast, there are several reports about massive destruction to natural resources and ecosystems with intensive public participation.[124]

One explanation to the phenomenon is that there are very few channels and incentives provided by the governmental organs with which the general public can participate directly in environmental protection decision-making and practice. In other words, the Chinese system of environmental protection basically applies a "top-down" management approach, with poor feedback mechanisms from those concerned with environment at the lowest range of the society to decision-makers at the top. Eventually, this situation reinforces the "blanket control" approach, which could worsen the environmental situation in the time ahead. Another assumption may be connected to the current political situation since the government is trying to make every effort to "stabilize" the society. Any sensitive discussions or debates, such as environmental pollution issues, may be considered as a stimulus to generate social "unrest". This assumption may be backed by the fact that reports about environmental pollution problems can be hardly found in newspapers since the beginning of 1990.

5.6. Two Options: Producing More Coal or Improving Energy Efficiency?

Based on the above discussion and analysis of the existing problems turn to be clear that the present pattern of intensive energy production development and inefficient use of energy will have to change, because there are growing concerns both within China and abroad about the environmental consequences of pollution and CO_2 emissions within such a model of energy development. Therefore, it should be reasonable to assume that China will have to make a tough policy choice: producing more coal or improving energy efficiency in the coming decades. What is the optimum option the Chinese government may choose?

Optimum policy-making has to be based on reasonable cost-benefit analysis, depending on indigenous conditions. It has been argued that the investments needed for achieving an annual conservation capacity of one ton of raw coal is 347 yuan ($73.6), which is lower than the investments required to produce the same amount of coal (about 400 yuan in the 1980s). In addition, the "pay back" time for investments in energy conservation projects is shorter than that in energy production.[125] It was estimated that if energy efficiency measures were implemented effectively, about 300 Mt of coal would be saved annually in China.[126] In other words, it means about one-third of the total coal production output could be saved, which would be enough to be used to supply the total energy demand of the UK at the 1989 level. From a global point of view, several international experiences also drew a similar conclusion: "Analysis has shown that the potential savings [from energy conservation] are so large that demand growth can feasibly be held to zero, or even be made negative."[127]

In this respect, the direct benefits from energy conservation and efficiency improvement are obvious, but there are also "indirect" or "hidden" sources of benefits from energy conservation. The "pay back" ratio of investment may turn out to be several times higher than the original amount of investment. Taking an example from the increase of coal combustion efficiency in industrial production process, there are potential benefits from: increased air quality and decreased air pollutants; the potential gains from mitigating SO_2 emissions on the damages to forests and agricultural production systems caused by acid rain; reduction of CO_2 emissions and delay of global warming; decrease of solid waste from coal burning; saving invaluable coal mine resources for future generations; release of the heavy burden on coal transportation; protecting natural environment from further deterioration; positive effects to human health and animal species; rising competitive capacities from more efficient industry and so on. Should all of these externalities be taken into cost-benefit analysis, there would be a better chance for policy-makers in favor of energy conservation and efficiency. However, it requires substantial inputs and improved cost-benefit analysis methodologies before and during the policy-making process, and also a better understanding of global environmental issues and public concerns in conjunction with national development policies, including energy and environmental policies.

The international communities have also presented the potentials for energy efficiency improvement in China. A recent international comparative study on the impacts of energy costs to mitigate CO_2 emissions suggests that "the higher CEEI (costless energy efficiency improvement) value for China (an annual rate of 1.0%), compared to 0.5% for the USA and the OECD regions, 0.25% for the Soviet Union and Eastern Europe, reflects its enormous potential for energy efficiency improvements, [because] China uses about four times as much energy per unit of GDP as any other region. Unless China makes more efficient use of its energy resources, it will become exceedingly difficult to achieve rapid economic growth targets."[128]

Another study argued that "comparing the known rates of energy use in specific end-uses in China with the best available, economically justifiable technologies, it is evident that China could maintain a 2% rate of energy efficiency improvement for almost eight decades - without any new technological breakthroughs".[129]

Based on the review of the current characters, performance and pros and cons of energy and environmental policies in China, it can be assumed that the interrelations between energy sector development and environmental protection, including the impacts of CO_2 emissions on global climate change, have not so far been fully realized by governmental policy-makers, and, to a lesser extent, scientists in China.

In the long run, global climate change in relation to GHGs emissions will become the top agenda in international relations and negotiations. Tensions between nations and regions at the global level may arise proportionally regarding GHGs emissions and the potential costs or benefits of, as well as reasonable shares of CO_2 deduction treaties among nations with different social and economic situations. There are already indications that arguments and possible conflicts are arising over the release of GHGs into the atmosphere by developing countries, such as China and India.[130] It is not impossible that China may face a rather difficult situation in the future in respect to its responsibility for potentially releasing more than 20% of the global CO_2 by the middle of the next century. In considering the above argument, it should be reasonable to suggest a re-examination of the existing energy and environmental policies and strategies in China, and their relation to global CO_2 issues. A strategic change should be made by adjusting the present energy policy to an end-use efficiency-oriented policy that focuses on energy conservation and efficient production and use of energy resources.

