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Section 14

"Environmental and Economic Challenges to Coal's Future in China,"

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Environmental and Economic Challenges to Coal's Future in China

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Environmental and Economic Challenges to Coal's Future in China

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Introduction

Coal accounts for approximately 75 percent of China's total primary energy consumption, and is by far the largest contributor to air pollution. The highest growth sector for coal consumption is the power sector, accounting for about 36 percent of total coal consumption in 1993. Over the 1994-2010 period most new, large power plants are expected to be coal-fired. Therefore, the availability and price of coal, as well as environmental constraints will be critical to foreign investors evaluating coal and power projects in China.

The purpose of this paper is to provide useful technical, economic and environmental information and analysis on coal and the power sectors of China. The target audiences are potential investors and government energy and environmental policy people. This paper suggests a number of important energy and environmental policy issues that need to be addressed in a timely fashion in order to promote adequate levels of investment in coal and power developments in China. Although this paper highlights problems faced by foreign investors in coal and power, it is important to balance these problems against the large investment opportunities developing in these sectors.

China is the world's largest producer and consumer of coal -- about 1.1 billion tons per year. At a moderate 6-7 percent growth rate in gross domestic product (GDP), China will double coal consumption and related pollution within two decades. The environmental dimensions of the problem will constrain economic growth if not reduced through enforcement of sound environmental policies. The most serious long term problem facing coal in China is not depletion of coal reserves or competition from alternative energy sources, but meeting the environmental challenge. All foreign investors in coal-fired power plants in China need to evaluate the impacts of increasingly stringent environmental legislation on their long term competitive position.

As shown in Figure 1, China already accounts for over 70 percent of total SOx emissions in Asia and about half the total emissions of NOx and CO_2. Emissions vary widely between regions in China. This paper examines regional differences that investors will need to consider in locating power plants, and in the emissions control technologies that need to be considered.

Figure 2 shows that coal is by far the largest contributor of four pollutants in China, accounting for 90 percent of SO_2, 83 percent of CO_2, 70 percent of particulates, and 50 percent of NOx. The environmental implications, domestically and internationally, of doubling coal consumption over the next two decades are too serious to be dismissed by either Chinese policy makers or foreign investors in China's coal and power sectors.

Energy, Coal and Economic Growth

The move from a centrally planned economy to a market oriented economy has been accompanied by a shift in the relationships between economic growth (GDP) and energy and coal consumption. During the period before market reforms (1954-1977) both energy and coal growth rates grew at a faster rate than GDP.[2] The shift toward a market economy after 1977 was accompanied by GDP growth rates above both energy and coal growth rates. This is illustrated in Figure 3, which shows the elasticities of energy and coal to GDP for the centrally planned (non-market) and open-market (emerging market economy) periods.

The ratio, or elasticity exceeds 1.0 before market reforms indicating energy and coal growth rates were greater than GDP growth rates. Economic reforms after 1978 have been accompanied by slower growth rates in energy and coal than GDP and elasticities below 1.0. There are a number of contributing factors to the slower growth rates in energy and coal consumption associated with market reforms in China. Two important factors are: (1) the impacts of a shift away from energy intensive heavy industry toward light industry, and (2) higher prices and reductions in subsidies to unprofitable enterprises have encouraged more efficient use of energy.

With respect to the relationship between the growth in electricity and

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[2] During the 1953-1978 period China's reported *national income growth*, which is similar to GDP growth. In this paper GDP is substituted for national income growth for the 1953-1978 period.

GDP, China is anomalous among lower income economies in Asia. In most developing economies, electricity growth rates are greater than GDP growth rates. However, in China, during the 1980s GDP grew at a faster growth rate than electricity, resulting in an elasticity of 0.82. This unexpectedly low elasticity is attributable to at least three important factors. First, elasticity is a measure of the ratio of actual supplies of electricity to GDP. In China, the electricity *supplies* have been less than demand, therefore underestimate the elasticity of *demand* for electricity (perhaps 10-35 percent). Second, price reforms brought about substantial efficiency gains that reduced the growth in electricity consumption. Third, the shift from energy intensive heavy industry toward light industry reduced the growth in energy and probably electricity consumption.

Figure 4 shows the projection of electricity and GDP growth rates over the 1994-2010 period. The exceptionally high double digit GDP growth rates of the early 1990s are anomalous and are much higher than the average 7-8 percent GDP average growth rate projected for the 1993-2010 period. The elasticity of electricity to GDP is projected to average below 1.0, but could be higher in the late 1990s.

Environmental Problems of Coal Burning

The two largest air-born environmental problems facing China are particulates and SOx associated with coal burning. Most larger power plants in China have emissions control devices for particulates, however efficiencies vary widely and many power plant operators are negligent in the operation of particulate control equipment. Particulate control adds only 1-3 percent to the cost of electricity and greater than 98 percent removal efficiencies can be readily achieved where regulations are enforced. Meeting stringent particulate emissions requirements will not deter foreign investments in China's power sector. Investors will need to ensure that adequate historical information is available on particulates in an area prior to start-up of new power plants to avoid misunderstandings about the source of particulates.

According to Kato et al. (1991), the average sulfur content of China's coal is 1.35 percent and SOx emissions are directly related to increased coal burning. As previously shown in Figure 1, China already accounts for over 70 percent of total SOx emissions in Asia and this share is increasing. Emissions vary widely in different regions of China due to differences in quantities and qualities (particularly sulfur and ash contents) of coal consumed, the alkalinity of soils, and climatic conditions. The most directly measurable environmental impact is acid rain which occurs primarily in southern China (Lu, 1993). The two primary reasons for this are: (1) the much higher sulfur content of coal in the south, and (2) the mostly alkaline soil in the north neutralizes a portion of SOx emissions in northern regions.

In China, annual average concentrations of SOx average about 2 tons/km^2 -- similar to the United States. However, regional concentrations vary widely. For example, around Chongqing, Sichuan Province, average annual concentrations are about 36 tons/km^2, and in the Chongqing urban area, SOx concentrations reach 600 tons/km^2.

Figure 5 shows the 12 cities with the highest annual average concentrations of SOx in $\mu g/m^3$.[3] These 12 cites have annual average concentrations of SOx ranging form 142 $\mu g/m^3$ in Baotou and Tianjin, to 351 $\mu g/m^3$ in Chongqing. The cities in Figure 5 are only illustrative of some cities with high SOx concentrations, and may not be representative of regional trends.

Environmental Standards in China

China's environmental standards are evolving and are already stringent in some cases. The problem is often not weak environmental standards but lack of enforcement. Ambient air standards are divided into three categories: I, II, and III. The most stringent category I standards apply to cities and areas

[3] The 12 cities had the highest SOx concentrations in the 70 cities shown in Table 5. There are probably other cities, not listed in Table 5, that have high SOx concentrations. In addition, there can be considerable differences in average SOx concentration estimates from different sources.

designated by the central government. Local governments establish category II and III areas. Category I, II and III standards limit concentrations of SOx to 20, 60, and 100 $\mu g/m^3$ respectively.

The power sector's emissions of SOx is projected to grow from 5.3 million tons in 1991 to about 10 million tons in 2000.

Reducing SOx Emissions in the Power Sector

The three options for reducing SOx emissions in the power sector are substitution away from coal, substitution of lower sulfur coals, and use of emissions control technologies. In addition, building higher stacks and locating power plants further from urban populations are important in reducing impacts on urban populations, but do not reduce China's contribution to global pollution. These options are briefly examined.

Alternative Energy Options

China has ambitious plans to accelerate nuclear power and hydroelectric developments. The premier project is the 18 GW Three Gorges hydroelectric project in southern China which will be the world's largest hydroelectric project if completed as planned. Although this project is controversial on environmental, social, and economic grounds, China is proceeding with the project. However, when Three Gorges is completed around 2010, it will only contribute about 3 percent of China's projected 530 GW of installed capacity (Li and Johnson, 1994). Accelerated development of hydroelectric capacity will only maintain hydro's share of total installed capacity at about 25 percent through 2010.

Ambitious plans by China to install 35 GW of nuclear power capacity by 2010 are likely to be tempered by the large capital requirements; and 10-20 GW of capacity appears to be a more realistic target for 2010.

The oil potential is insufficient to even meet domestic transportation needs, and will continue to decline in importance as a fuel for power generation. The role of natural gas can be substantially larger than generally expected, but will require policy changes to accelerate active foreign investment in exploration and long distance pipeline developments.

After reviewing all energy options, coal becomes the only economic option that can meet the majority of China's increased energy needs over the 1995-2010 period.

Location of Coal-fired Power Plants

Local impacts of coal burning can be reduced by locating plants further from urban and industrial centers. China's plans to develop mine-mouth power plants will distribute a greater share of pollution away from urban and industrial centers. In addition, the use of higher stacks spreads pollutants (SOx, NOx, and particulates) over a wider area, and is effective in reducing ground level concentrations of pollutants.

Emissions Control Technologies.

A range of emissions control technologies is available that greatly reduces emissions of particulates, SOx, and NOx, and in some cases increases efficiency. The two most common SOx control technologies are flue gas desulfurization (FGD) and fluidized bed combustion (FBC). A number of more advanced technologies that substantially increase energy efficiencies are expected to become commercially available within a decade.

The present generation of emissions control technologies (including particulates, NOx, and SOx controls) add 0.8US¢/kWh to 1.4US¢/kWh to the cost of electricity, or 15-30 percent to total electricity costs in typical Asian power plants. However, in China with average electricity costs of about 3-4 US¢/kWh, the increased costs for foreign emissions control technologies would add an unacceptably high 20-45 percent to power costs. These technology costs are too high for widespread use in China. However, use of high-efficiency emission control technologies permits the location of power plants close to urban and industrial centers where the waste heat from the power plants can be utilized, and energy efficiencies increased.

It is difficult to project the role of emissions control technologies in

China over the 1994-2010 period. China appears more likely to rely on the use of lower efficiency, domestically manufactured technologies that are expected to cost less than half of high-efficiency imported technologies. Imported technologies are more likely to be used in highly polluted areas and in rapid growth, high income coastal areas, where costs can be more easily passed on to consumers. Foreign joint-venture power projects may be required to meet higher environmental standards than 100 percent owned Chinese projects.

