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What Goes Up:

Recent Trends in China's Energy Consumption

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Abstract

Since 1996, China's energy output has dropped by 17%, while primary energy use has fallen by 4%, driven almost entirely by shrinking output from coal mines and declining direct use. Since China is the world's second-largest emitter of greenhouse gases, it is important to understand the sources of this apparent transformation, and whether it portends a permanent change in patterns of energy use. This remarkable reversal of the long-term expansion of energy use has occurred even as the economy has continued to grow, albeit more slowly than in the early 1990s. Generation of electric power has risen, implying a steep fall in end uses, particularly in industry. Available information points to a variety of forces contributing to this phenomenon, including rapid improvements in coal quality, structural changes in industry, shutdowns of factories in both the state-owned and non-state segments of the economy, improvements in end-use efficiency, and greater use of gas and electricity in households. A combination of slowing economic growth, industrial restructuring, broader economic system reforms, and environmental and energy-efficiency policies has apparently led to at least a temporary decline in, and perhaps a long-term reduction in the growth of energy use, and therefore greenhouse gas emissions.

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Key Words

China, energy consumption, coal, energy intensity, energy efficiency

1. Introduction

Coal output in China—the world's second-largest consumer of energy—has dropped precipitously since 1997, and power generation capacity is in oversupply in some areas. Meanwhile, economic growth has slowed from its torrid double-digit pace to moderate rates, according to official figures. Does this dramatic shift from rapid growth and relative energy shortage to stagnating growth and emerging surpluses represent a short-term perturbation in China's expected long-term growth trajectory, or does it indicate the beginnings of permanent changes to the pattern of development? What lies behind this remarkable change? It may be, for instance, that the combination of a renewed drive to reform state-owned enterprises (SOEs) along with growing economic difficulties will lead to an irreversible shrinking in capacity in the state sector, and that energy demand growth will resume from a lower baseline than previously prevailing rates. It may also reflect the results of years of fuel-switching, efficiency gains, and economic restructuring. Or, the reported economic and energy figures may all be seriously flawed. The answer is likely a combination of all these suppositions, along with many other factors.

Understanding the forces behind this decline has immediate and apparent implications for forecasting China's energy demand, setting policy priorities, and assessing China's role in a possible future international regime of greenhouse gas reduction activities. Questions about the environmental sustainability of China's continued economic growth are inextricably linked to the country's coal-based energy system (McElroy, *et al*., 1998). In this paper, we analyze trends in energy supply and demand in China over the past several years, tying developments in the energy industry and major demand sectors to economic restructuring. With so many unknowns, and problems with data quality, we cannot help but raise many questions in the course of attempting to answer others. We nevertheless hope that this paper will contribute to the discussion on the drivers of change in China's energy system and economy.

2. The Phenomenon and Possible Explanations

Contrary to all earlier expectations, China's output and consumption of primary energy went into decline in 1997, driven by a decline in China's most important fuel, coal. Estimated total primary energy use in 1999 will be about 39 EJ, 4% below the 1996 peak.[1] Meanwhile, consumption of oil and electricity has continued to grow. The decline in primary energy has occurred despite robust GDP growth of 8.8% in 1997 and 7.8% in 1998, as reported by the government. These sharply divergent trends in energy and economic growth are puzzling, and a number of explanations have been suggested, among them the following:

1. A slowdown in heavy industry in response to slowing economic growth has caused demand from the largest users to drop.
2. Bankruptcies and mergers resulting from the on-going program of SOE reform have shut down many state-owned factories that were large, inefficient consumers of energy.
3. Slower growth in electricity demand has cut growth in demand for coal from the utility sector, now the largest consumer of coal.
4. Policies in the power sector to eliminate small generators have reduced net growth in electricity generation and slowed growth in coal use even more by getting rid of inefficient units.
5. The recent buyers market for coal has allowed consumers to switch to higher quality coal, leading to greater end-use efficiency and lower total demand.
6. Reforms in the coal sector that have led to the shutdown of many small mines have reduced "oversupply".
7. Changes in the structure of China's economy, away from energy-intensive heavy industries and towards less energy-intensive, high-technology industries and services, are reducing energy demand.
8. Residential use of coal has fallen as more urban dwellers move into apartments with central heating and consumers switch to electricity and gas for cooking and water heating.

[1] See Table 1 for conversion factors used in converting Chinese energy data in this paper.

9. Relatively higher prices for electricity have stimulated energy conservation, leading to substantially lower demand.
10. Reductions in energy use are overstated; energy consumption is significantly greater than production as China's enormous stockpiles of coal are used, and recent energy and economic statistics are inaccurate.

In the sections that follow, we examine the evidence relating to these possible explanations. All of them may have some relevance, though some will be more important than others. After going through the evidence, we will conclude by assessing the above propositions in light of available data.

In this type of investigation, based on secondary sources and statistics, it is difficult to prove causation. There are many forces at work in China's economy, and there can be no simple, direct connection between the aims of economic and social policies and the changes observed in aggregate statistical indicators. The best we can do is to determine whether the patterns we find are consistent with the proposed explanations.

3. Energy Trends

China's overall energy output has fallen off drastically in the past several years. Estimated energy production in 1999 will be more than 17% below the 1996 peak (Figure 1; Table 2). Natural gas and hydropower output have grown somewhat, and oil production has been constant, while coal production and nuclear power generation have both dropped.

The picture for primary energy consumption basically mirrors that of energy production, peaking in 1996 and falling since then (Figure 2; Table 3). In the mid-1990s, consumption rose more slowly than production, and has fallen more slowly as well. The main reasons for this difference are, most likely, rising net imports of oil, growing net exports of coal, and stockpiling of coal, followed by drawdowns of those stockpiles. Inadequacies in statistics on energy supply and consumption may also play a part. For instance, oil supply and consumption figures may be understated, as oil products (mainly diesel) that are smuggled into the country would not be reflected in import statistics, but their use may be reported. Similarly, some of the thousands of coal mines that were to have been closed in the campaign in 1999 to shut down inefficient and unsafe, and mainly non-state mines, have continued to operate. These ostensibly closed mines cannot report output, while consumption may continue to be reported or estimated, causing coal supply to appear to drop faster than use. Supply and consumption of the various energy forms are treated in turn below.

3.1. Coal

From a peak of nearly 1,400 million metric tons (Mt) in 1996, China's coal production slid to 1,250 Mt in 1998, and will fall further in 1999 to a projected 1,030 Mt. This would be the country's lowest coal output since 1988. Coal's share of total primary energy output would fall to 68%, the lowest level since the founding of the People's Republic of China (Sinton *et al*, 1996). According to current government plans, production in 2000 will be limited to 900 Mt, a level last seen in 1986 (Reuters, 1999d).

The downturn in coal output is intentional. In the mid-1990s, the central government began to require that large state-owned mines limit output. This was part of a package of reforms in the coal mining sector, aimed at turning around the financially troubled state-owned mines, that included laying off large numbers of workers from state-owned mines and closing down dangerous but low-cost non-state mines. In 1998, the government directed that 25,000 small, non-state mines and 40 state-owned mines be closed, accounting for about 250 Mt of output annually (Ling, 1999). Reportedly, 23,000 small mines were closed by May 1999, although prices have been little affected by changes in supply (ERM, 1999). The rapid fall in total coal output seems to indicate that these, and perhaps other mines have actually closed or reduced production substantially. Local mines, both state-owned and township mines, accounted for 62% of coal output in the peak year of 1996, but this percentage is expected to fall to 55% in 1999 as closures progress (Wang, 1999a). Preliminary statistics for 1999 show that most of the fall in output has been from small mines, and that production at large state-owned mines has actually risen (Bloomberg, 1999c).[2] Some unreported production continues at some small mines that have been officially closed, however, as news reports on fatalities at "closed" mines indicate (SCMP, 1999g).[3] Some consumers have been prohibited from purchasing the output from closed mines, and thus have an incentive to keep quiet about using such coal, which would cause it to disappear entirely from statistics.

China has been exporting substantial amounts of coal and coke; in 1998, exports totaled 32 Mt of coal and 11 Mt of coke, or 4% of coal output (Figure 3). By comparison, only very small quantities of coal are imported, mainly for metallurgical use, although amounts are increasing, as for exports (Reuters, 1999c). The small tariff on imported coal has hindered import growth, even in Guangdong, where delivered prices of domestic coal are virtually at import parity. Imports could grow to as much as 59 Mt per year by 2010 with the reduction or abolition of import tariffs under the WTO and further removal of subsidies to state mines (Bloomberg 1999d).

China has long been known to have very large stockpiles of coal, providing a substantial cushion for consumers in the face of the rapid reduction in output. The size of stockpiles has not been well characterized, however, and it is not clear whether official figures attempt to include the ubiquitous small stockpiles around the country. At the end of 1998, the total volume of coal stored in officially recorded stockpiles was 198 Mt, only 13 Mt lower than at the beginning of the year, despite the large fall in reported coal output (Wang, 1999a; China Energy Watch, 1999). In 1999, the government has planned the draw-down of a record 90 Mt to stabilize market supply in the face of severe production cuts (Wang, 1999a).

This extraordinary reduction in overall coal use comes at a time when conversion of coal to other energy forms has remained fairly constant. Statistics indicate that power generation has continued to rise, albeit at a slower rate than earlier in the decade. Steel output shows a similar trend, implying that use of coke has gone up as well (SSB, 1999).[4] Coal gas use has risen as more urban residents have been connected to town gas supplies, and the building area served by central heating has expanded. Virtually all the decline in coal use has therefore been in end uses, and particularly in industry. If the underlying data are correct, these trends point to a precipitous drop in final (or direct) use of coal, from 685 Mt in 1996 to about 506 Mt in 1998, and further to an estimated 434 Mt in 1999, 37% below the 1996 level (Figure 4, Table 4).[5] In 1999, then, the structure of coal consumption was exactly the reverse of 1980, when 64% of coal was used directly and the remainder was used to generate power and steam and to make coke and coal gas.

A problem in assessing the actual decline in coal consumption arises from a shift in the last few years to the purchase of higher-quality coal in a buyer's market. This higher-quality coal, with lower ash content and higher heating value, allows consumers to reduce the volume of coal purchases to achieve the same delivery of energy. In Chinese statistical treatment, raw coal contains on average 5000 kcal/kg (20.9 MJ/kg), but the actual value varies considerably nationwide. In the utility sector alone, the average heat content of delivered coal was 200 kcal/kg (84 MJ/kg) higher in 1997 than in 1996, and in 1998 the average rose by a further 100 kcal/kg (42 MJ/kg) (Jie and Li, 1999). Other factors aside, the increase in average heat content over the two years would have reduced coal consumption in the power sector by 30 Mt. However, it is not possible with available statistics to determine the extent to which quality improvements in other

[2] In the first eight months of 1999, output from township-run mines fell 5.5% compared to the same period in 1998, that from local state-owned mines was about the same, and that from key state-owned mines rose 5.5%.