6. New Environmental Concepts and Approaches

In the last ten years, as reflected in governmental policy changes, the evolution in understanding of the relationships between economic development, environmental protection and sustainable eco-systems development has undergone several stages:

> Economic Growth ---> Environmental Pollution Control ---> Comprehensive Regional Environmental Protection ---> Eco-Development

The development trends in eco-agriculture and afforestation are two evident examples, indicating the trends for further policy-making and implementation, even though these policies are still in an initial stage of development and on an experimental scale.

6.1. Eco-Agriculture

According to a recent report from the Ministry of Agriculture in China in June 1990, the development of eco-agriculture, which was implemented with 36 pilot projects around the country during the last few years, has shown great prospects for the future development of agriculture and the improvement of ecosystems in rural areas. It was reported that in 1989, the efforts to develop eco-agriculture had helped the project areas increase their grain output by more than 15%, and the grain production per acre increased by 10%. The total cotton output increased 77.8%, and the output per acre increased by 18.3%. Ecological farming also helped crops survive from severe natural disasters.

For instance, Heilongjiang province in northeastern China has met a serious drought and a cold spring in 1987, followed with continuous rain and early frost in autumn, then a strong snowfall, the worst in 50 years. The crop production in the province generally decreased in that year. By contrast, Liuhe village, one of the pilot area of eco-agriculture, survived from all the disasters and had a 56.1 percent increase in crop production.[131] Another case is the experience obtained from the eco-agricultural systems development in Lumiying village of Daxing County, Beijing, which was awarded the name "World Eco-Agriculture Village" by UNEP (United Nations Environmental Program) in 1987, due to its remarkable progress in contributing to eco-development in rural areas.[132]

The majority of the eco-agriculture experimental projects started in 1984. There have been some reported successes from Fujian and Zhejiang provinces though, of course, at a small-scale, village-based level. The main policy measures adopted in eco-agriculture development are as follows:

- Rural afforestation;
- Comprehensive utilization of agricultural products by applying "Ecological Engineering' principles with biogas as a major medium;

- Popularization ecological techniques through rational use of fertilizers and pesticides;
- Adjustment of rural industrial structures with more emphasis on "pollution-free" industries through the use of "clean technology" in production processes.[133]

In responding to such developments, experts have called for further governmental policy actions: to build up eco-agriculture in a broad perspective; to protect the agricultural ecological environment. Starting in 1984, China has so far built up 15 eco-agricultural counties, 430 eco-agricultural towns, 430 villages and farms and one ecological city (Yichuen city in Jiangxi province of southern China), covering a total area of 2.5 million hectares, of which 1.7 million are farmland.[134]

The main promoter for the recent eco-development in China is Prof. Shijun Ma, Director of the Research Center of Ecology under the Academy of Sciences. He introduced the principles of "ecological engineering" not only into agricultural practice, but also in urban developments, such as ecological cities.[135] This development practice is still in an initial stage, however, it indicates a way in which sustainable development may be able to be achieved at the local scale.

6.2. Afforestation

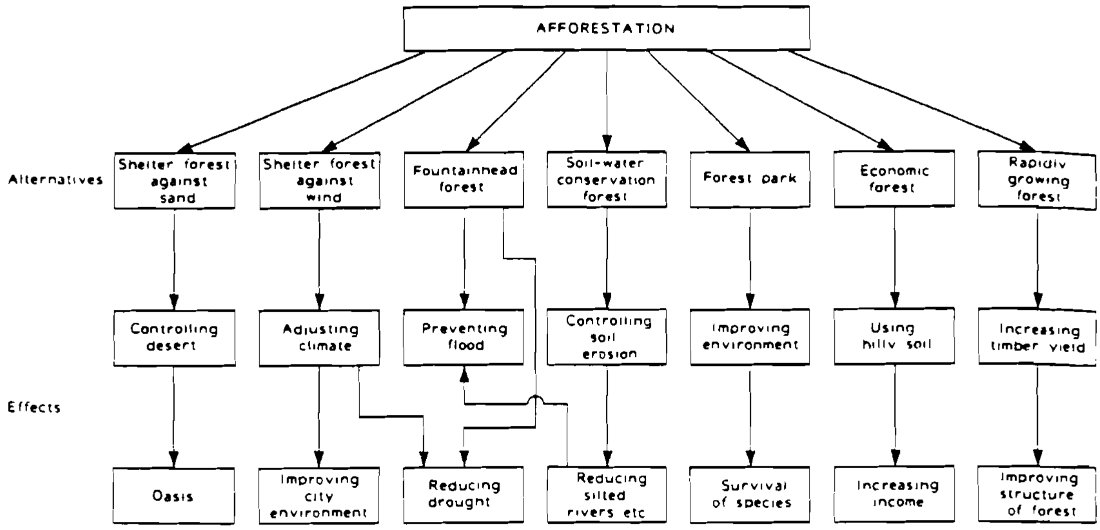
Since the beginning of this year, China has started an extensive campaign in strengthening forest planting and management to "re-green" the country because of the rapid decline of existing forest resources. By 1989, the coverage area of forest in China was 13% (125 million hectares) over the whole territory, compared to 12% in 1979.[136] However, per capita woodland in China is less than 0.12 hectares, ranked No.121 in the world. Timber consumption per capita is only 9.4% of the world average. The probability that the forest resources of China would be exhausted by the end of this century if no prevention measures were effectively adopted has been warned of.