Low Sulfur Coal

China has substantial reserves of low sulfur coal, and can import low sulfur coal to coastal areas. The share of low sulfur coal used is likely to substantially increase over the 1995-2010 period. Enforcement of emissions and ambient air quality regulations would provide strong incentives to utilities to purchase lower sulfur coals. In some areas, premiums may develop for coals with very low sulfur and ash contents.

CO_2 Emissions in the Power Sector

On average, one ton of Chinese coal produces 0.5 tons of carbon. At present there is no economic technology for recovering CO_2 emissions from burning fossil fuels. For each kilowatt hour generated, coal releases about 1/4 more CO_2 than oil and 2/3 more CO_2 than natural gas. Fuel switching can reduce CO_2 emissions; however, as previously discussed, large scale switching to oil and natural gas is not a practical option.

In China the average efficiency of power plants in 1992 was reportedly 29.3 percent, a small 7 percent improvement over 1980. Efficiencies of 35-37 percent are typical of modern coal-fired power plants, and produce about 20 percent less CO_2 emissions/kWh than average power plants in China.

The Chinese government is emphasizing increased efficiencies in new power plants, and has a goal to increase efficiencies to 33 percent by 2000. Achieving this goal will depend on how rapidly older, inefficient plants can be retired or retrofitted.

The Ministry of Electric Power's policy is for efficiencies of 37 percent for new coal-fired power plants supplying electricity across large power grids. At present, China is planning for standard sizes of 300 MW and 600 MW for domestically manufactured generators and 350 MW and 660 MW for imported generators.

Coal Resources and Reserves in China

China is well known to have large resources and reserves of coal. However, the percent of resources that are economic to mine (reserves) is speculative. As shown in Figure 6, coal accounts for more than 90 percent of China's energy resources. Using the Chinese definition, China has about 1.0 trillion tons of coal reserves (Ministry of Energy, 1992). This estimate includes both proven coal and estimates of coal resources, yet to be proven. More useful is the World Energy Council estimate of total reserves of coal (anthracite, bituminous and lignite) at 115 billion tons (BP, 1994). Chinese researchers have confirmed that the World Energy Council estimates are reasonable. Even though total reserves are speculative, there is no indication that serious depletion of China's coal reserves will constrain expansions over the 1994-2010 period.

Figure 7 shows the regional distribution of China's coal resources. The distribution of resources is highly skewed, with 86 percent of China's coal resources concentrated in the three northern regions, and only 7 percent of coal resources located in the south.

Figure 8 shows coal production and consumption by region. The central region is the only major net exporting region, and all three of the eastern coastal regions are major coal importing regions -- each importing over 50 million tons per year. The coastal regions are projected to continue to experience rapid economic growth over the 1994-2010 period, and are expected to substantially increase coal imports.

The southeast region is the largest coal importing region in China. To date, imports have come from other Chinese provinces, however substantial imports from overseas are probable over the 1995-2010 period, with Australia and Indonesia being the most likely suppliers.

Types of Chinese Coal Mining Enterprises

China's coal is produced by three different categories of mining enterprises. *State* mines are primarily large mines managed by the Ministry of Coal. *Local state* mines, mostly fall into the category of medium sized mines, and the smallest mines are operated by townships, villages and private individuals (*TVP mines*). Since open door policies were announced in the late 1970s, the three types of mining enterprises have increased production at very different rates. As shown in Figure 9, the biggest change has been for smaller local TVP mines that have more than doubled their share of production from 18 percent in 1980 to 41 percent in 1993. State mines have been the largest loser, with their share of production declining from 56 percent in 1980 to 41 percent in 1993.

The key factors behind the rapid growth in small TVP mines are that they require little capital, have been able to avoid many of the safety and environmental constraints required of large mines; and use large numbers of cheap, relatively unskilled miners. However, the costs of the rapid expansion of TVP mines has been substantial in terms of coal resource waste, mine accidents, and environmental damages. As shown in Figure 10, TVP mines typically recover less than 20 percent of the coal seam compared to more than 50 percent in state mines (Wang, 1992). The death rate in TVP mines averages 8.5 people per million tons of coal mined -- more than 6 times as high as state mines. In addition, up to half of all TVP mines are illegal and often mine into the coal reserves of legal mining enterprises. An important government policy issue is to control TVP mines, while maintaining overall production, and to promote expansions of more efficient and safer, larger mining enterprises.

More than 90 percent of state mines are reportedly losing money, and the large central government subsidies of the past are likely to be reduced over the net decade. Consequently, foreign investments will be essential to sustain the projected growth in coal consumption in China.

Coal Quality and Availability of Low-sulfur Coal

China has the entire range of coal qualities with respect to heat contents, divided as follows: 13 percent lignite, 75 percent bituminous coal, and 12 percent anthracite. The reported high ash contents in much of the coal used in the power sector does not mean that China has inherently low quality coal. The prices paid for coal used in power plants are quite low in most inland areas, and miners have little incentive to separate dirt and rocks from the coal in mining. Less than 20 percent of the China's coal is washed, of which about 90 percent goes to the iron and steel industry. The conclusion is that China can produce higher quality coal though improved mining and coal preparation practices. Coal washing adds only a modest 0.1¢/kWh to the price of electricity, and in many instances may be the lowest cost option to improve power plant efficiencies and reduce emissions.

Availability of Low-Sulfur Coal

The average sulfur content of coal produced in China is in the 1.3-1.4 percent range, with wide variations between regions. The largest, high quality thermal coal deposits in China are in the northern part of Shaanxi Province and western Inner Mongolia. This region, reportedly has extensive reserves of premium thermal coal with sulfur contents of 0.5 percent and less, ash contents in the 10 percent range, and high heat values in the 7,000 kcal/kg (12,600 Btu/lb) range. This region will play an increasingly important role in meeting the growth in coal demand in China's power sector. The key problem is the remote location of these premium deposits and lack of adequate transport capacity to the rapid growth in coastal provinces.

As shown in Figure 11, the sulfur contents of coal burned in power plants in 1990 was 14.3 percent high sulfur coal (>2% S), 39.2 percent medium sulfur coal (1-2% S), and 46.5 percent low sulfur (<1% S) (Jiang, 1994).

Figure 12 shows the average sulfur contents of coal produced for every province in China. The heavily shaded provinces produce high sulfur coals averaging more than 2.0 percent. As shown in Figure 12, high sulfur coals are produced mostly in the south-central part of China, with Sichuan having the highest average sulfur content at 3.2 percent. The combination of Sichuan's large population of 110 million people and the highest pollution levels in China make this a priority province for widespread introduction of SOx emissions control technologies and substitution of natural gas from the substantial reserves in the province.

Most of the higher sulfur coals are located in the southern half of China. Although some northern provinces, such as Inner Mongolia, produce medium sulfur coal, reserves of low sulfur coal are substantial.

Figure 13, shows the estimated sulfur contents of coals consumed in China by province. In most provinces, the reported sulfur content of coal consumed is similar to the sulfur content of coal produced. This pattern is expected to change over the 1994-2010 period, as more premium, low sulfur coal is transported between provinces, and increasingly displaces high sulfur local coal production.

Coal Transportation and Prices

The uneven distribution of coal reserves -- mostly far from the rapid growth industrial areas -- results in most coal being shipped long distances. About 86 percent of China's coal is transported to markets, with rail accounting for about 60 percent of coal shipments. The average distance the coal shipped in China is estimated at about 600 kilometers.[4]

The problems of severe constraints on the rail transport system for coal are well known to Chinese officials, and improvements in the rail system have been appreciable over the 1980-1993 period. However, the rapid growth in coal demand has outstripped the growth in transportation capacity. Major changes in the Chinese rail transport system will need to occur over the next two decades to accommodate a 75-100 percent increase in coal shipments in

4 Excludes unreported, but significant, short distance coal movements by small miners.

China.

Long distance transportation costs in China are typically around 0.6 US¢/ton-km, however, differences in prices between inland mines and coastal plants indicate actual costs in the 1.5 US¢/ton-km range. The large discrepancy in costs is due to various payments made in addition to the direct rail transport costs -- referred to as transaction costs. The severe shortages of rail capacity, and dependence of most major producers on one transport option increases the opportunity for high transaction costs. The potential for reducing these transaction costs exists and could eventually result in more competitive prices of coal shipped to coastal markets.

Coal Prices

Historically, the state has usually set coal prices below open-market prices. In 1994, the Chinese government officially removed price controls on coal and prices are now determined by market force. Figure 14, shows a sample of coal prices in China in mid-1993. These prices provide a general indication of price differences between provinces, but are not weighted average prices, and substantial variations occur within provinces.

As shown in Figure 14, coal prices in the coal producing inland areas are much lower than prices in coastal areas, where most of the growth in demand occurs. Prices in some coastal areas, such as Guangdong, are the same or slightly higher than international thermal coal prices. The combination of high prices in coastal areas, rapid increases in electricity demand in these areas, and availability of competitive supplies of coal from other countries (particularly Australia and Indonesia) lead to the conclusion that imports to some coastal provinces (particularly southeastern provinces) is likely over the 1995-2010 period.

Figure 15 shows the movements in coal stocks as a percent of annual production over the 1980-1993 period. In China, shortages become more serious when coal stocks fall below about 14 percent of production and prices soften when stocks exceed about 16 percent of production. These generalizations should be used with caution, because lack of transport capacity can lead to high stocks in one region and shortages in other regions.

Coal Consumption Forecasts

Consumption of 1.1 billion tons in 1993 is projected to increase to approximately 1.5 billion tons in 2000 and 2.1 billion tons in 2010. Figure 16 shows the projected increases in coal consumption over the 1993-2010 period. Electricity generation is the dominant growth sector for coal consumption, with a projected increase of 530 million tons over the 1993-2010 period. This projection is based on increases in coal-fired generation capacity from 117 GW in 1993, to 195 GW in 2000 and 320 GW in 2010.

Although the increase in coal consumption in the iron and steel industry is only about 10 percent of the power sector, China is projected to lead the world in growth in metallurgical coal consumption.

Conclusions

Coal accounts for about 75 percent of China's primary energy consumption, and is the leading source of air pollution in China and Asia. Projected moderate GDP growth rates of 7-8 percent, will lead to a doubling of coal consumption in China over the next two decades, accompanied by major increases in environmental pollution.