[3] While "feigned compliance" is a typical reaction for mines in the non-state sector, the campaign to close mines has also met with violent opposition at state-owned mines (see for example SCMP, 1999c).

[4] Coke production, on the other hand, leveled off after 1995, after a large jump in production, with much of the new output intended for export markets. Coke production fell slightly in 1998. Even if coke output shrank in 1999 back to 1994 levels, however, conversions would still account for 61% of total coal use, instead of the 64% we have estimated.

[5] Although final consumption statistics are not yet published for years after 1996, it is possible to calculate apparent final consumption. Estimates for 1999 are based on projections for annual totals. See Table 4 for details.

end-use sectors accounts for the apparent decline in consumption, but it may be on the order of 20%, or another 30 Mt.[6]

Availability of official statistics on final energy consumption lags those on production by up to two years, so our estimates for the most recent years are residuals, and probably less reliable than statistical reports of consumption. Additionally, there is a substantial statistical "balance", which reached a high of 75 Mt in 1996, that has introduced an uncertainty of 2% to 5% in each year over the past decade. It is certain that reported coal consumption in 1998 and 1999 will be different from the estimates presented here. The evidence to hand now, however, strongly suggests that those consumption statistics, when available, will display a significant and sustained decline in direct use of coal. If we have underestimated coal use in the period from 1997 to 1999 by 5%, for example, then the main effect would be to shift the peak year of coal use from 1996 to 1997.

Since industry is by far the largest direct user of coal, the drop in direct coal use suggests that there has been a significant slowdown in industrial output in some sectors and a widespread shutdown of industrial capacity that has caused demand to dive. Physical and economic output figures for industry provide mixed support for such an interpretation, although there is ample anecdotal evidence and some statistical evidence that state-owned and non-state factories have been closing (SSB, 1999). The share of coal in total household energy use has also been dropping, from 90% in 1980 to 60% in 1996, but that is a long-term phenomenon that began in the early 1990s, and there is little evidence to suggest an accelerated shift in the structure of household fuel demand (SSB, 1992 and 1997).[7]

Data on prices reinforce the impression that the recent drop in coal consumption is due to a fall in demand. After significant new energy price reforms in 1993, real prices for coal (and other energy products) rose at a far higher rate than those for other industrial products (Figure 5). While coal prices continued to rise until 1997, they fell in 1998, implying a large drop in demand compared to supply, since markets for coal are relatively free. This occurred even before the campaign in 1999 to shut down mines, suggesting that the move, in part, may be intended to support coal prices by restricting supply. We further explore possible explanations for demand shifts later, in the section on trends in the economy.

A variety of evidence suggests that limitations on coal transport capacity are not associated with the overall drop in coal use. The decline in coal prices, for example, indicates that consumption is not limited by transport bottlenecks; prices could be expected to rise if transport capacity was insufficient to deliver enough coal to end users. Inadequate coal transport capacity has been a long-held concern in China, driving construction of rail projects from the interior coal-producing regions to demand centers along the coast. There may be reasons to remain concerned about coal transport capacity in the future, even if total coal demand continues to fall or level off. For instance, the closure of small, local mines implies that consumers will have to rely more heavily on coal from larger mines that is brought in by railroad and truck. Still, recent reports have indicated that the railways are very concerned about declining volumes of coal to be transported, and consequent falling revenues (Wang, 1999a). Statistics confirm this trend. Just over half of China's coal is shipped by rail, and combined shipments of coal and coke peaked in 1996 at 425 million ton-km, nearly 34% of total rail freight turnover (SSB, 1998). By 1998, the figure had dropped to 387 million ton-km, under 32% of total rail turnover (SSB, 1999).

3.2. Oil

Oil production has stagnated in China during the 1990s, as rising output from offshore fields has offset declines in a number of important eastern oil fields. Demand, however, continues to rise, particularly for transport fuels, resulting in a continuing increase in imports of both crude oil and petroleum products. By 1998, China's external dependency for oil had risen to 26% (SSB, 1999).

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[6] This estimate assumes that the increase in heat content in coal supplied to the utility sector applies also to all direct end-use.
[7] Moreover, after dropping in the first half of the 1990s, the tonnage of coal used by households began growing again in 1996.

At this level of import dependency, the domestic market has become increasingly affected by changes in the international market, leading to severe disruptions in early 1998, when international oil prices collapsed. Faced with fixed ex-refinery and retail prices up to twice the level of import prices, oil consumers sought alternatives to the high-priced oil. By late spring 1998, smuggling had become rampant, to the degree that domestic refineries were forced to cut back on production as their own inventories of high-priced oil swelled. The government was forced to move decisively in June 1998, when a new import and pricing regime was announced along with a substantial crackdown on smuggling. Shortly thereafter, imports of crude oil, diesel fuel and gasoline were banned or sharply curtailed in order to provide protection to the domestic refiners and to allow the draw-down of refinery stocks (SCMP, 1999d).

Consequently, customs figures showed a substantial drop in oil imports in 1998; crude oil imports fell from 35 Mt to 27 Mt and oil products from 23 Mt to 21 Mt, resulting in a decline in apparent oil consumption of 2.9%. Reports, however, suggest that smuggling brought anywhere from 8 to 12 Mt of additional product to market, sustaining an apparent demand growth of 1.3% to 3.3% (New York Times, 1999; Reuters, 1999a).[8] This growth is consistent with both transportation statistics, which show continued growth in road and air traffic for both freight and passengers, and with the typically observed increase in light diesel demand spurred by the large infrastructure construction projects China has initiated to maintain economic growth (SSB, 1999).

The uncertainty introduced by smuggling into oil demand calculations increases the difficulty of projecting consumption in 1999. The import ban on diesel continues, and the government has encouraged the reduction in crude oil exports in order to increase domestic supply without increasing imports. Restructuring of the national oil companies China National Petroleum Corporation (CNPC) and Sinopec has also increased pressure to maintain a degree of protection in order to assist the companies while they cut costs and increase efficiency leading up to proposed international stock market offerings and expected increased competition after formal WTO entry. Sinopec has offered, however, to lift the diesel import ban at the time of China's formal WTO entry, although restrictions of total import volumes, import channels, and domestic marketing will remain in place for a number of years (Reuters, 1999b).

The fastest growth in domestic oil demand has been for two products not under strict import controls. Fuel oil demand has risen rapidly in the last few years, particularly from industry and power generators in southern China, and imports now account for about one-quarter of total consumption. LPG demand has been strongly spurred by rising demand in households as they continue to shift away from coal, and imports continue to grow dramatically. In 1998, LPG imports jumped 33%, and now account for nearly half of domestic consumption (Bloomberg 1999a).

With fuel oil, LPG and diesel demand likely to continue steady growth in 1999, particularly as the government continues its large-scale infrastructure investment projects, oil consumption is likely to increase by a further 1.5 to 3.0%. Smuggling remains a problem, though on a smaller scale than in 1998, and it will be difficult to accurately determine the increase from official figures (Table 3).

3.3. Natural Gas

China's natural gas production has been gradually rising since the mid-1990s, as new fields come on line, particularly offshore fields, and new pipelines are built. Despite the recent growth, natural gas still accounts for only about 3% of the nation's energy output, the same as in 1980, and significant growth requires long-term investments in development of new resources and infrastructure for imports. Current output is about 23 x 10^9 m^3 (bcm) per year, but China has

[8] Citing a study by the China International Capital Corporation, the *Times* reported that four major international suppliers exported 14.9 Mt of light diesel to China in 1998, while Customs recorded only 6.7 Mt of legal imports. Hong Kong customs reported 5.9 Mt of light diesel exports to China in the first 11 months of 1998, while China reported only 3,192 tonnes of light diesel imports from Hong Kong during the same period. Assuming other volumes of light diesel and other products were smuggled from other sources, total smuggled volumes may have reached as high as 12 Mt.

targeted expansion of combined onshore and offshore output to 30 bcm in 2005 and 50 bcm in 2010 (Fridley, 1999). Output in 2010 is to be supplemented by annual imports of 50 bcm, but this assumes optimistically that a planned 3 Mt (4.2 bcm) LNG terminal in Guangdong and several mooted international pipeline projects go forward. China also plans to produce up to 10 bcm per year of coalbed methane by 2010, but this will require significant investment to raise it from its current level of 500 million m^3 (mcm).

The government has made investment in natural gas more attractive by adjusting domestic prices closer to internationally comparable levels. Gas field prices have been raised substantially since 1994, and now range from about US$1.55 to US$2.40/GJ (US$1.65 to US$2.50/MBTU), and retail prices in cities range up to over US$5.70/GJ (US$6.00/MBTU), comparable to US levels (China OGP, et al., 1998). However, gas pricing varies substantially from city to city, and in the absence of a national pipeline network, a true market for natural gas does not yet exist.

Potential demand for natural gas in China is likely to be as large as any potential supplies, at least in the short term. There is currently very little natural gas-fired power generation in China, but the country would benefit enormously by replacing coal-fired power plants (particularly small ones) with gas turbines. Even greater benefits, in terms of improving human health, are to be had by replacing household coal use with natural gas, currently underway on a major scale in a number of cities, including Xi'an and Beijing. As a result, growth in natural gas consumption in the next few years will likely be more affected by supply constraints than the level of general economic activity, even if overall energy consumption continues to decline.

3.4. Electricity

Power generation has risen faster than production of any other form of energy, rising at an average rate of 7.8% per year since 1980 to reach nearly 1,179 TWh in 1998 (Figure 6). Growth was fastest in the early 1990s, reaching the double digits in several years, slowed to 2.8% in 1998, and has recovered somewhat in 1999. In 1997, coal-fired power plants accounted for 92% of power generated by fossil fuel-fired units, with small oil- and gas-fired units making up the remainder (Zhou, et al., forthcoming).

Installed generating capacity has risen slightly faster than generation, at 8.2% per year since 1980, reaching 270 GW in 1998 (SSB, 1998a; *People's Daily*, 14 September 1999). Installed capacity at the end of 1998 was 6.2% higher than in 1997, as projects already underway were completed. Many power plant construction projects have slowed, however, and approvals and financing of new projects have been delayed, and preferential treatment for foreign power developers has been scaled back (SCMP, 1998a). This slowdown comes as capacity has surpassed demand in many areas of China, particularly along the coast and in the northeast. In 1998, the State Development and Planning Commission (SDPC) estimated that roughly 40% of China's area experienced surpluses of generating capacity, while 20% still suffered power shortages, with the remaining 40% in balance (SCMP, 1998b). This excess is reflected in falling average capacity factors since 1995 (Figure 7).