The government has realized the danger of forest exhaustion. According to the Ministry of Forestry, the tree planting campaign in 1989 organized 300 million volunteers to plant 1.7 billion trees, which was a record figure during the last 40 years. This year, a total 5.3 million hectares of artificial woodland have been planted, which accounted for 5% of the existing forest resources.[137]

During the last 12 years, a large forest planting project called "The Green Wall" project has been conducted to protect the northern China from sand storms. Hundreds of millions of people are involved in this mass campaign. As a result, a total 137 million trees have been planted to form a shelter forest in an area of 7,000 km long and 400-1,700 km wide along the northern and northwestern parts of China. This measure has protected 8 million hectares of farmland from the tough sand storms and further decertification.[138] Another large afforestation project called the "Upper and Middle Reach Yangtze River Area Shelter Belt Project" has been launched by the State Council this year in order to eliminate soil erosion and improve the environmental situation in the area. The overall target of this afforestation project is to develop a forest area of 200 million hectares along the Yangtze River in the next 30-40 years, reported by Gao, Dezhan, Minister of Forestry.[139]

The government is now making every efforts to collect funds for afforestation projects because of financial constraints in the afforestation movement. Efforts have also been made to strengthen the administration of afforestation. **Figure 5.3** gives a view of the current afforestation strategy and the expected effects. From the policy point of view, China has adopted a "walk-on-two-legs" policy to speed up the pace of afforestation. It means that, on the one hand, the central government gives more support to afforestation efforts through mass campaign and volunteer tree planting movements; on the other, a decentralized policy has also been implemented so that the local and regional governments are encouraged to formulate diversified and flexible policies, depending on their local situations. Farmers are given more economic incentives, such as private ownership of hillland for planting trees. This policy is beneficial to both farmers and ecosystem improvement. Farmers increase their income and ecosystems benefit from an improved natural environment situation, particularly in relation to reducing the rates of soil erosion and deforestation.

Figure 5.3 The Anticipated Effects of Afforestation in China



Source: Cheng, Hong, (1989), "The Situation and Prospects of Forestry in China", *land Use Policy*, Jan. p.72

One thing is clear: that the Chinese government has realized the important interlinkages between economic development, forest resources and ecological equilibrium. But so far there has been little discussion about the role forests can play as a carbon sink in mitigating the greenhouse effect.

Conclusions

To sum up, the above analysis illustrates how the current energy and environmental policies are formulated and implemented in China, as well as pointing out existing characteristics and problems, particularly in relation to CO_2 emission problems. The central points and some recommendations are briefly presented as follows.

First of all, the Chinese experience in energy/environmental sector development during the past decade has demonstrated that China is apparently moving along a path characteristic of most of the developing countries: a low stage of economic development, the lion's share of energy consumption to industry, fast growing energy demand in the residential/commercial sector, lower energy efficiency and pressing environmental problems. What seems particular in China is the problematic supply-oriented energy policy and the heavy dependence on coal burning as a major energy source. the burning of coal has been increasingly recognized by the Chinese government as a major cause of growing environmental deterioration, ecosystems inequilibrium and a tremendous release of CO_2 to the global environment. In the long run, such a policy will not be sustainable in terms of carbon emissions both because of national environmental conditions and international acceptance. In this respect, a major policy adjustment is needed in China in order to shift toward more compatible modes of development. The adjustment of policy should be based on an increasing understanding among policy-makers, and more fundamentally among the general public, about the interrelations between economic growth, energy sector development and environmental protection.