Although efforts are underway to diversify away from coal, about 70 percent of China's total energy needs are projected to be met by coal to 2010. Therefore, pollution associated with coal use must be reduced to limit serious increases in environmental damage. The two most important options to reduce total emissions of SOx are increasing the percentage of low sulfur coal consumed, and the timely introduction of sulfur control technologies. Both options are important in slowing the deterioration of China's environment.

China is the largest *potential* market in Asia for emissions control technologies for SOx; however foreign technologies are likely to account for only 10-20 percent of the total power generation market by 2010. Domestically manufactured, less efficient but less expensive technologies are expected to account for the largest share of the market for emissions control technologies for SOx after about 2000.

Environmental problems and options vary widely among provinces. Therefore, foreign investors in China's power sector will need to assess the long term environmental situation at each location, plus be aware of national environmental trends. Many Chinese power plants do not meet existing standards, but this is likely to change in the future. Regardless of existing legislation, foreign investors in power plants in China should be prepared to meet relatively strict emission standards.

References

BP, 1994, BP Statistical review of World Energy.

Jiang, Minhua, 1994, "Development of CCT in Chinese Power Industry", presented at the APEC Technical Seminar on Clean Coal Technologies in Jakarta, October 11-13.

Kato, Nobuo, et al., 1991, Analysis of the Structure of Energy Consumption and Dynamics of Emissions of Atmospheric Species Related to Global Environmental Change in Asia, NISTEP Report No. 21, November.

Li, Binsheng and Charles Johnson, 1994, "China's Booming Electricity Sector -- The Opportunities and Challenges", presented at the AIC Power Generation in China Conference, March 23-25, Atlanta, USA.

Lu, Yingzhong, 1993, Fuelling One Billion: An Insider's Story of Chinese Energy Policy Development, Washington Institute Press, Washington, DC.

Ministry of Energy, 1992, Energy in China, P.R. China.

Wang, Zhuokun, 1992, "Effective and Rational Utilization of Coal Resources", Energy of China, No. 4, 1992 (In Chinese).

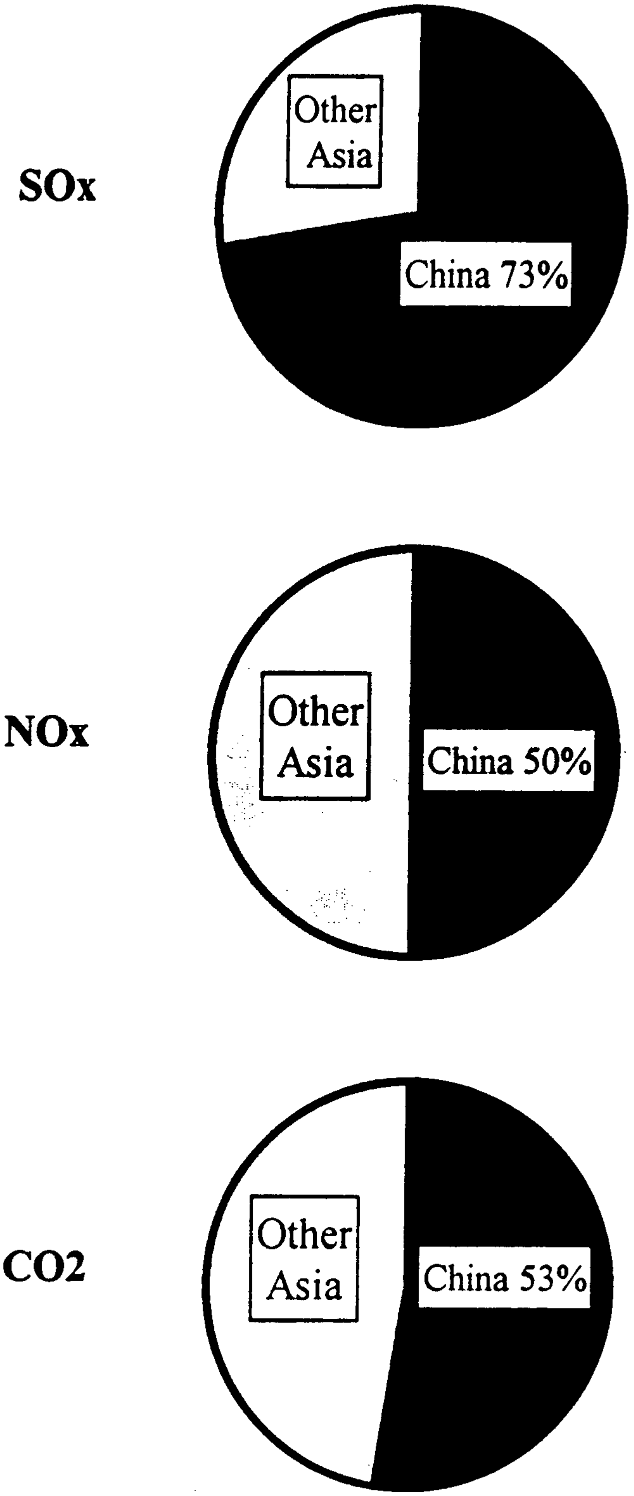

Figure 1. China's estimated percent of SOx, NOx and CO2 emissions in Asia in 1993.

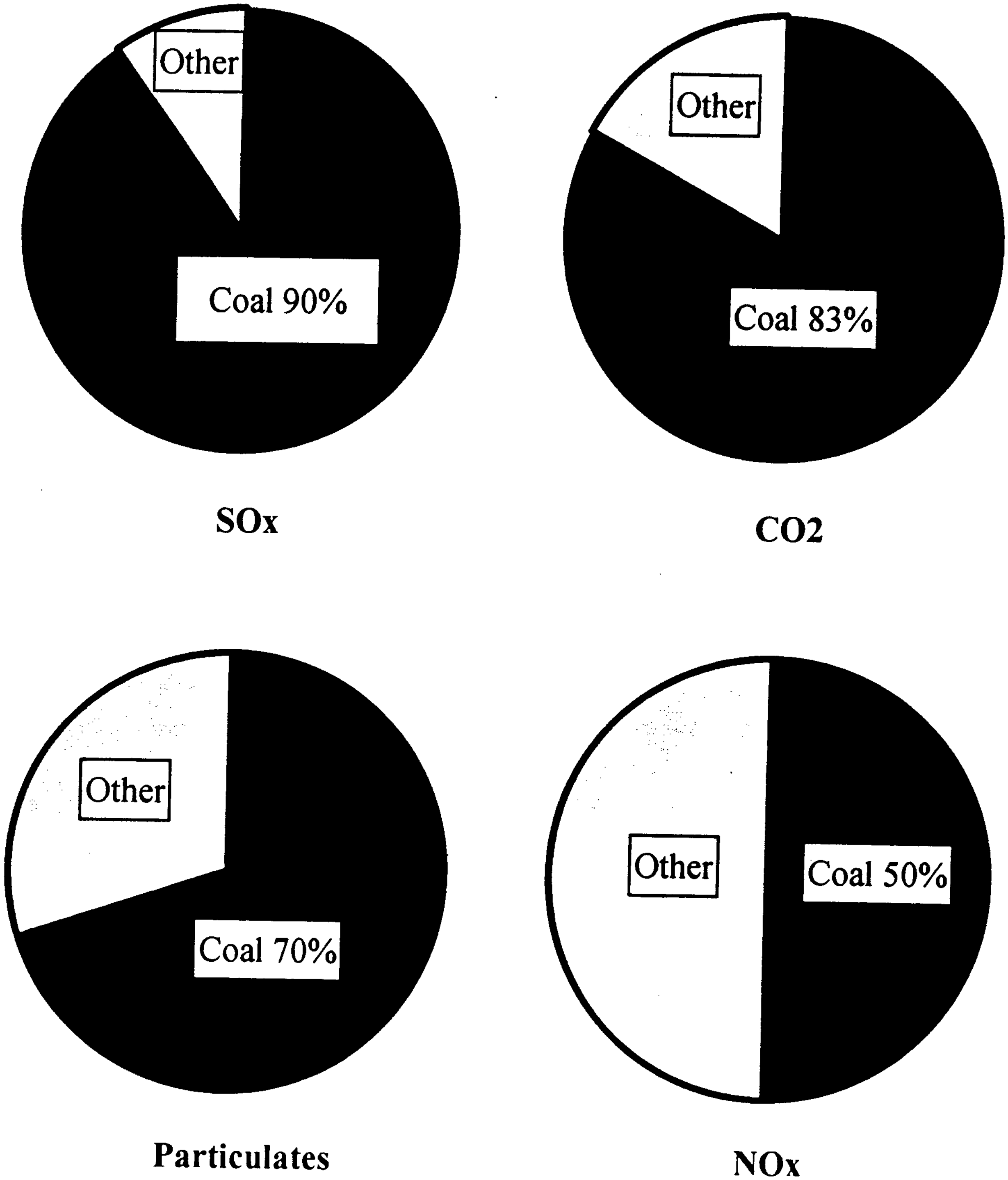

Figure 2. Coal's share of particulates, SOx, NOx and CO2 emissions from fossil-fuel consumption in China.