Another factor contributing to slower growth in power generation is the closing of small power plants. For years, the central government has prohibited (with varying degrees of effectiveness) the construction of small power plants, and has advocated that existing ones be taken out of service. Coal-fired power plants of 50 MW and under tend to be less efficient and more highly polluting per kW of generating capacity than larger plants. With growth in demand slowing, and sensitivity to environmental pollution gaining strength, the government has renewed its commitment to shutting plants down. According to one report, 2.84 GW of plants smaller than 100 MW were closed in 1997 and 1998, and a further 1.8 GW were slated for closure in 1999 (Ling, 1999). This is to be followed by closure of an additional 7.74 GW in 2000, so additional efficiency gains will be likely be forthcoming (Wang, 1999b). Shutting down of old, inefficient, and rarely used plants could account for reduced coal use in the utility sector of 5 to 10 Mt of coal per year.[9]

[9] In the early 1990s, China had about 8 GW of installed capacity at power plants under 6 MW (Sinton *et al*., 1996). These generated about 10 TWh per year, operating at capacity factors of 0.15 and under. These plants

In general, the size of the average power plant in China is growing, since most new plants are larger than older ones. From 1993 to 1997, when installed capacity of coal-fired generating units grew from 119 GW to 171 GW and the installed capacity in all size categories rose, the fraction of coal-fired units 300 MW and larger grew from 21% to nearly 29% (Table 5).[10] A major implication is that the average efficiency of generation should be rising substantially, always assuming, of course, that efficiencies for larger plants are higher, and that average efficiencies for each plant remain constant. Even with relatively rapid efficiency improvements through this kind of structural change in the utility sector, though, coal consumption per kWh generated would probably not decline faster than 1% to 2% per year,[11] or 5 to 10 Mt per year. In 1998, for example, the amount of coal required to generate one kWh in the average plant fell by 5 grams of standard coal equivalent (gce), or about 1.3%, avoiding consumption of more than 6 Mt coal (Zhou, 1999). Such improvements in generation efficiency would account for a small, but significant portion of the recent annual declines in coal demand.

On the other hand, many industrial enterprises have their own power generation capacity, including cogeneration units, diesel- and coal-fired units, and equipment that uses waste heat and combustible gases from industrial processes to generate power. This self-generation capacity has been growing in recent years (Zhou, 1999). This would most likely have the effect of bringing down the average efficiency of power generation, since the smaller power units typically have efficiencies far below those of central power plants. The situation is complicated, however, since cogeneration units, which provide both heat and steam, and units using waste heat and gas typically raise the efficiency of power generation. A more thorough understanding of the structure and trends among self-generators would be needed to determine the net impact on coal use.

Assuming that China avoids a recession, it is likely that power demand and output will continue to grow at a more rapid rate than in 1998. Preliminary indications suggest that power generation will rise by about 4% in 1999. Along with economic growth, there is a long-term trend in China—as in other developing economies—towards electrification in industry and households, as new end-use applications become widespread (e.g., computers, office equipment, and environmental control equipment) and as electricity substitutes for fuels in current end-use applications (e.g., cooking). There is also tremendous latent consumer demand for power in China. Many households across China pay high premiums to upgrade wiring to handle larger loads, indicating that limits to transmission and distribution constrain demand. Even if overall energy use continues to drop, it is quite possible that power demand will keep growing.

3.5. Biomass and Other Renewable Energy

Biomass energy remains a significant source of energy for much of China's rural population. Most biomass fuels are used for home cooking and heating and for agriculture, and are not tied to major portions of economic activity. In energy terms, the amount used is approximately equivalent to oil consumption. Unlike oil, however, biomass use has been dropping since the 1980s, as greater supplies of coal and electricity have become available to rural residents, who make up the largest portion of China's population. Between 1991 and 1996 alone, biomass energy use in China's rural areas fell by nearly one fourth, while the ratio of biomass energy use to commercial energy use fell from 0.26 to 0.15 (Table 6). Biogas use has been rising, but it still accounts for less than 1% of biomass energy.

Most areas of China have at least one large renewable energy resource. More than most developing countries, China has made significant—and relatively successful—efforts to promote renewable energy use, particularly as an adjunct to the overall programs for rural development and electrification. China expects to have around 20 GW of renewable power generation capacity

often have heat rates twice as high as the national average, but, even assuming national average heat rates, they would have used 5 to 6 Mt of coal per year in the early 1990s.

[10] At the same time, however, the percentage of units in the smallest category, under 50 MW, rose from 19 % to almost 22%. These units are typically at small, county- and city-level power plants and at large industrial enterprises.

[11] This is about twice the rate that prevailed in the early 1990s.

in 2000 (mainly small hydro; the figure excludes large hydro), or over 7% of total installed capacity, compared to just over 15 GW in 1993 (Table 7; The World Bank, 1996). Adding in electricity from large hydropower projects, direct use of biomass fuels and solar heating of water and buildings, one quarter of China's energy is already supplied by renewable sources (RTCCCCS, 1999).

3.6. Outlook

According to the Energy Research Institute, China's plans call for continued reductions in relative dependence on coal, by between 15 and 20 percentage points over the next two decades (Bloomberg, 1999b). This presumably starts from the share of about 75% that prevailed for most of the 1990s, so that by 2020 coal would account for 55% to 60% of commercial energy use. If total energy use were to grow at an average of 3% over this period, then China would use 72 EJ of primary energy in 2020, 80% more than the amount consumed now. Coal use would rise 40% to 50% compared to current levels, which is easily achievable given the current resource base. Consumption of primary energy sources other than coal would have to triple during that period. If oil is assumed to retain its current share (about 20%), then China in 2020 would need about 360 Mt of oil, twice the current rate of domestic production. This could be easily imported, probably without major impacts on global markets or foreign exchange reserves. Consumption of natural gas, hydroelectricity, nuclear electricity, and other energy sources combined would have to quintuple.

If recent trends continue, non-biomass renewables will continue to make up a significant portion of China's energy mix in the near to medium term. In the long run, although even the most optimistic projections predict only a minor role for renewables over the next several decades, there is hope that renewables may break out of niche markets and represent a growing share of total energy, so long as there is continued support for the development of renewable energy markets and industries.

Within the Chinese leadership and the community of energy experts who advise them, there is universal agreement on the need for greater end-use efficiency, but opinion is divided on how to proceed with development of China's energy supplies. The debate essentially is about whether to continue relying on coal, consuming more of it using clean-coal technologies and coal-fired power plants, or to diversity energy sources and rely more heavily on imported oil and gas as well as domestically exploited renewable energy resources. Some of the main aspects of the discussion concern security, employment and other issues associated with state-sector reform, as well as environment. Some believe that continuing to use coal to meet most energy needs would fulfill the goal of energy security through self-reliance, while others feel that China's interests are best served by participating fully in international trade in energy products, particularly "cleaner" sources such as oil and natural gas, and by developing domestic renewables, especially hydropower, and potentially nuclear power. For many, however, the debate is driven mainly by economic issues. The coal industry, with seven million workers, is one of the country's largest employers, and efforts to reform the industry are already quite painful (Chang and Zhao, 1999). While all agree that the state mines need to be strengthened to return the sector to profitability, in part through the closure of small, inefficient mines, some feel that employment levels should be maintained at the highest level possible, which would be consistent with continued reliance on coal as the primary fuel in China's energy mix. Finally, while there is broad agreement that energy-related environmental problems are in need of solutions, some feel that problems can be addressed even with coal remaining as the backbone of the energy system, while others see diversification away from coal as an essential step. Still, environmental regulations increasingly have teeth, and shifts in local and regional fuel structures, generally away from coal, can be attributed at least in part to environmental statutes. The ongoing debate over energy development may not result in any radical shifts in fuel mix, since trends are increasingly dominated by the logic of markets, including international markets for energy commodities.

4. Economic Trends

Information on recent changes in economic activity offer some explanations for the observed changes in patterns of energy supply and use in China, but available data do not provide answers for all the important questions, particularly those behind the apparent drop in direct use of coal. In this section we discuss what can be learned about the forces shaping energy use from published GDP and physical output statistics, as well as information on enterprises and employment.

Despite deceleration in the past several years, China's economy continues to grow rapidly. GDP grew by 7.8% in 1998, and the official target for 1999 is 7%, consistent with performance in the first three quarters (People's Daily, 1999a; SCMP, 1999b). The official statistics have their detractors, however, and there are strong reasons to believe that growth has been overstated. Maddison (1997) developed an alternate set of GDP figures for China that show annual average growth between 1980 and 1995 to have been about two percentage points below official figures (Table 8). More recent figures from Standard and Poor show a similar discrepancy (SCMP, 1999f).[12] Figure 8 compares official GDP figures with a composite revised estimate of GDP, showing average annual growth rates of 9.8% and 7.6% respectively. Industrial sector GDP shows a similar pattern, with official figures displaying 11.8% annual growth, and the revised estimate 9.7%. These revised GDP figures have implications for energy intensity trends, as discussed below.

Changes in structure of the economy are commonly identified as a major factor in China's declining energy intensity. According to a common line of reasoning, industry, and particularly heavy industry, have given ground to less energy-intensive high-technology and service sectors. While these latter sectors have indeed grown, however, heavy industry has also expanded. Heavy industry, and particularly chemicals, chemical fertilizers, steel, and cement, along with power generation are the main drivers behind trends in coal use. Real economic output and physical output in these industries has grown rapidly, at rates similar to those for "newer" high value-added light industrial sectors. The result is seen in Figure 9; manufacturing GDP has kept a fairly constant share of GDP (40% to 43%) since the mid-1990s, slightly higher than in previous years. Services have expanded gradually to account for about one third of value added, mainly at the expense of agriculture. At the broad sectoral level, then, the structure of the economy has not "lightened".

The major changes in energy intensity need to be sought within the industrial sector. Figures on industrial gross output value show a steady annual rise (reaching nearly 12-fold the 1980 value in 1997), and show that heavy industry has consistently contributed slightly more than half of sectoral output (Figure 10). The share has fluctuated somewhat, and has fallen consistently since 1994 to 51% in 1997 (SSB, 1998a). More recent figures on value added show that in 1998, light industry continue to grow slightly faster than heavy industry (at annual rates of 9.1% and 8.5%, respectively), but heavy industry grew slightly faster than light industry in the first half of 1999 (SSB, 1999; People's Daily, 1999b).[13] This suggests that shifts between industrial subsectors may account for a small amount of the continuing decline in energy *intensity* of the economy, but does little to explain the recent shrinking of total energy *demand*.

Explanations need to be sought within major energy-consuming industrial subsectors, like metals, building materials, and chemicals manufacturing. Very important changes have been taking place within industrial subsectors—such as changes in product mix (including production of very high value-added goods that were not manufactured in China a decade ago), changes in physical energy intensity, and turnover of equipment and enterprises. Some partial data are available to illuminate those stories of structural change at the subsectoral level, and indicates that, in at least some important sectors, continued structural reform within industry has contributed to the decline in overall energy demand. While growth in cement and chemicals remain firm, the growth has primarily come from middle and large-size plants at the expense of small inefficient producers. In

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[12] It should be noted that some economsts believe that official GDP figures may actually underestimate growth over the past 20 years (SCMP, 1999a).