Second, the existing "supply-oriented" energy policy focusing on production and burning of coal should be replaced by an "user-oriented" policy that emphasizes energy efficiency and conservation through increased end-use energy efficiency improvement, complemented with continuous technological innovation and improved energy production and utilization management. This should be a long-term policy, being integrated into national planning and regional/local development strategies.

Third, energy efficiency improvement is the most cost-effective way to satisfy energy demand and reduce the heavy burden on energy production and supply, but it will not be possible to succeed in the absence of free-market adjustment. It means an adequate reform of the energy price system is needed to end the operation of the existing "dual price system", by introducing an energy price mechanism in which the prices of energy products depend on the costs to produce them. However, this change requires a transition period that will rationalize the whole economic structure and the centrally-planned system into a free-market-oriented mechanism in which the price of goods are determined by their costs. This step is essential also in the sense that it will provide a relatively favorable condition for China's adapting to global carbon limits and taxation in the future.

Fourth, the Chinese government is not well convinced of the seriousness of CO_2 emissions and the associated global climate change; consequently, no progressive policy actions have been undertaken so far, but rather a "wait-and-see" strategy. In such a context, considerable uncertainties exist regarding China's attitudes, situation and position in the context of global climate change issues. There has apparently been little research undertaken on investigating GHGs problems in China. Due to the strategic importance of China's role in global efforts to mitigate CO_2 emissions and delay global warming, detailed studies should be promoted in order to understand the real situation of economic development, energy system performance, resource conditions, environmental and ecosystems limits and boundary conditions in China, and also the "externalities", such as political, institutional and social conditions, that may shape all of these development process in one way or another. These studies should be in line with the global R & D on climate change and carbon limit strategies. In addition, an enforced international cooperation should be promoted to assist China with adequate information and expertise on global climate change. This will further bring China into a better position to understand and actively join the ongoing international efforts and agreements on global climate change and GHGs reduction actions. From another viewpoint, China can also provide an appropriate environment for international scientific communities to gain a better understanding of the energy-climate-ecology interactions because of China's vast territory, diversified natural resources and rich historical data on climate change. Most important in the Chinese case - the ten year exercise in economic reform, energy sector development and environmental protection may provide valuable experience, both positive and negative, to international community, particularly to the developing countries.

Fifth, "self-reliance" is not a sustainable policy in the long run, due to the growing importance of international interdependence, communications and cooperation, particularly relating to GHGs issues. The lack of appropriate technologies and funds have greatly limited China's ability to achieve energy conservation and efficiency improvements targets. These obstacles could be relatively removed through rationalized international technology transfer and financial assistance, such as transfer of "clean technology" or energy saving technology to developing countries like China as alternatives to energy production technology, plus credit to support alternative rural energy development and afforestation, as is already being promoted by the World Bank and some developed countries.[140] It has to be realized that there still remains considerable resistance among international communities on the Chinese government's action against the "pro-democracy" movement last year. However, to bar China from international communities will not bring about any change in political constitution; arguably, an "opened" China with 1.1 billion people will eventually evolve, following up the global tide, toward a more democratic society. From the global warming point of view, any isolation of China will virtually offset the global efforts to reach GHGs reduction targets.

Sixth, if coal substitution strategies are recommended, renewable energy sources may be considered as one of the options that can be developed with less costs and considerable benefits, even though it may take decades to achieve substantial development. Adequate policies should be formulated to strengthen renewable energy sources development. Research and development on renewable energy technologies should be conducted, depending on indigenous resource conditions at the regional and local levels. This would be an optimum solution to satisfy rural energy demand in particular and release the pressing energy shortages and ecosystems inequiliblium in rural areas. This alternative development will also have great advantages for reducing CO_2 emissions.

Seventh, further development will be needed to strengthen policy tools, such as Environmental Impact Assessment (EIA), based on improved cost-benefit analysis methodologies, which may provide a better chance for policy-makers to understand the complex energy/environment/ecology/climate interrelations. This would be universally justifiable in linking up the missing points between the costs of environmental protection/carbon reduction and the potential benefits from achieving environmental protection objectives. A better understanding of this issue, particularly by decision-makers, will help raise the probability of reaching agreements in future international negotiations on carbon reductions and taxation. In the case of developing countries, improved policy tools may help reduce possible tensions or conflicts between nations or regions. In a practical perspective, improved EIA should include the value of CO_2 release in the project evaluation process.

Finally, it can be argued that eco-agriculture and afforestation are the most cost-effective ways to restore ecosystems inequiliblium in China and elsewhere in the world. This is a practically applicable approach to realize the so-called "think globally, act locally" strategy, concerning global climate change issues and combating measures. For this reason, more research should be undertaken to investigate the optimum means of realizing such a development strategy, particularly in developing countries.

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