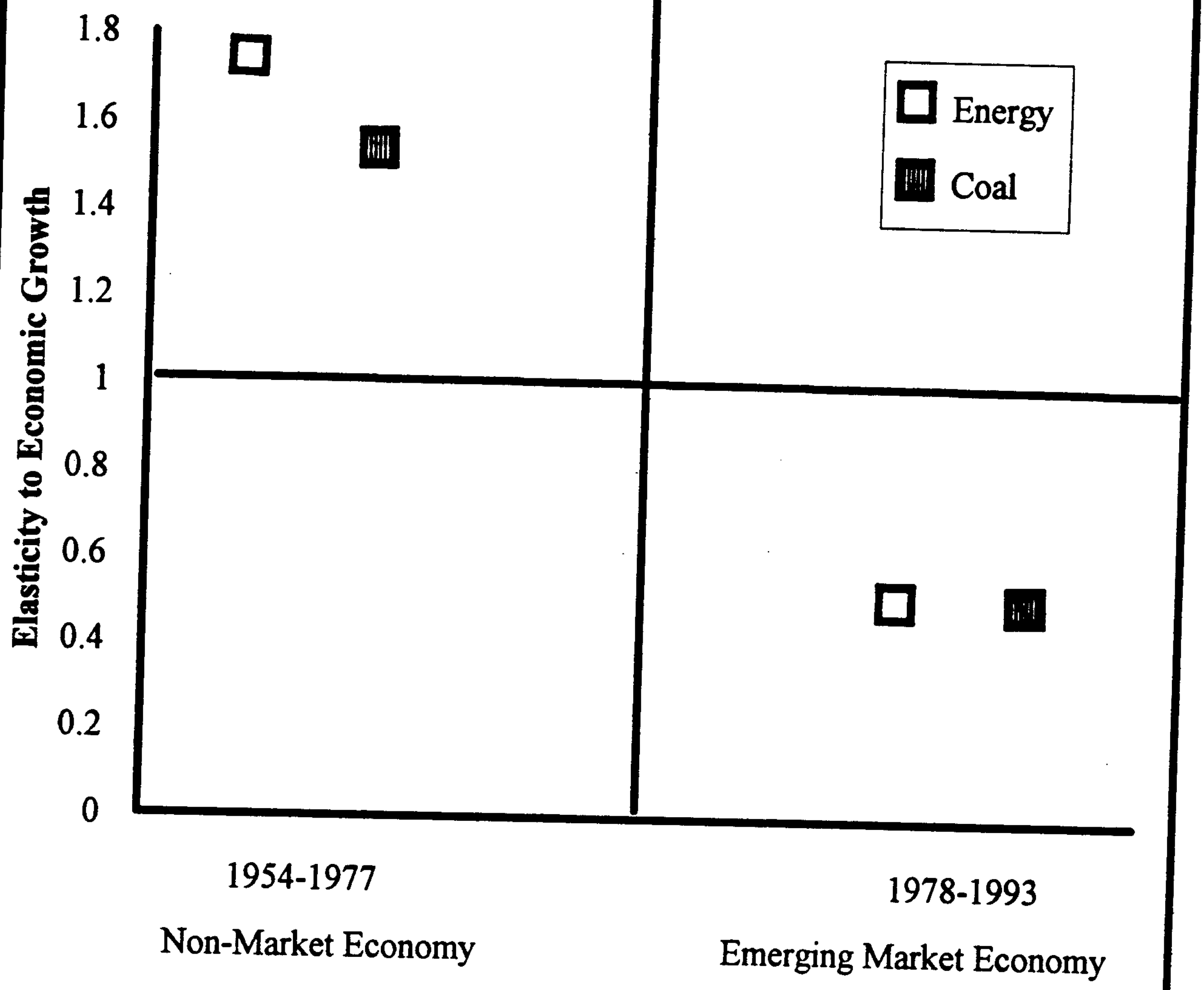

Figure 3. Elasticities of energy and coal consumption with respect to GDP in China.

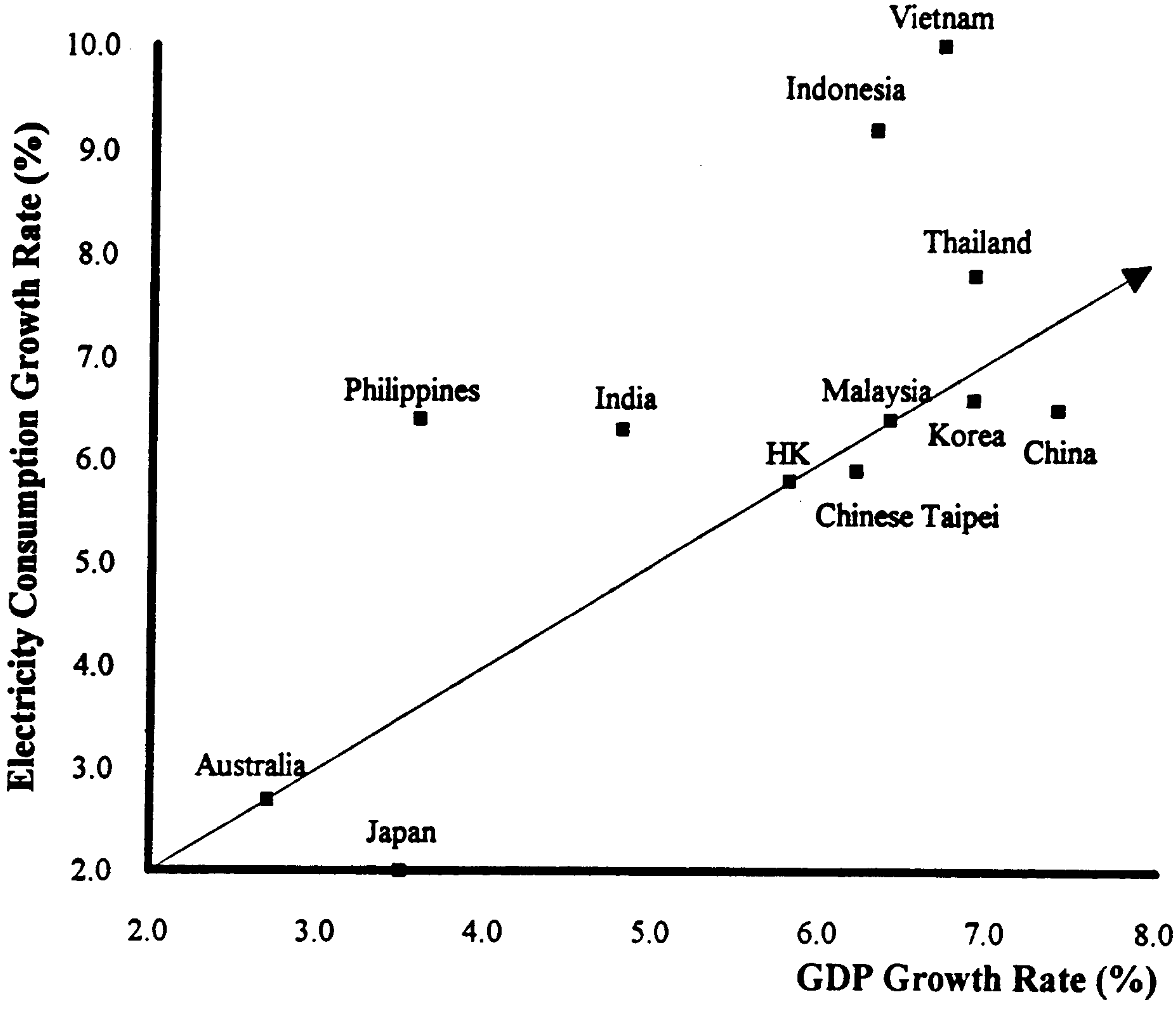

Figure 4. Projected electricity and GDP growth rates: 1993- 2010

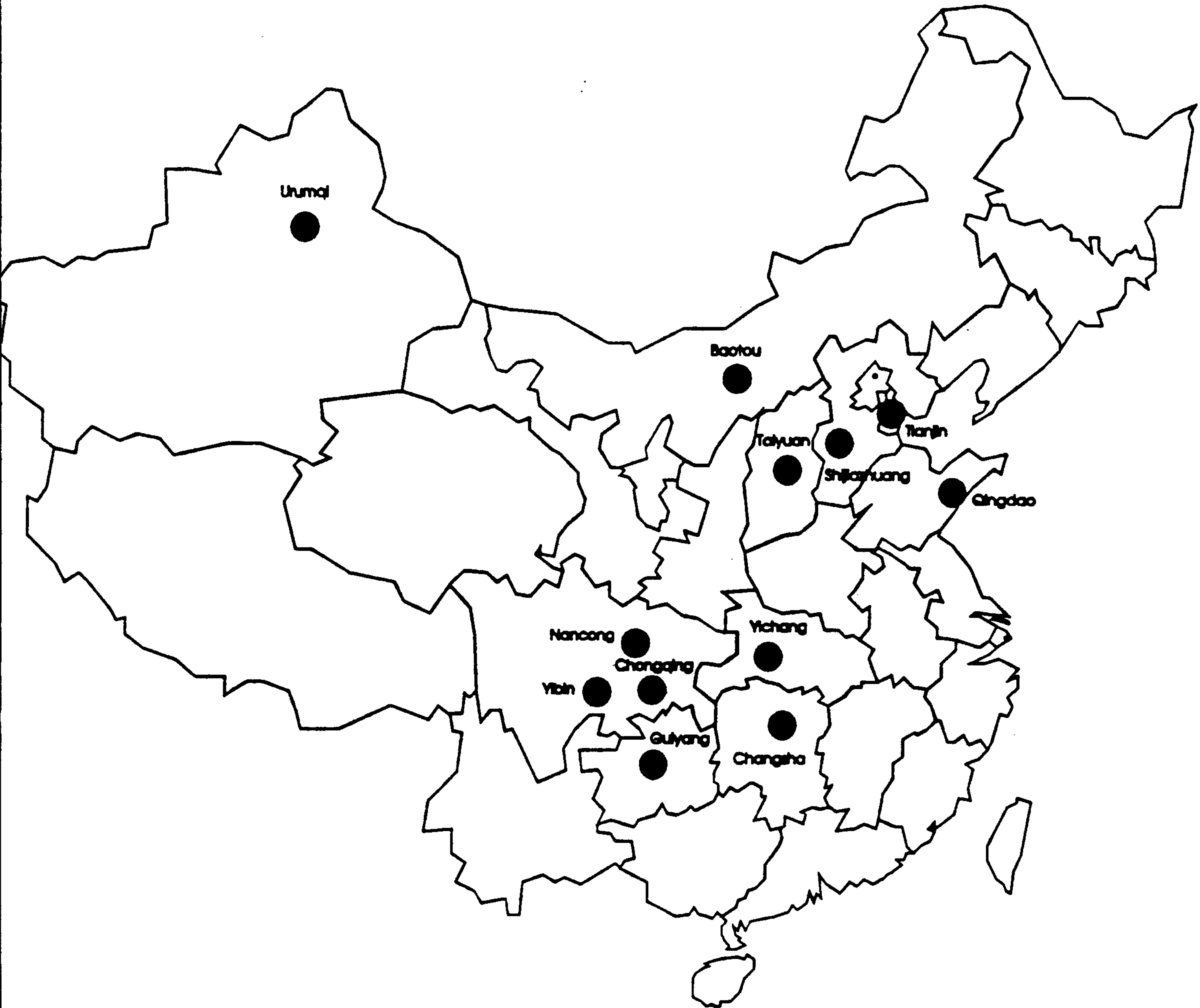

Figure 5. Cities with the highest annual average sulfur dioxide concentrations in 1991

Source: National Environmental Protection Agency of China

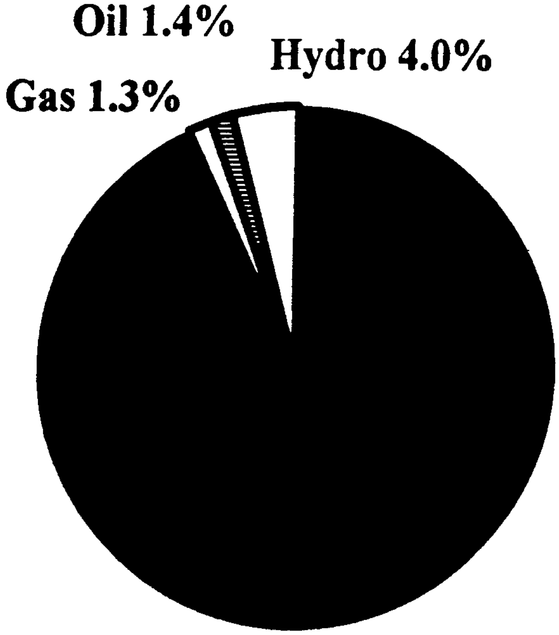

Figure 6. Shares of China's primary energy resources.