[13] These figures cover state and non-state industrial enterprises with annual sales revenue of 5 million yuan or more, a category that accounted for 60% of industrial value added in 1998.

the first half of 1998, cement production rose only 0.9% over the comparable 1997 period, but output from large and medium-size plants grew 10.1%.[14] Within the chemicals sector, production of synthetic ammonia for fertilizer production fell 2.6% in the first half of 1998, but output from small producers, which use coal instead of natural gas or oil as feedstock, dropped 10%. The fall in production of other building materials also evidently contributed to the 1998 decline in industrial energy consumption: in the first half of 1998, production of bricks fell over 18% and of tiles nearly 15% (Wang, 1999a).

There is other evidence that reforms are achieving their intended aims and are leading to substantial industrial restructuring. An alternate breakout of the 1998 value added series for industry show that the state sector, while it still produces over half of sectoral output, is growing much more slowly than other segments of industry (Figure 11). State-owned industry grew by just under 5% in 1998, while state-controlled joint stock companies, collectives, and FDI enterprises grew by about 12%, 9%, and 13% respectively (People's Daily, 1999b). One would expect that these latter categories would be generally more efficient—and less energy-intensive—than state-owned enterprises. Shifts in ownership structure then, could be responsible for a portion of reduced energy intensity and energy demand.

Statistics on the number of industrial enterprises confirm the impression that, in recent years, there has been significant attrition, either through mergers or bankruptcies. Figure 12 shows that the total number of industrial enterprises has been falling since the mid 1990s, and the trend has continued through 1999. This is true for both the state-owned and collective categories; numbers of "other" enterprises, such as joint ventures and joint stock companies, have grown.[15] Employment trends are in line with this; the work force in industry has fallen by over one million employees annually since 1997, a trend consistent with the shutdown of many plants (SSB, 1999). Industrial output has, meanwhile continued to grow, so that output per firm has risen steadily (Figure 13). This is consistent with the idea that reforms have worked to close a large number of firms, leaving behind larger enterprises—that presumably are more efficient.

Output of many heavy industrial products has actually not slowed very much, however (Figure 14). To stimulate the economy, the central government has gone on a bond-financed infrastructure spending spree, which has prevented demand for steel and building materials from falling farther than it otherwise might have. In 1998, the government issued 100 billion (10^9) yuan (US$12 billion) in bonds, and in 1999 another 60 billion yuan (US$7.2 billion), with the funds earmarked for already approved highway, water supply, wastewater treatment, and other infrastructure projects (SCMP, 1999e).

There is, undeniably, a basic weakness in demand for heavy industrial products. One sign of overcapacity is the institution of price controls on certain heavy industrial products in 1997, intended in part to help struggling state-owned enterprises remain solvent in the face of increasingly vicious price-cutting. While output of many products continues to rise, the increments are smaller than they might otherwise be. In the case of steel, for instance, China's manufacturers are increasingly in competition with low-cost imports from Russia and other formerly planned economies, despite quotas on imports (China Daily, 1999).

Overall, the decline in energy consumption appears to be largely due to decline in production of some energy-intensive products (such as bricks, tiles and ammonia), further consolidation of capacity from small producer to middle- and large-scale producers, a general economic slowdown; and weakness and closures in the state sector.

5. Energy Intensity

Economic energy intensity is an overall measure of how much energy is used to produce a unit of economic output in a country or a sector. The recent drop in total energy use has caused this ratio to fall. Using official GDP figures, China's overall economic energy intensity has dropped

[14] On the other hand, small shaft kilns continue to account for a large part of new cement-manufacturing capacity, so that efficiency gains in new facilities are less than they might be.
[15] China's tens of millions of tiny private industrial enterprises peaked in the early 1990s, and have plateaued near 60 million (SSB, 1999).

phenomenally over the past two decades, even when energy use was rising quickly (Figure 15). Recalculation of primary energy intensity using the lower, revised GDP estimates still gives a long-term decline in energy intensity. This change in underlying GDP figures, however, moves China from being a major exception, with energy intensity falling far faster than any other country, to a "normal" country, with energy intensity falling at about the same rate as the US and Taiwan—still rather quickly (Figure 16). Electricity intensity has fallen rather more slowly than primary energy intensity, as electricity's share in end use rises (Figure 15). Recalculation of electricity intensity, however, shows that there has been virtually no net change over the past 20 years—a finding that is consistent with development experience in other countries, where electricity intensities tend to rise along with incomes and industrial development. These trends in primary energy intensity and electricity intensity are expected to remain much the same in the coming years.

6. End-Use Energy Efficiency

Since the early 1980s, China has adopted a far-reaching series of policies and programs to promote greater efficiency in energy end uses in all sectors. Besides direct support for energy efficiency projects (accounting in some years for 10% or more of all investment in energy), administrative and regulatory structures were developed to manage energy use, standards for process and equipment efficiency were developed, building energy codes were formulated, and a nationwide network of technical service centers was established (Sinton *et al*., 1998). In 1998, the national Energy Conservation Law came into force, codifying the country's approach to promoting energy efficiency under a more market-oriented economic system. Numerous international assistance projects have aimed to help China raise energy efficiency, over the years developing from direct assistance for demonstration projects and technology transfer, to more recent projects aimed at more comprehensive transformation of markets, e.g., for lighting products and home appliances.

In the 1980s, when the government directly controlled a much larger portion of the national economy, it was simpler to gauge the impact of these programs. In the 1980s, when the energy intensity of the economy fell by a third, from one third to one half of the change was attributable to improvements in energy efficiency, largely due to government-led investment programs and regulatory activity, both through retrofits of existing equipment and construction of new capacity (Sinton *et al*., 1998). Since the deepening of ownership, management, and financial reforms in the early 1990s, and the consequent spinning off of investment and operational decision making to managers and local officials, it has become much more difficult to quantify the relationship between efficiency policies and changes in technical efficiency. While it is clear that greater technical efficiency continues to play a significant role in changing patterns of energy use, determining how much efficiency improvements have contributed to the recent declines in energy use would require detailed sectoral case studies.

7. Environmental Regulation

All across China, and particularly in the wealthy coastal provinces, cities and towns are gradually becoming stricter in enforcing limits to pollutant emissions. When local administrations are supportive, environmental protection bureaus can levy significant emissions fees and fines, mandate process changes, and apply more drastic measures. In some cases this results in installation (and often operation) of pollution control equipment, or replacement of old production equipment. In other cases, urban factories move to rural locations, or shut down altogether.

Forceful application of environmental regulations has the potential to change industrial energy demand significantly. The regulation of sulfur dioxide emissions in China's legislatively defined "acid rain control zones" may, for instance, result in greater use of washed coal and installation of flue-gas desulfurization (FGD) equipment at power plants. Coal washing would provide a higher heat-content product that would burn more efficiently, reducing demand for coal, all else being equal. FGD, on the other hand, requires a great deal of a power plant's output, raising demand for coal inputs to power generation. In general, although the effect is hard to quantify, emissions controls and workplace health regulations have contributed to the rise in industrial demand for electricity.

Forcing urban factories to move or to replace equipment often results in the use of newer, generally larger, cleaner, and more efficient equipment. While there have been large markets in China for used production equipment, introduction of newer equipment still tends to increase average energy efficiency. Closing down heavily polluting factories contributed to concentration in industries, which tends to favor cleaner production, and, again, greater energy efficiency.

Whatever net effect environmental regulations have on industrial energy demand, e.g., a rise in electricity use and a fall in direct use of coal, it is likely to be drowned out by the effect of the economic forces discussed above.

8. Conclusions

In the absence of more in-depth research into the causes of the decline in China's energy consumption, few definitive answers are available, but we can make some provisional conclusions. It is clear that the decline in energy consumption is, in essence, a decline in coal consumption, as the other primary energy forms did not record a decline in consumption. Moreover, the fall in coal consumption appears to be concentrated in direct uses; based on available data, coal consumption for conversion (power generation, heating, coking, and coal washing) has remained stable.

The decline in direct coal use reflects the convergence of a number of trends, both short- and long-term. Additional investigation is warranted to determine if the short-term trends are indeed of a transitory nature, or will continue to affect coal consumption over the long term. Among the short-term trends, the economic downturn beginning in 1998 appears to have had the greatest impact on coal use, reflected both in the slowdown in growth of electricity generation and in the absolute decline in demand from industrial subsectors such as building materials and chemicals, among others. This decline in demand was shaped by a second near-term trend as well—the government's promotion of industrial restructuring though consolidation, increases in scale of facilities, and closures. Reducing production from or closure of small ammonia producers, for example, resulted in both lower energy consumption and higher average energy efficiency of the remaining productive capacity.

The electric utility sector also appears to be reducing energy consumption through closures of small plants in favor of more efficient producers. As the government moves to shut down all condensing units of 50 MW or smaller, emphasis is being placed on greater utilization of the larger generating plants of higher efficiency.

A third short-term trend with longer-term implications stems from the emergence of a buyer's market in coal. With prices depressed and coal oversupplied, consumers have been able to preferentially purchase cleaner coal with higher heat content, resulting in a decline in apparent coal consumption even with higher economic output. Since China's energy consumption peaked in 1996, we estimate that this factor alone is accounts for about 40% of the total decline in apparent energy consumption. It is uncertain, however, whether this trend can be sustained once energy demand resumes faster growth and coal output rebounds, but it is likely to remain a factor affecting consumption in 2000, as the government continues to suppress coal output to manage the surplus market.

At the same time that slower economic growth, industrial reform, and higher coal quality have resulted in a substantial reduction in coal consumption, other longer-term trends are also having a continued impact. The shift from state-owned to collective, private and foreign-invested ownership of production is widely seen as a shift to greater efficiency, particularly since the productive assets of the non-state sector are often newer and better operated, even in some rural township enterprises. The product mix is also improving, providing greater quality and value of output per unit of energy input. Although industry remains the leading sector of the economy, within the industrial sector certain energy-intensive subsectors have declined while others of lower energy intensity have gained in importance. These are all natural processes of economic growth and modernization, and it is not inconceivable that these changes will be further spurred as China gains formal WTO entry and broad sectors of domestic industry are subjected to greater international competition. Under the influence of policies promoting restructuring and technical change as well as economic growth, these changes are likely to remain factors in reducing the magnitude of energy demand growth for some time to come.

Sustained support for environmental and energy efficiency policies is a factor in the continuing decline of coal use by residential consumers. Dropping fairly steadily since its peak in 1988, residential coal use is being aggressively replaced by cleaner forms of energy such as LPG, natural gas, town gas, and electricity. Planned expansion of natural gas use from 20 bcm today to 100 bcm in 2010 will benefit millions of residential users and allow for further substitution of coal. Long-term implementation of policies and programs to promote energy conservation has helped to accelerate improvements in end-use efficiency in most sectors.

The available data on current energy consumption in China are too poor to allow us to precisely assess the contribution of each factor to the total decline in consumption since 1996, though partial information allows us to estimate that about two fifths of the decline came from the increase in coal quality, and the balance was due to all other factors combined. The economic slowdown and disruption of the state-owned industrial sector is likely to be the largest source of the balance of the decline. The available data for 1999 confirm a continuing slowdown in coal output and consumption, and the outlook for 2000 is similar, though electricity use is already showing signs of a rebound. Until the many uncertainties regarding the nature of the current decline are resolved, looking out beyond 2000 is extremely difficult. For instance, it is now impossible to assert with any assurance that China will resume the same type of rapid economic and energy demand growth seen in the past 20 years.

Overall, a combination of slowing economic growth, industrial restructuring, broader economic system reforms, and environmental and energy-efficiency policies has apparently led to at least a temporary decline in, and perhaps a long-term reduction in the growth of energy use, and therefore greenhouse gas emissions. China is currently undergoing a profound economic and social transition, and further research is needed in the areas highlighted in this paper to provide a stronger understanding of the changing driving forces of energy demand in China, and to provide a realistic understanding of the country's longer-term energy outlook.

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Tables

Table 1. Conversion Factors

		equals:		
Energy Type	***One***	**GJ**	**metric tons of standard coal equivalent (tce)**	**Barrels of oil equivalent (boe)**
Standard Coal	Mt	29.31	1.000	5.147
Average Chinese Coal	Mt	20.93	0.714	3.676
Oil	Mt	41.87	1.429	7.353
Natural Gas	Tcm	38.98	1.330	6.846
Electricity	MWh	11.84	0.404	2.080

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Table 2. Primary Commercial Energy Production in China, 1980-1999

Units: EJ

	Coal	Oil	Natural Gas	Hydro-electricity	Nuclear Electricity	Total
1980	13.0	4.4	0.6	0.7		18.7
1981	13.0	4.2	0.5	0.8		18.5
1982	14.0	4.3	0.5	0.9		19.6
1983	15.0	4.4	0.5	1.0		20.9
1984	16.5	4.8	0.5	1.0		22.8
1985	18.3	5.2	0.5	1.1		25.1
1986	18.7	5.5	0.5	1.1		25.8
1987	19.4	5.6	0.5	1.2		26.8
1988	20.5	5.7	0.6	1.3		28.1
1989	22.1	5.8	0.6	1.4		29.8
1990	22.6	5.8	0.6	1.5		30.5
1991	22.8	5.9	0.6	1.4		30.7
1992	23.4	6.0	0.6	1.5		31.4
1993	24.1	6.1	0.7	1.7	0.0	32.5
1994	26.0	6.1	0.7	1.9	0.2	34.8
1995	28.5	6.3	0.7	2.1	0.1	37.8
1996	29.2	6.6	0.8	2.3	0.2	38.9
1997	28.8	6.7	0.8	2.5	0.2	38.8
1998	26.2	6.7	0.9	2.6	0.2	36.3
1999	*21.6*	*6.7*	*0.9*	*2.7*	*0.1*	*32.0*

N.B. Estimates are in italics. Some totals may appear different than sums of individual figures due to rounding.

Source: SSB, 1992 and 1999.

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Table 3. Primary Commercial Energy Consumption in China, 1980-1999

Unit:s: EJ

	Coal	Oil	Natural Gas	Primary Electricity	Total
1980	12.8	3.7	0.5	0.7	17.7
1981	12.7	3.5	0.5	0.8	17.4
1982	13.4	3.4	0.5	0.9	18.2
1983	14.4	3.5	0.5	1.0	19.4
1984	15.7	3.6	0.5	1.0	20.8
1985	17.0	3.8	0.5	1.1	22.5
1986	18.0	4.1	0.5	1.1	23.7
1987	19.3	4.3	0.5	1.2	25.4
1988	20.8	4.6	0.6	1.3	27.3
1989	21.6	4.9	0.6	1.4	28.4
1990	22.0	4.8	0.6	1.5	28.9
1991	23.1	5.2	0.6	1.5	30.4
1992	24.2	5.6	0.6	1.6	32.0
1993	25.4	6.2	0.6	1.8	34.0
1994	27.0	6.3	0.7	2.1	36.0
1995	28.7	6.7	0.7	2.3	38.4
1996	30.4	7.3	0.7	2.2	40.7
1997	29.0	8.3	0.7	2.5	40.5
1998	28.5	7.9	0.8	2.6	39.9
1999	*27.6*	*8.1*	*0.9*	*2.5*	*39.1*

N.B. Estimates are in italics. Some totals may appear different than sums of individual figures due to rounding.

Coal: See Table 4 for estimate of 1999 coal use.

Oil: Assume 3.0% growth in consumption in 1999, supplied by increased imports.

Natural Gas: Assume same ratio of production to consumption in 1999 as in 1998.

Primary Electricity: Assume same ratio of generation to consumption in 1999 as in 1998.

Source: SSB, 1992 and 1999; Table 4.

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Table 4. Coal Balances, Mt, 1980-1999

	SUPPLY					CONSUMPTION											
						Transformation						***End Use***					
Year	Production	Imports	Exports	Stock Change	**Total Supply**	Power Generation	Heating	Coking	Gasification	Coal Washing (net loss)	**Transformation Subtotal**	Industry	House-holds	Other End Use	**End Use Subtotal**	**Total Consumption**	Balance
1980	620	2	(6)	10	**626**	126	-	67	1	27	**222**	216	116	56	**388**	**610**	16
1981	622	2	(7)	7	**624**	128	-	59	1	27	**215**	215	121	56	**392**	**606**	18
1982	666	2	(6)	(3)	**659**	135	-	61	1	28	**225**	232	125	61	**417**	**642**	17
1983	715	2	(7)	(13)	**698**	143	-	64	2	30	**238**	254	131	64	**449**	**687**	10
1984	789	2	(7)	(17)	**768**	159	-	70	2	31	**262**	278	140	70	**488**	**750**	18
1985	872	2	(8)	(39)	**828**	165	15	73	2	35	**290**	297	156	74	**527**	**817**	11
1986	894	2	(10)	(13)	**873**	181	16	81	2	36	**316**	311	158	75	**545**	**861**	12
1987	928	2	(14)	16	**933**	204	19	88	2	38	**350**	338	165	75	**579**	**929**	4
1988	980	2	(16)	31	**997**	230	21	89	3	37	**380**	361	175	79	**615**	**996**	1
1989	1,054	2	(15)	(28)	**1,013**	254	24	96	4	39	**416**	372	170	78	**620**	**1,037**	(24)
1990	1,080	2	(17)	(42)	**1,022**	272	30	107	4	41	**453**	358	167	77	**602**	**1,055**	(33)
1991	1,087	1	(20)	(11)	**1,058**	301	34	109	4	47	**495**	369	165	76	**610**	**1,104**	(46)
1992	1,116	1	(20)	(3)	**1,095**	335	39	113	5	44	**534**	388	148	71	**607**	**1,141**	(46)
1993	1,150	1	(20)	21	**1,153**	368	47	121	5	41	**582**	406	145	62	**613**	**1,195**	(42)
1994	1,240	1	(24)	15	**1,232**	401	55	139	8	44	**647**	429	130	74	**633**	**1,280**	(48)
1995	1,361	2	(29)	1	**1,335**	444	59	184	8	20	**715**	461	135	66	**662**	**1,377**	(42)
1996	1,397	3	(36)	9	**1,372**	488	64	185	6	21	**763**	476	144	64	**685**	**1,447**	(75)
1997	1,373	2	(31)	(13)	**1,332**	490	62	193	7	23	**776**	442	122	53	**618**	**1,392**	(61)
1998	1,250	2	(32)	*50*	***1,269***	*491*	*59*	*176*	*8*	*25*	***760***	-	-	-	***506***	***1,265***	(31)
1999	*1,030*	*2*	*(39)*	*90*	***1,083***	*494*	*60*	*178*	*8*	*26*	***766***	-	-	-	***434***	***1,200***	(157)

N.B. All 1996 and previous figures are from the State Statistical Bureau. Figures for 1997 and later in italics are estimates. Some totals may appear different than sums of individual figures due to rounding.

Production: 1999 projection is official estimate for annual output.

Imports & Exports: 1999 figure based on 20.6% increase in first 3 quarters of 1999 (Reuters, 1999c).

Stock Change: Figure for 1998 represents a substantial increase over previous years, while the estimate for 1999 reflects expectations that nearly half of reported total stockpile will be used (Wang, 1999a).

Power Generation:	1998 figure is based on reported 1998 power generation, expected improvements in generation efficiency of about 1.3%, and rise in coal quality of 120 kcal/kg. 1999 figure is based on estimated 1999 power generation, improvement in generation efficiency of 1.3%, and rise in coal quality of 100 kcal/kg.
Heating:	Estimates for 1998 and 1999 are based on the 1997 ratio of coal inputs for heating to coal inputs for power generation.
Coking:	Estimate for 1998 assumes 1997 ratio of coal input:coke output, and accounts for rise in coal quality of 120 kcal/kg. 1999 estimate assumes a 1% increase in coke output and coal inputs.
Gasification:	1998 and 1999 estimates assume 5% annual growth.
Coal Washing:	Losses in 1998 and 1999 are estimated to rise 1.5 Mt per year.
End Use Subtotal:	Estimates for 1998 and 1999 are the residuals left after subtracting transformation consumption from total consumption.
Total Consumption:	For 1998, total consumption is set equal to reported primary coal, taking into account improvement in coal quality of 120 kcal/kg. 1999 estimate is chosen to try to spread the changes in coal use between1998 and 1999 relatively evenly between the fall in end-use consumption, stock drawdowns, and balance (which rises significantly above its previous prevailing level, to account for assumed unreported production of coal from ostensibly closed local mines).

Source: SSB, 1997, 1998a and 1999; Bloomberg, 1999b, 1999c, and 1999d; Reuters, 1999c.

Table 5. Installed Capacity of Coal-Fired Power Plants

Unit Size, MW	1993			1997		
	No. of units	Total capacity (MW)	Total capacity % of total	No. of Units	Total capacity (MW)	Total capacity % of total
600 and over	6	3,600	3.0%	10	6,000	3.5%
300 to <600	73	22,780	19.1%	144	42,980	25.1%
200 to <300	162	32,600	27.4%	189	38,000	22.2%
100 to <200	217	23,993	20.1%	270	30,118	17.6%
50 to <100	267	13,530	11.4%	339	17,310	10.1%
<50	1,807	22,583	19.0%	2,374	37,073	21.6%
Total	2,532	119,086	100.0%	3,326	171,481	100.0%

N.B. Included only generating units over 6 MW.

Source: State Power Corporation, 1999; Zhou et al., forthcoming.