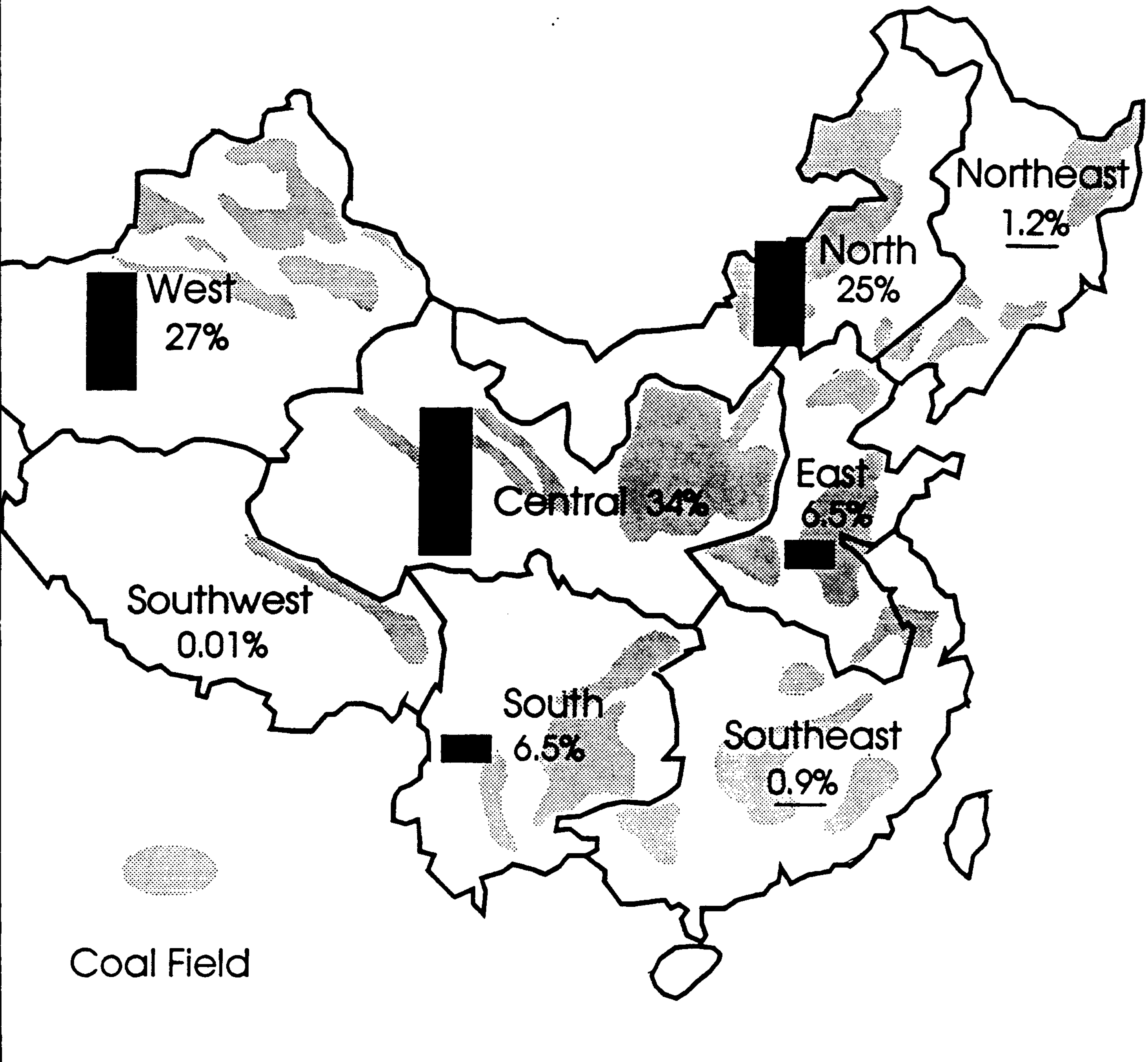

Figure 7. Distribution of China's Coal Resources

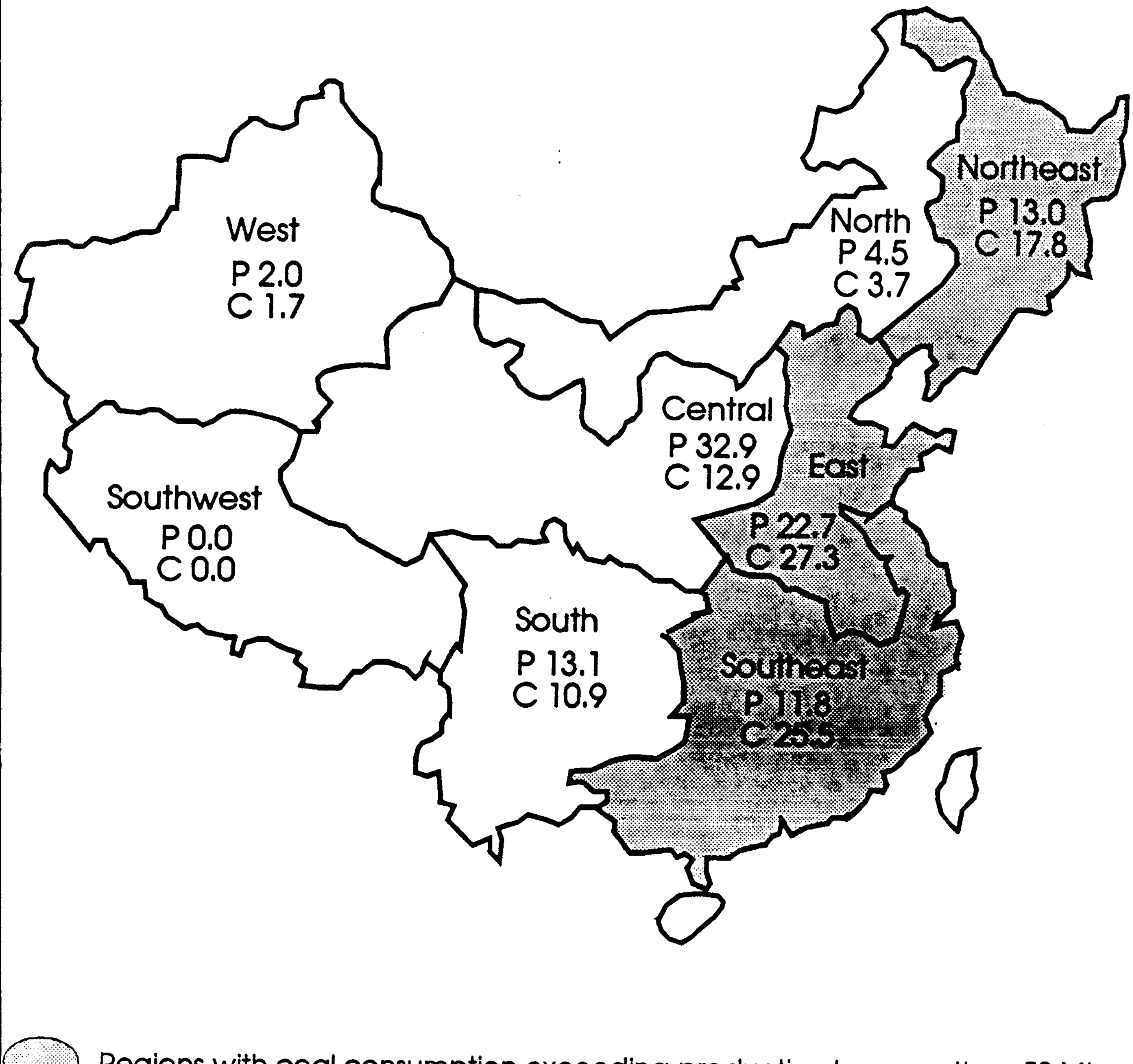

Figure 8. Percent of coal production (P) and consumption (C) in the eight regions of China