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Table 6. Biomass Energy Use in Rural China

Unit: EJ

Energy Form	1991	1995	1996
Biogas	0.02	0.03	0.03
Crop Stalks	4.81	4.42	3.52
Wood	3.02	2.93	2.43
Total Biomass	7.85	7.39	5.98
Ratio of Biomass to Commercial Energy	0.26	0.19	0.15

Source: SSB, 1997; Zhou et al., forthcoming.

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Table 7. Current and Future Installed Capacity of Renewable Power Generation, MW

Technology	Actual Total in Operation, 1993	Planned Total in Operation by:		
		2000	2010	2020
Small Hydro	10,055	19,850	27,880	39,158
Wind	30	400 [1]	3,170	8,500
Solar PV	3	35	200 [2]	500
Solar Thermal	0	35	-	-
Geothermal	31	106	200	330
Biomass	87	N/a	n/a	n/a
Ocean	0	0	200	400
Total	15,211	20,126	31,650	48,888

[1] While plans originally called for installed capacity of 1 GW by 2000, actual capacity by the end of 2000 is likely to be 400 to 450 MW.

[2] Includes both solar PV and solar thermal

N.B. Excludes large-scale hydropower capacity.

Source: The World Bank, 1996, based on renewable Energy Development Program and Ministry of Electric Power (now Sate Power Corporation) plans.

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Table 8. China's GDP: Official Figures and Revised Estimates

unit: 10^9 1995 yuan

	Total GDP		Industry GDP	
	Official Figures	Revised GDP estimates	Official figures	Revised GDP estimates
1980	1,366	*1,366*	439	*439*
1981	1,437	*1,455*	447	*453*
1982	1,568	*1,570*	473	*474*
1983	1,739	*1,697*	519	*506*
1984	2,003	*1,890*	596	*562*
1985	2,274	*2,087*	704	*647*
1986	2,474	*2,224*	772	*695*
1987	2,761	*2,414*	874	*765*
1988	3,073	*2,611*	1,008	*858*
1989	3,199	*2,668*	1,059	*886*
1990	3,321	*2,753*	1,095	*910*
1991	3,626	*2,914*	1,253	*1,011*
1992	4,141	*3,191*	1,518	*1,178*
1993	4,700	*3,502*	1,824	*1,370*
1994	5,292	*3,852*	2,168	*1,594*
1995	5,848	*4,181*	2,472	*1,785*
1996	6,409	*4,513*	2,781	*1,979*
1997	6,973	*4,846*	3,089	*2,170*
1998	*7,517*	*5,167*	*3,361*	*2,336*
1999	*8,043*	*5,478*	*3,677*	*2,533*
Annual Average Growth Rate	9.8%	7.6%	11.8%	9.7%

N.B. Estimates are in italics.

Source: SSB, 1998a and 1999; *SCMP*, 9/9/99 and 9/23/99; *People's Daily*, 2/27/99; Maddison, 1997.

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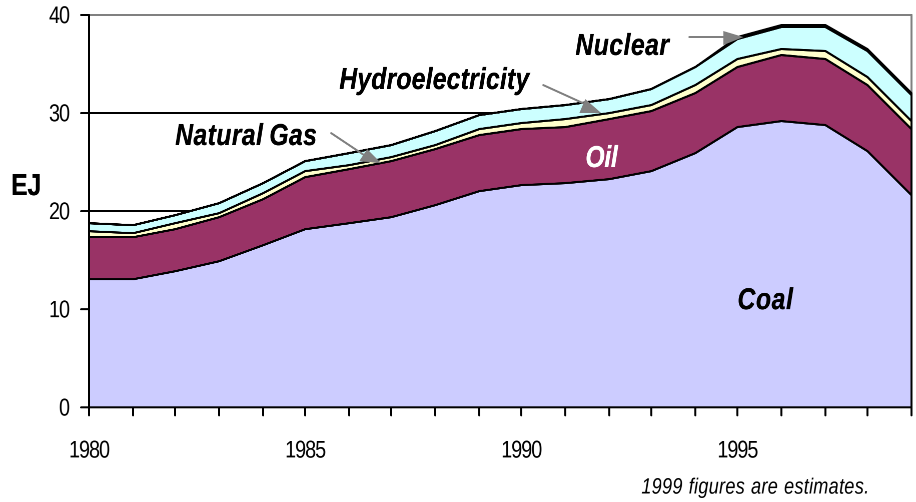
Figures

Figure 1. Primary Commercial Energy Production, 1980-1999



Source: SSB, 1992 and 1999; Bloomberg News, 1999.

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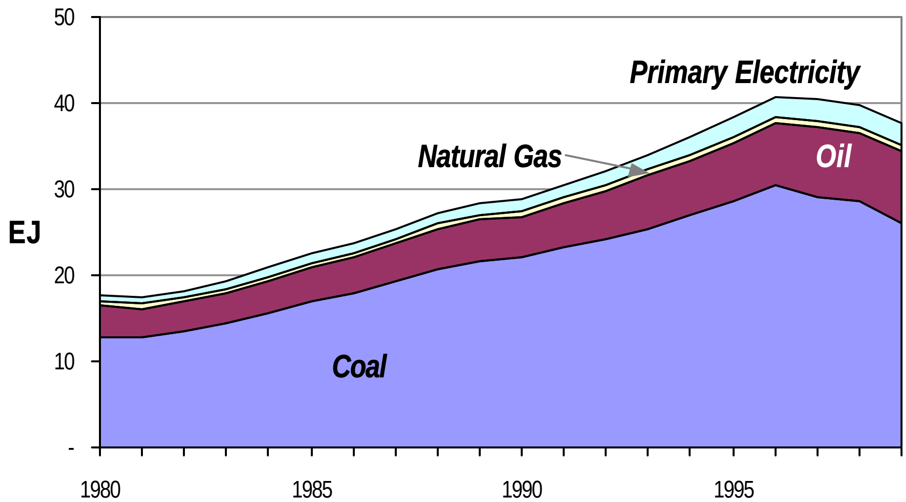
Figure 2. Primary Energy Consumption, 1980-1999



1999 figures are estimates.

Source: SSB, 1992, 1997, and 1999.

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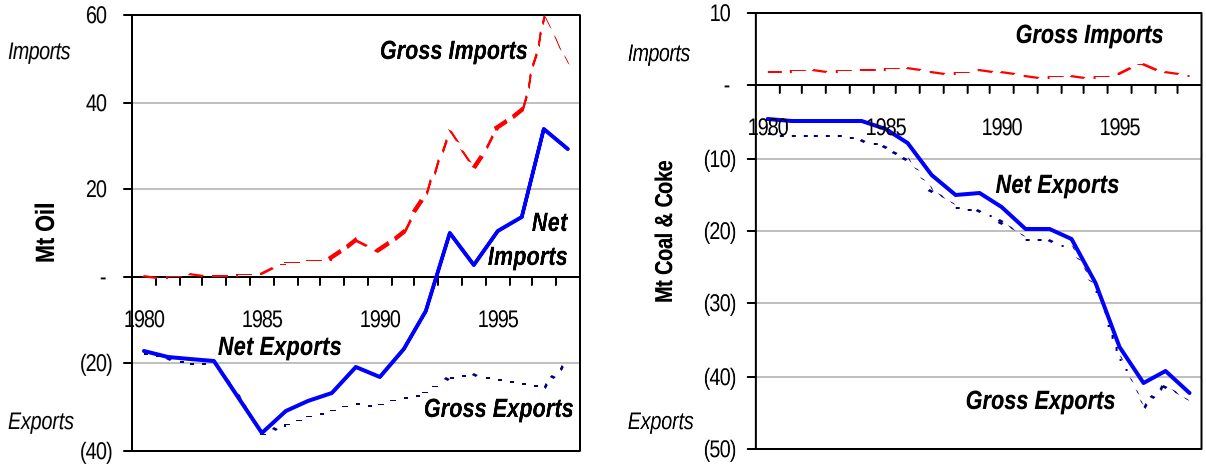
Figure 3. International Trade in Coal and Oil, 1980-1998



N.B. These are based on official customs figures, and do not include estimates of any smuggled products.

Source: SSB, 1998a and 1999.

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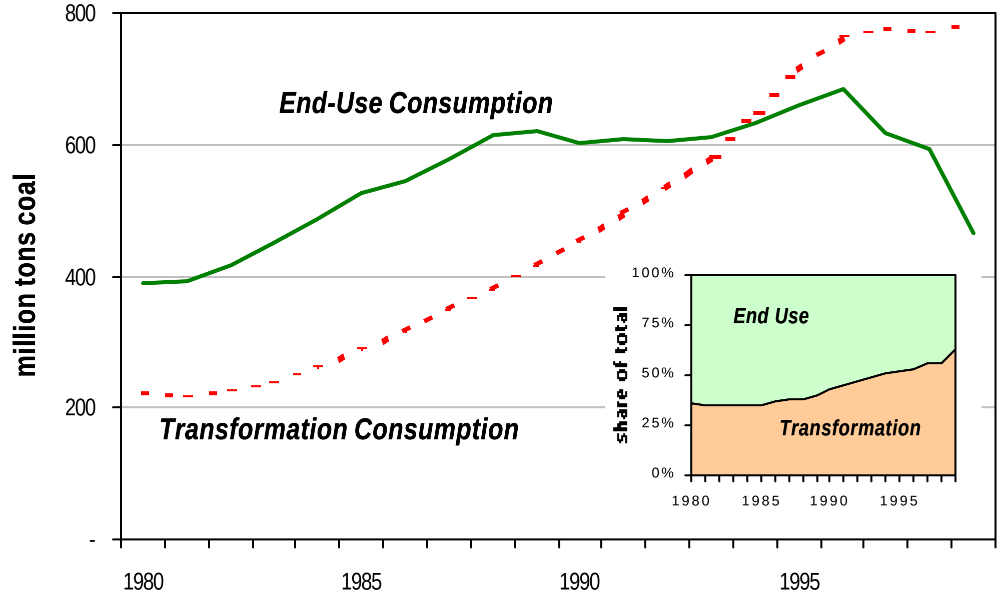
Figure 4. Structure of Coal Consumption, 1980-1999



1998-1999 figures estimated.

Source: Source: SSB, 1992 and 1999; Table 4.