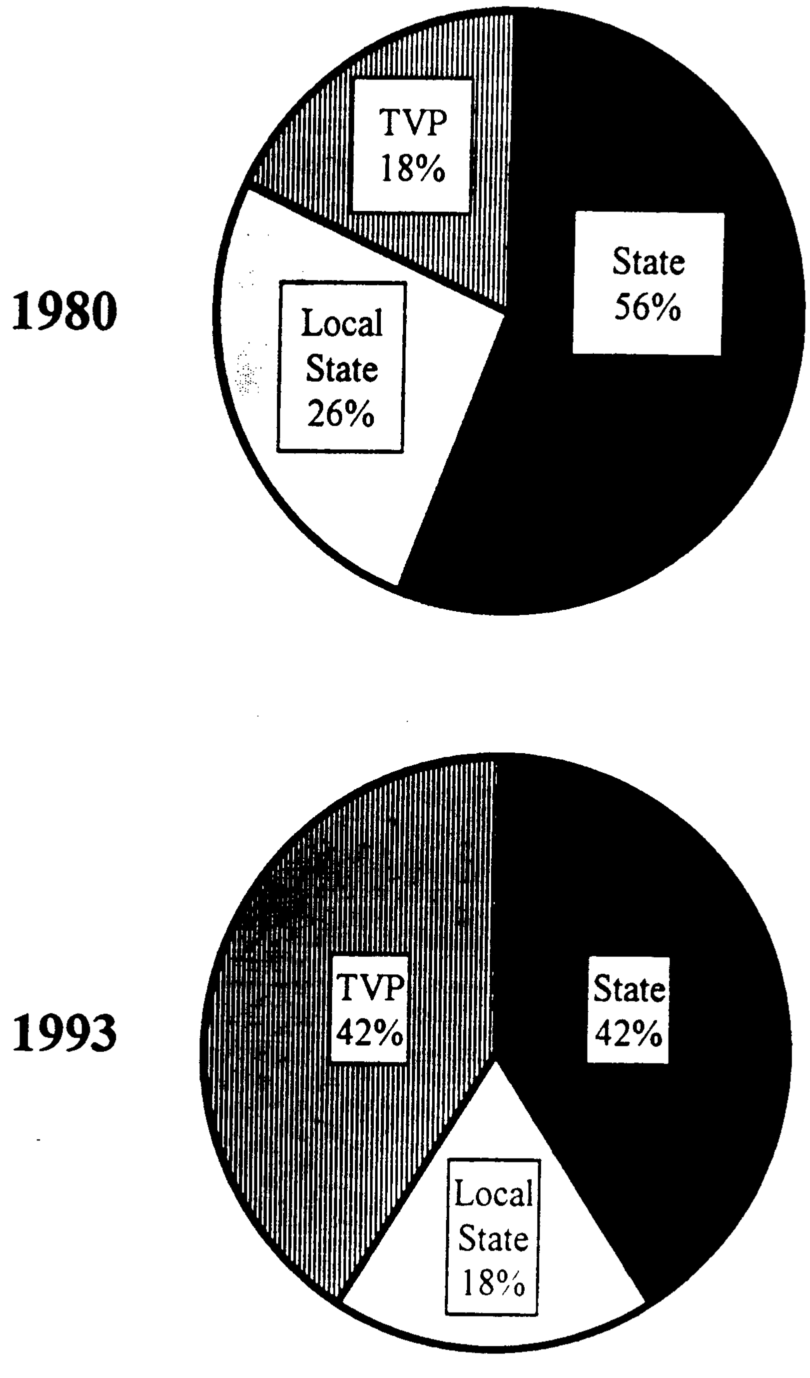

Figure 9. Changing shares of China's coal production by political-economic groups: 1980-1993.

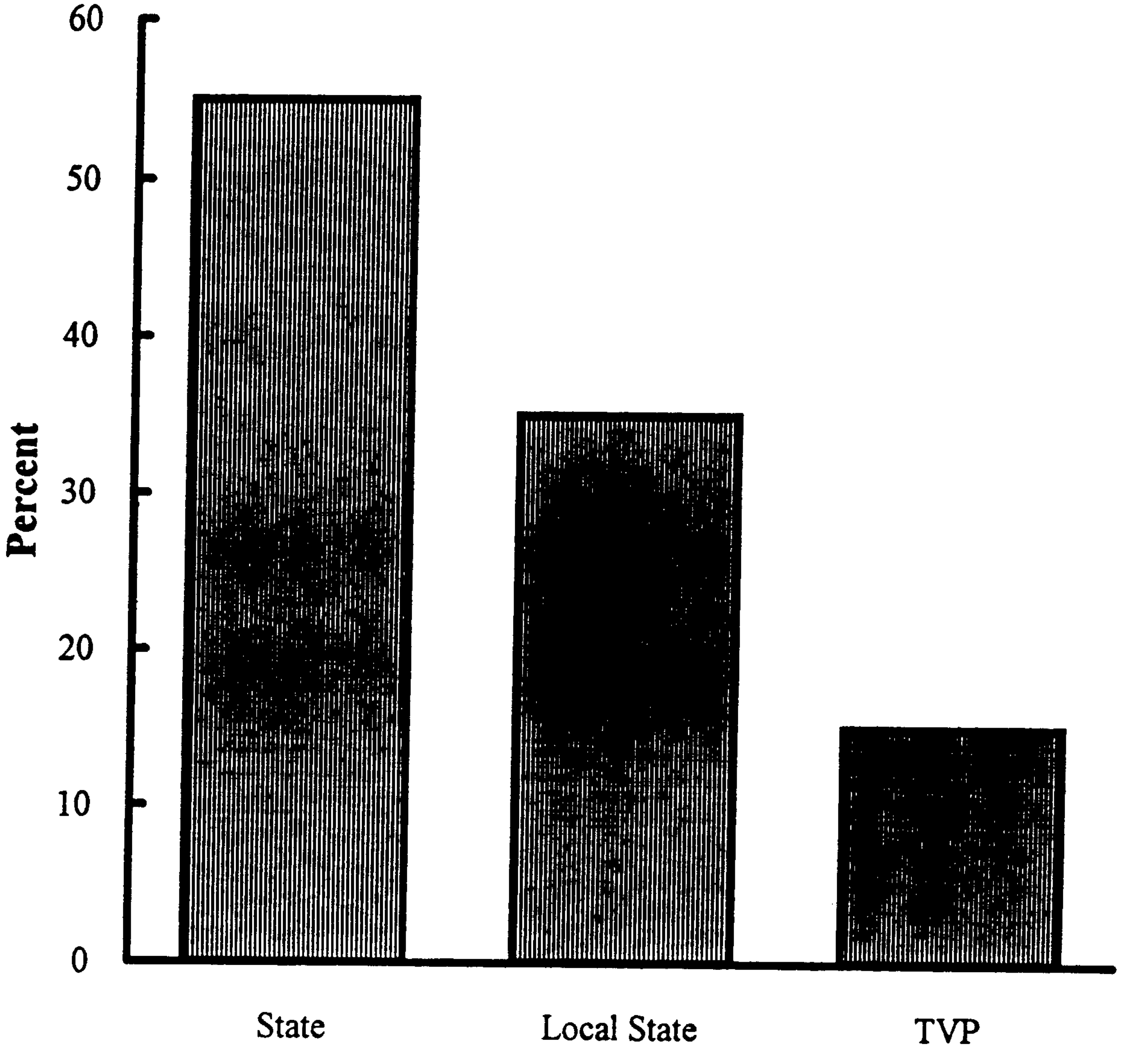

Figure 10. The recovery rates of China's coal mines by type.

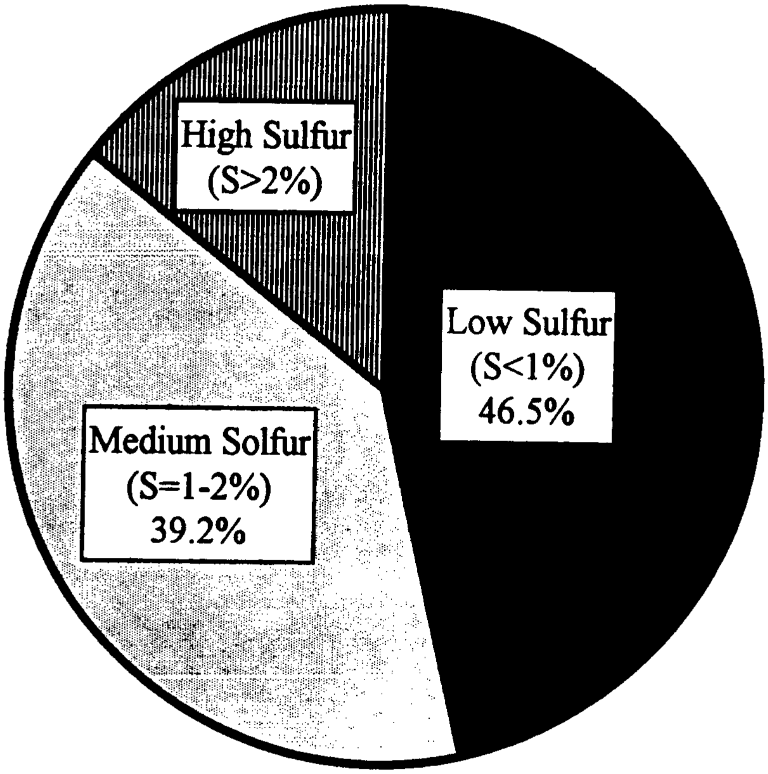

Figure 11. The shares by sulfur content of coal consumption in power plants in 1990.

Source: Jiang, 1994.