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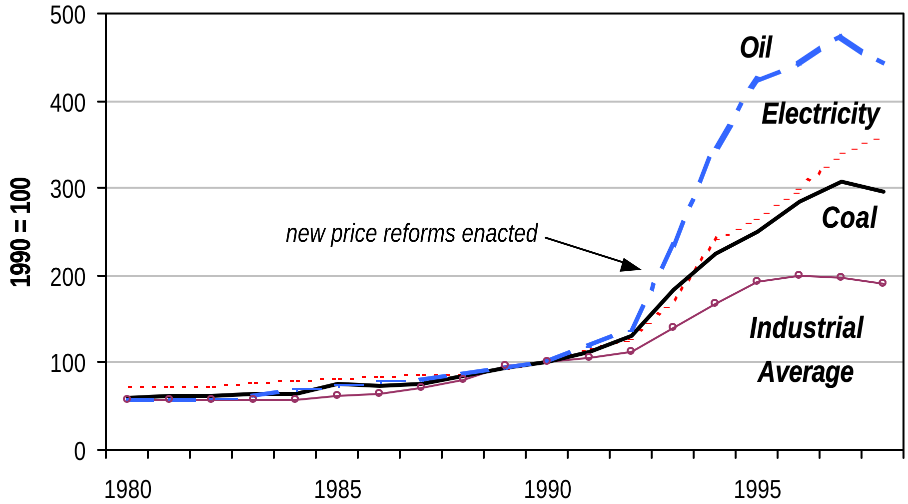
Figure 5. Ex-Factory Price Indexes for Energy and Industrial Products, 1980-1998



Source: SSB, 1999.

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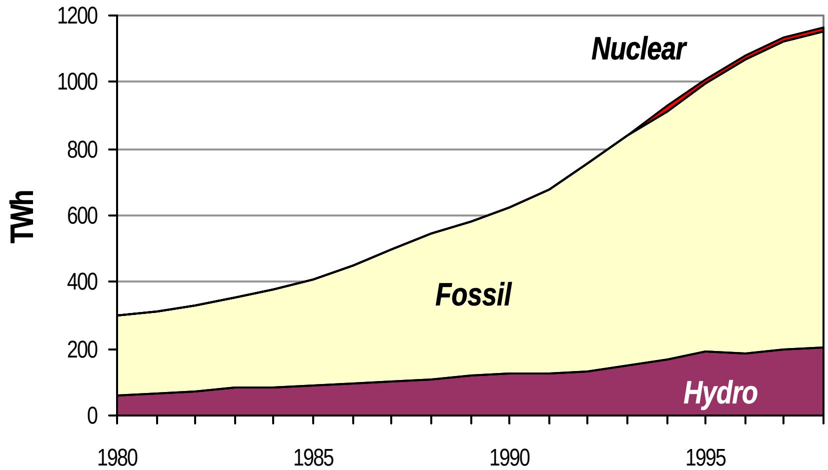
Figure 6. Power Generation, 1980-1998



Source: SSB, 1999.

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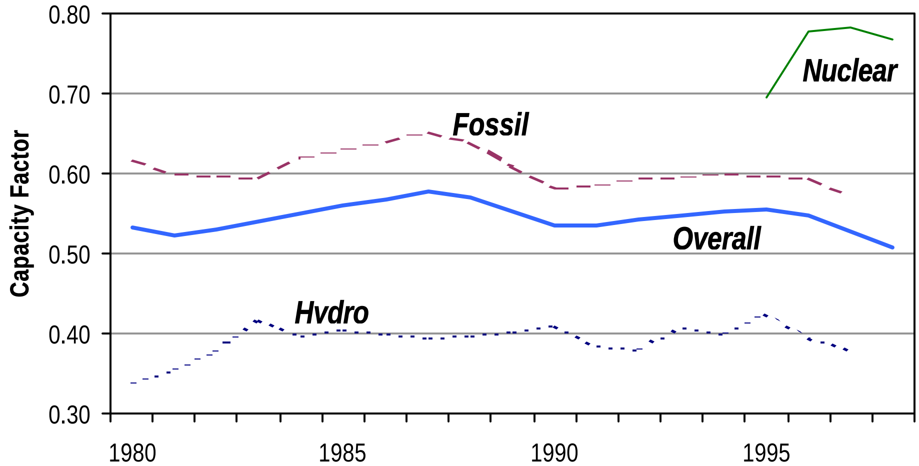
Figure 7. Average Capacity Factors for China's Power Plants, 1980-1998



Source: derived from SSB, 1999, State Power Corporation, 1998.

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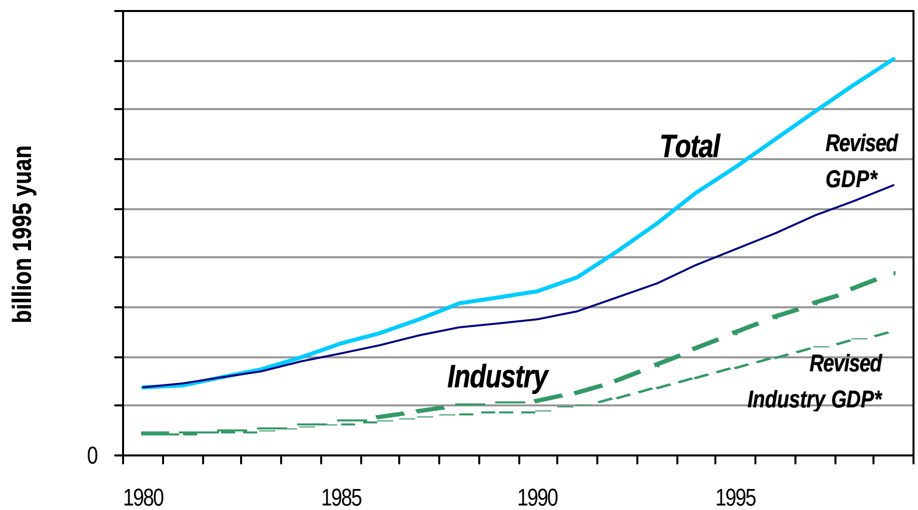
Figure 8. GDP in China: Official Figures and Revised GDP Estimates, 1980-1999



* Lower bounds are estimated based on Maddison, 1997 and Standard & Poor estimates, effectively reducing average annual growth in GDP by about two percentage points over 1980-1999. 1999 GDP is estimated.

Source: SSB, 1998a and 1999; *SCMP*, 9/9/99 and 2/23/99; *People's Daily*; Maddison, 1997.

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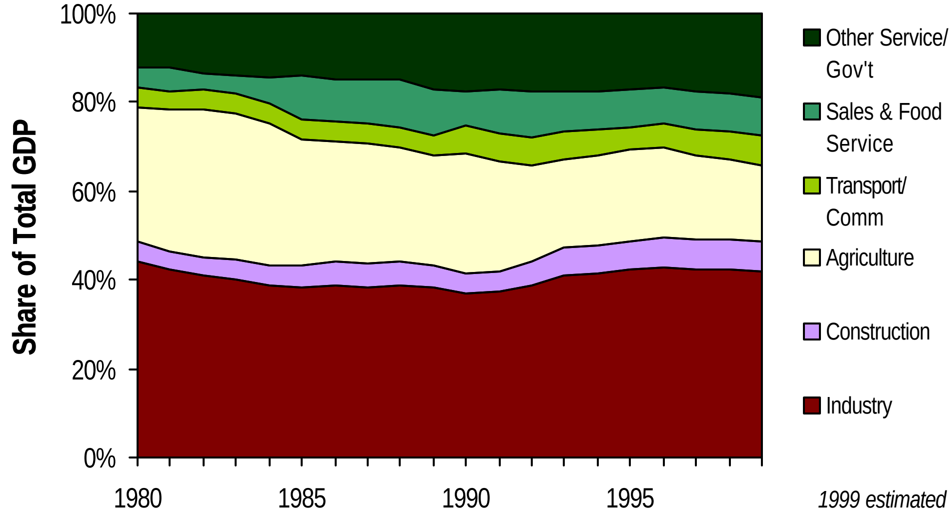
Figure 9. Structure of GDP, China, 1980-1999



Source: SSB, 1998a and 1999.

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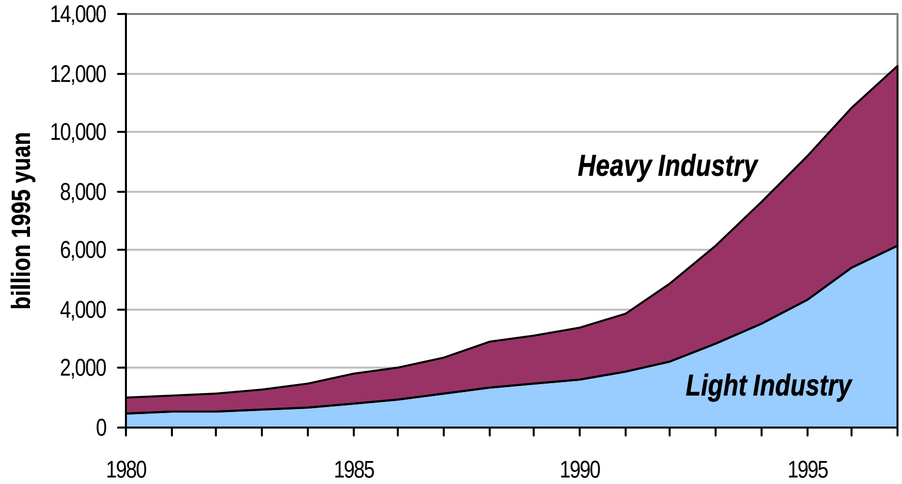
Figure 10. Gross Output Value from Heavy and Light Industry, 1980-1997



Source: SSB, 1998b.

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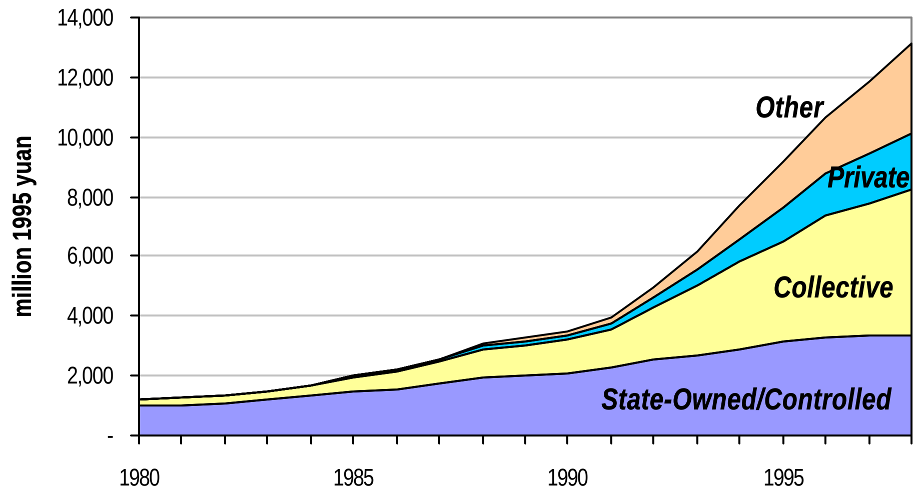
Figure 11. Gross Output Value of Industrial Enterprises by Ownership Type, 1980-1998



Source: SSB, 1999.