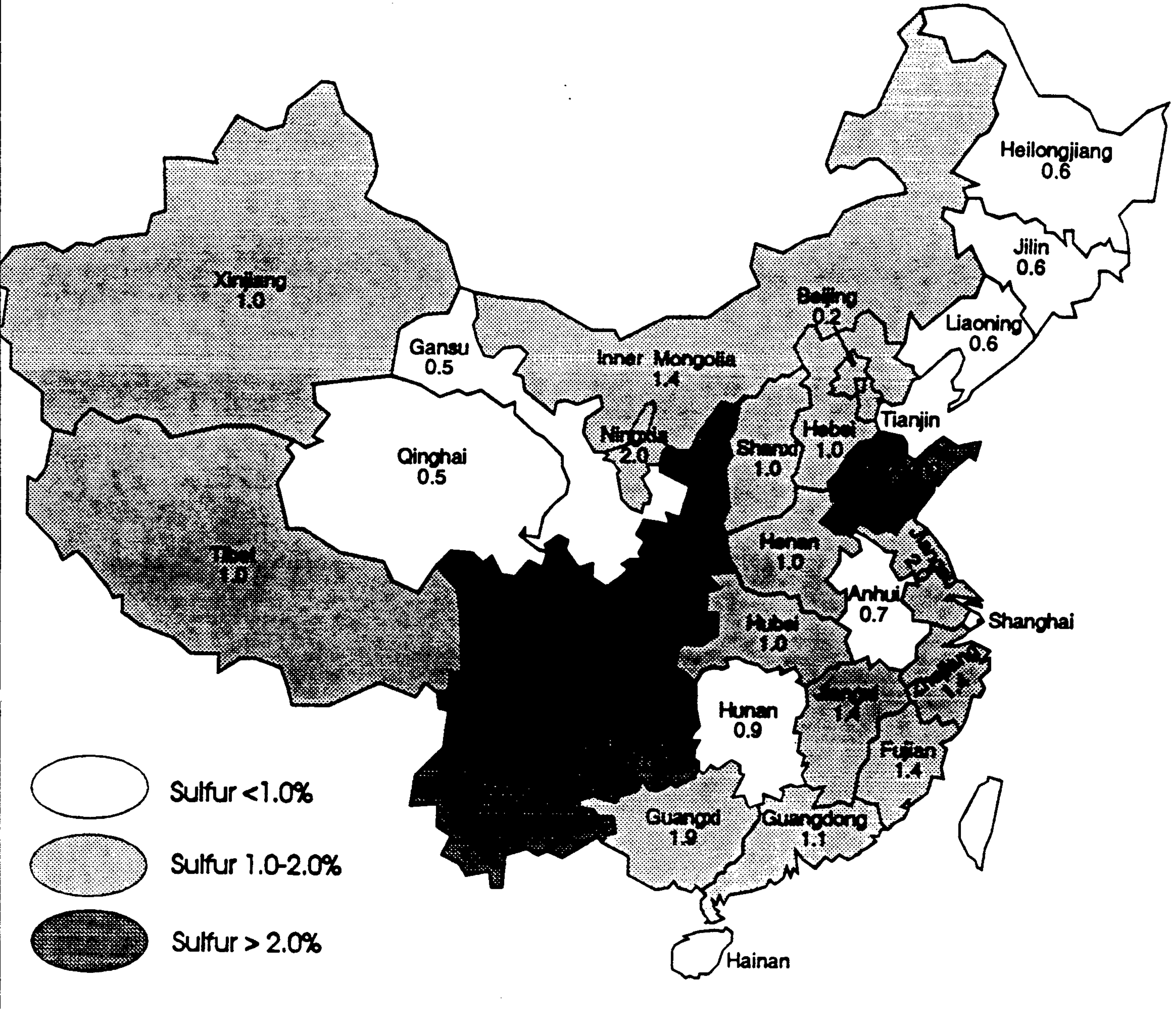

Figure 12. Sulfur content of coal produced by province

Source: Kato, et al, 1991.

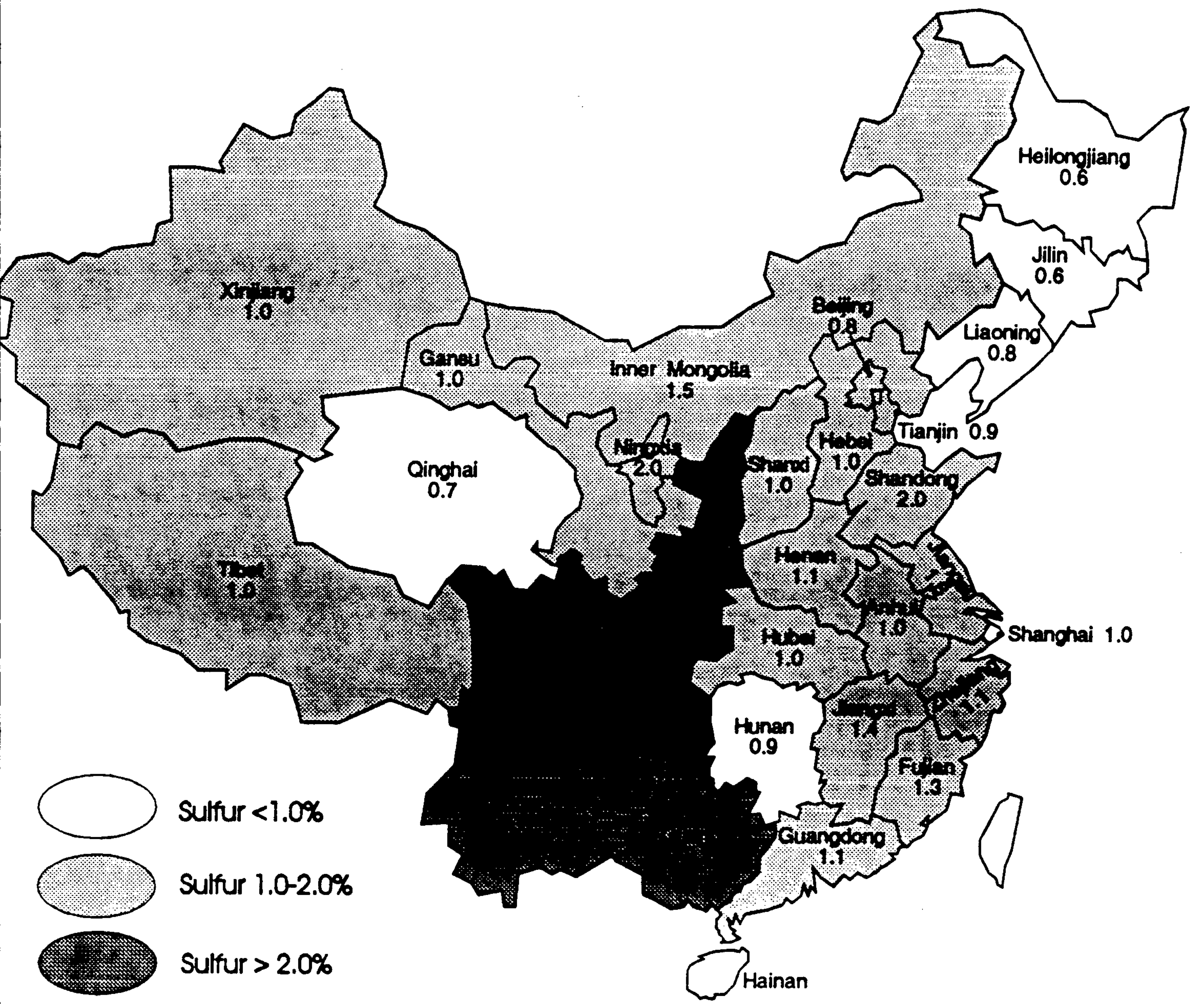

Figure 13. Sulfur content of coal consumed by province

Source: Kato, et al, 1991.

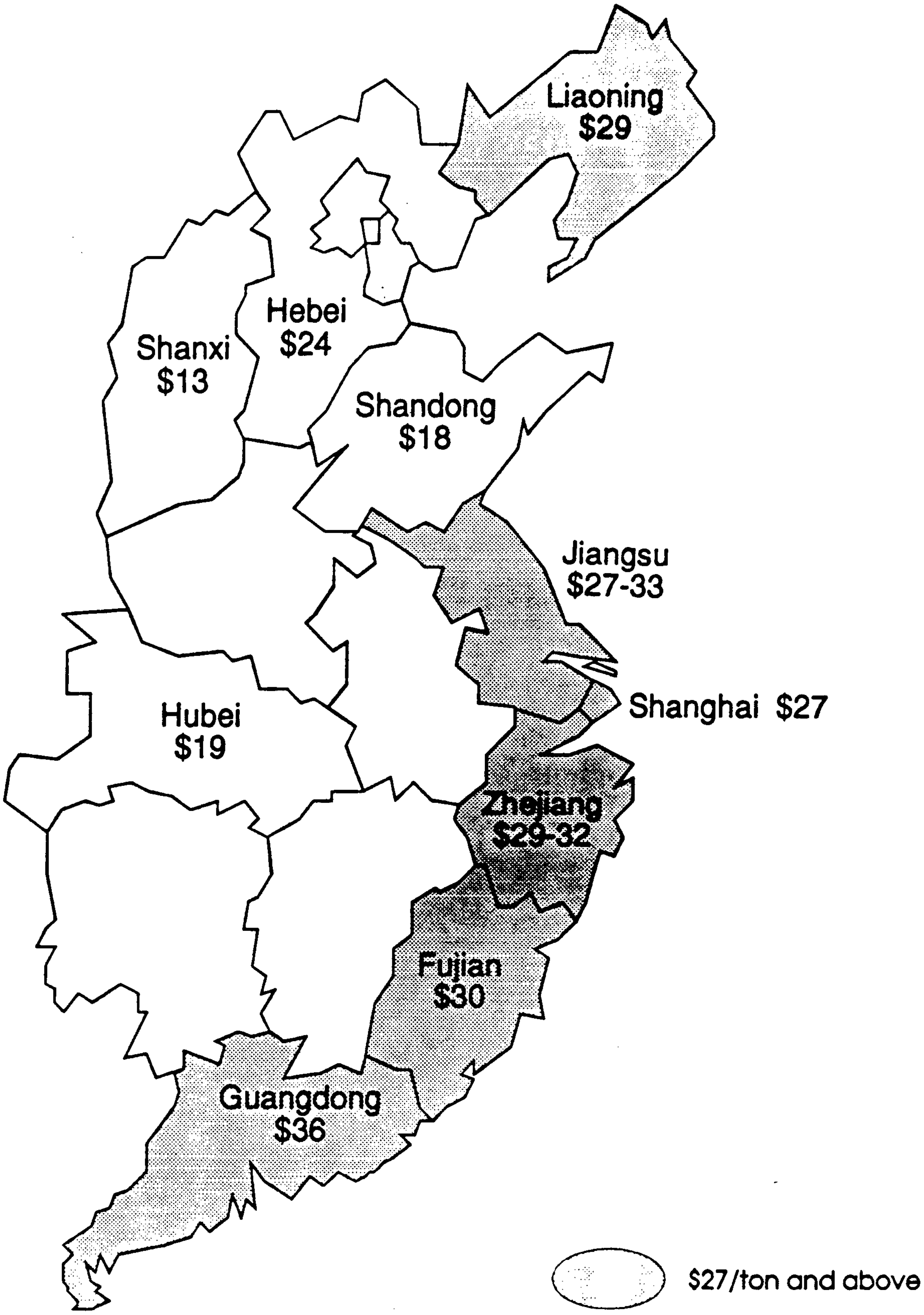

Figure 14. Coal prices in US$/metric ton in selected areas in mid-1993

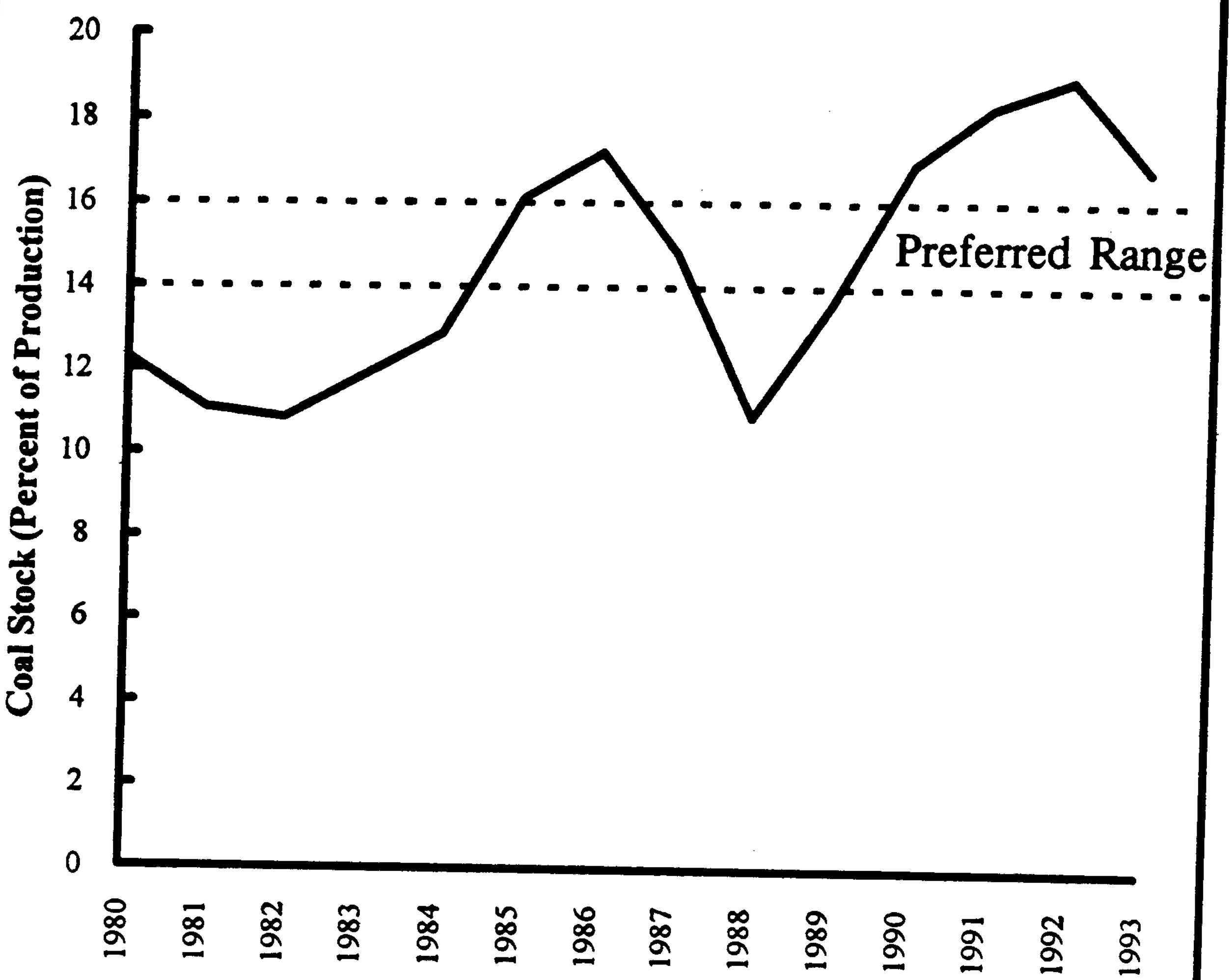

Figure 15. Coal stocks as a percent of annual production in China

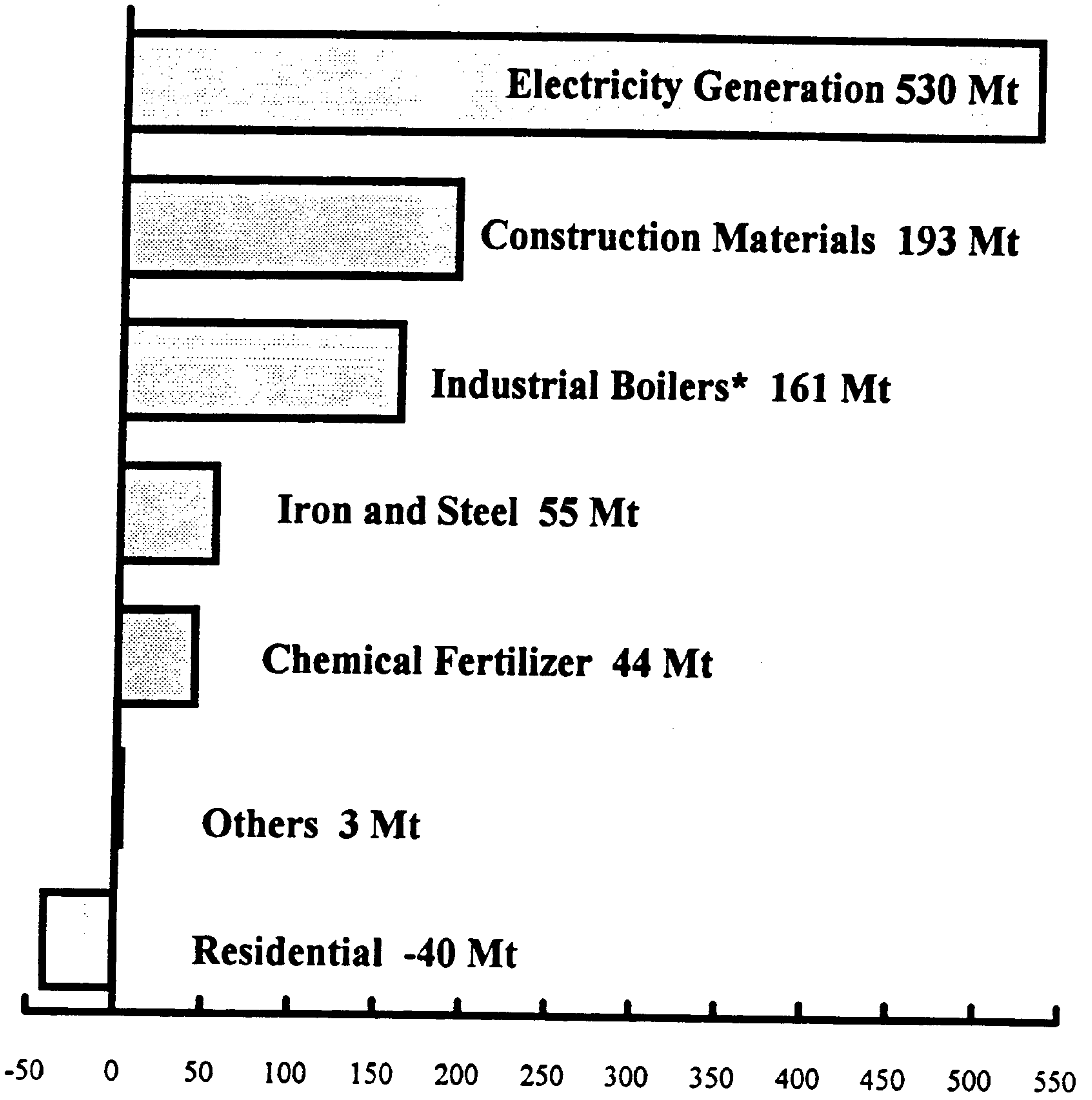

Figure 16. Projected growth in coal consumption by sector over the 1993-2010 period.

* Excluding the chemical, iron and steel, and construction materials industries.

Table 1. Annual Average Sulfur Dioxide Concentrations in Selected Chinese Cities in 1991 (μg/cubic meter)

	North				South		
NO.	City	Province	Emissions	NO.	City	Province	Emissions
1	Taiyuan	Shanxi	277	1	Chongqing	Sichuan	351
2	Urumqi	Xinjiang	207	2	Guiyang	Guizhou	341
3	Qingdao	Shandong	204	3	Yibin	Sichuan	305
4	Shijiazhuang	Hebei	162	4	Nancong	Sichuan	239
5	Baotou	Inner Mongolia	142	5	Changsha	Hunan	173
6	Tianjin	Tianjin	142	6	Yichang	Hubei	165
7	Shenyang	Liaoning	137	7	Hangzhou	Zhejiang	122
8	Jinan	Shandong	135	8	Shanghai	Shanghai	99
9	Datong	Shanxi	134	9	Guilin	Guangxi	85
10	Beijing	Beijing	122	10	Fuzhou	Fujian	82
11	Zibo	Shandong	121	11	Xuzhou	Jiangsu	81
12	Anshan	Liaoning	104	12	Guangzhou	Guangdong	70
13	Shizuishan	Ningxia	104	13	Chengdu	Sichuan	66
14	Lanzhou	Gansu	102	14	Suzhou	Jiangsu	65
15	Yuncheng	Shanxi	89	15	Hengyang	Hunan	62
16	Zhengzhou	Henan	86	16	Wenzhou	Zhejiang	61
17	Tangshan	Hebei	86	17	Nantong	Jiangsu	50
18	Anyang	Hebei	79	18	Nanning	Guangxi	50
19	Jilin	Jilin	75	19	Nanjing	Jiangsu	50
20	Dalian	Liaoning	75	20	Huaihua	Hunan	47
21	Xian	Shaanxi	68	21	Hefei	Anhui	46
22	Changchun	Jilin	61	22	Liupanshui	Guizhou	46
23	Yanan	Shaanxi	60	23	Kunming	Yunnan	45
24	Yinchuan	Ningxia	56	24	Baise	Guangxi	45
25	Baoji	Shaanxi	54	25	Ganzhou	Jiangxi	44
26	Xining	Qinghai	51	26	Nanchang	Jiangxi	41
27	Hanzhong	Shaanxi	50	27	Gejiu	Yunnan	41
28	Qinhuangdao	Hebei	45	28	Xiangfan	Hubei	40
29	Pingdingshan	Henan	43	29	Wuhan	Hubei	40
30	Hohhot	Inner Mongolia	35	30	Zhanjiang	Guangdong	37
31	Jiayuguan	Gansu	35	31	Sanming	Fujian	25
32	Tumen	Jilin	28	32	Anqing	Anhui	21
33	Harbin	Heilongjiang	27	33	Shenzhen	Guangdong	16
34	Daqing	Heilongjiang	15	34	Xiamen	Fujian	8
35	Hegang	Heilongjiang	13	35	Haikou	Hainan	4

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