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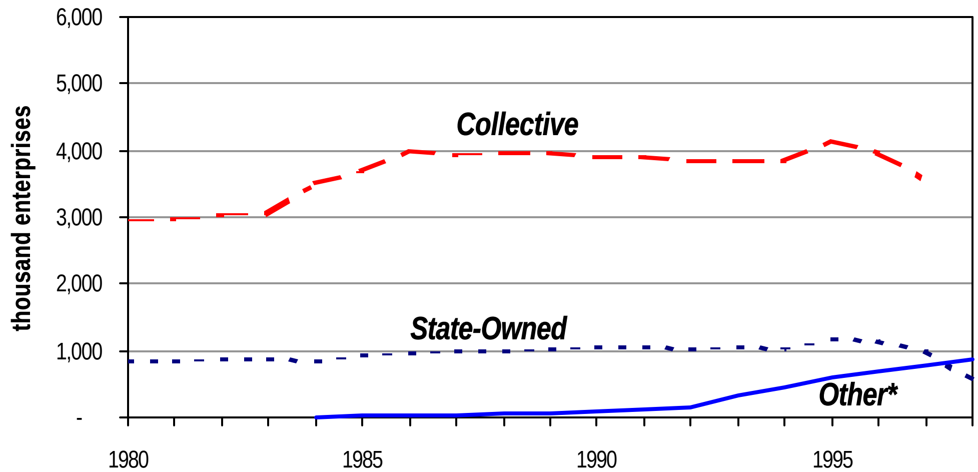
Figure 12. Number of Industrial Enterprises (at or above village level), China, 1980-1998



** Private, joint venture and joint stock/liability companies*

N.B. Does not include small private enterprises, which are very small and numbered nearly 60 million in 1997.

Source: SSB, 1999

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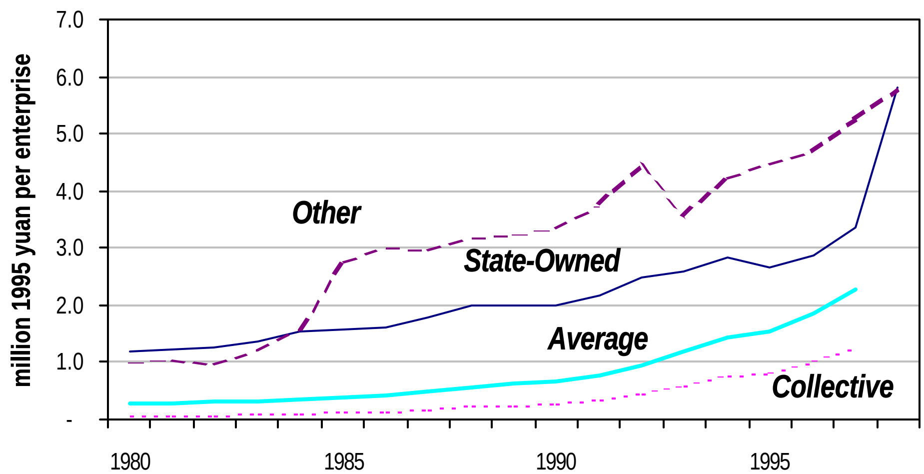
Figure 13. Average Gross Output per Industrial Enterprise (at or above village level), China, 1980-1997



Source: SSB, 1999.

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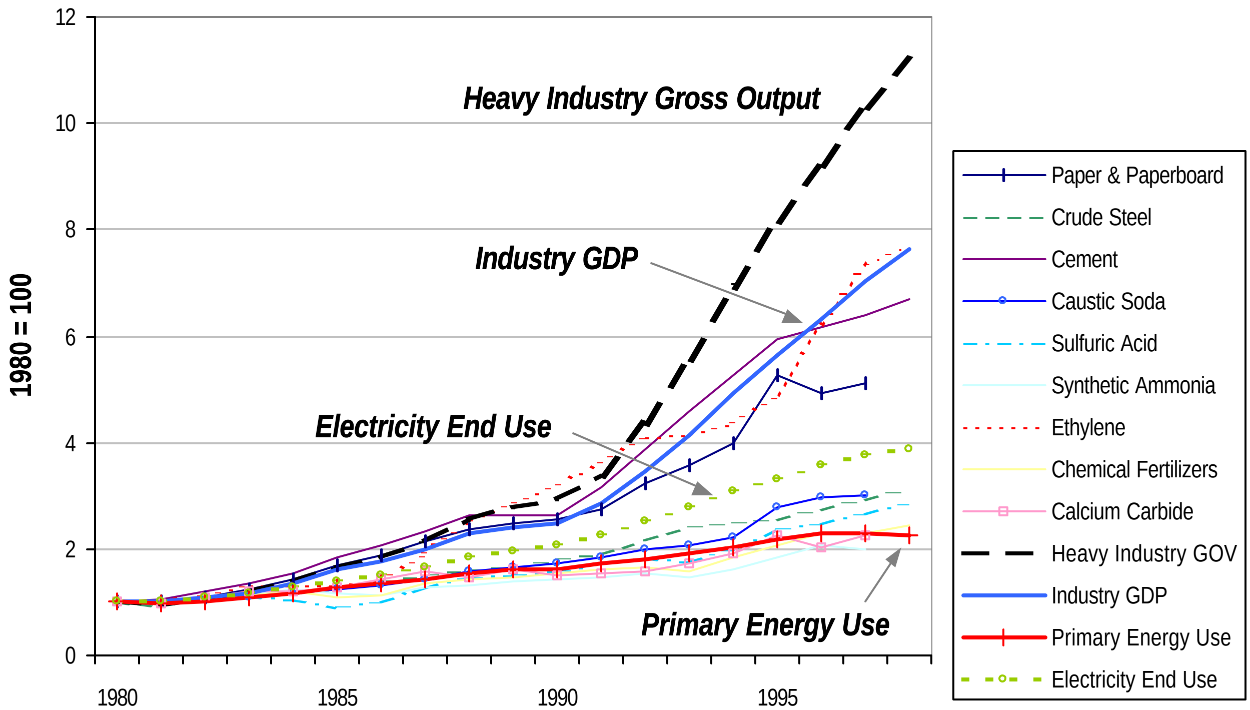
Figure 14. Industrial Output & Total Energy Use, China, 1980-1998



Source: SSB, 1999.

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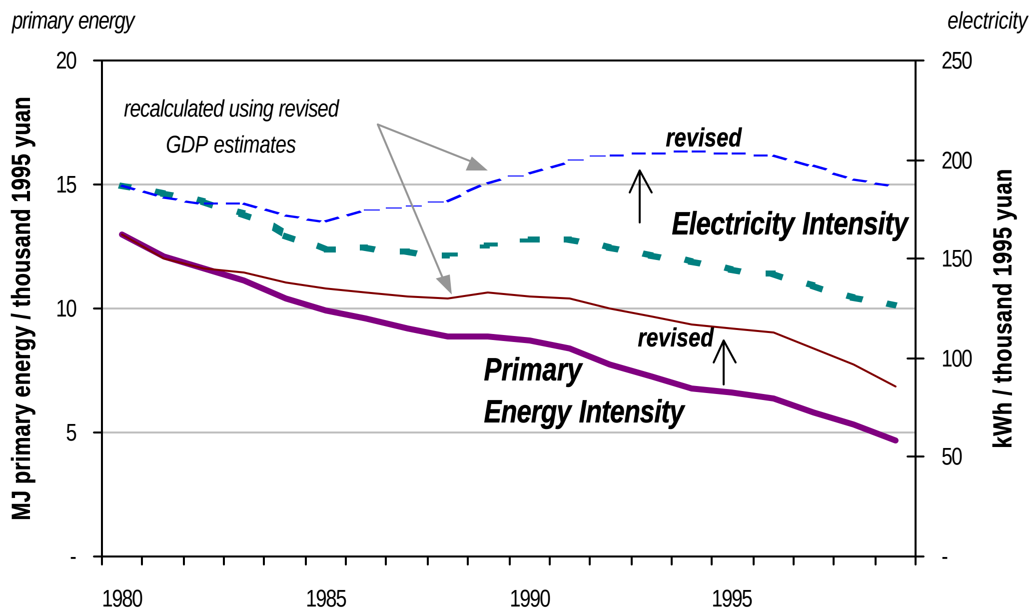
Figure 15. Energy Intensities of GDP,1980-1999



N.B. Revised GDP estimates used in recalculating energy intensities are displayed in Figure 8.

Source: SSB, 1998a and 1999; *SCMP*, 9/9/99 and 9/23/99; *People's Daily*, 2/27/99; Maddison, 1997.

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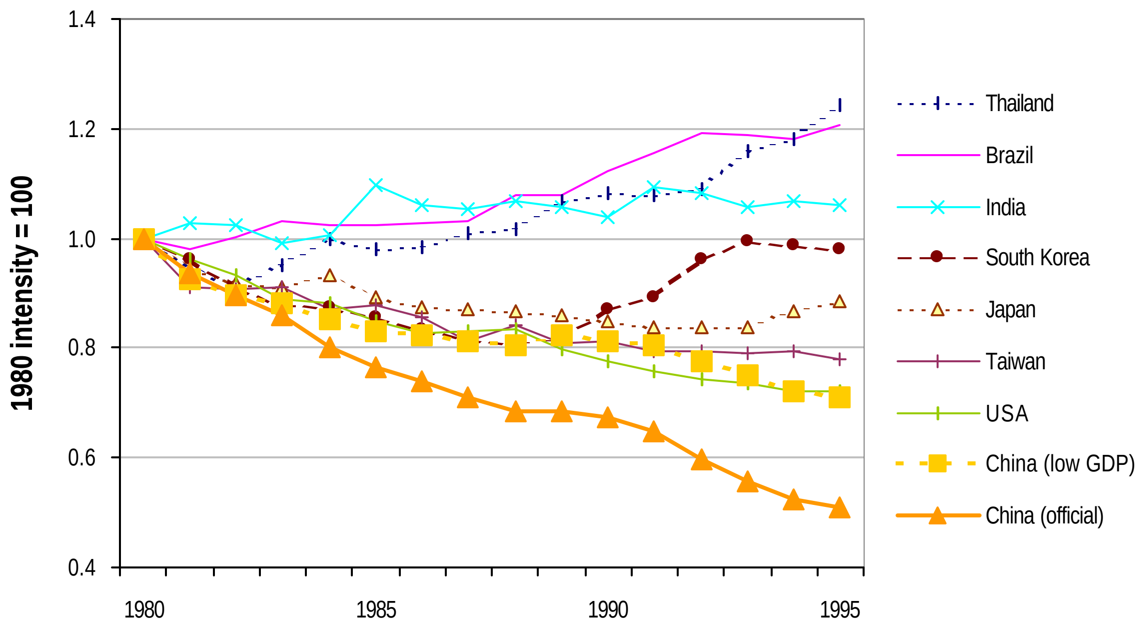
Figure 16. International Comparison of Economic Energy Intensities, 1980-1995



N.B. Indexes are based on energy intensities constructed with statistics on primary energy consumption and real GDP.

Source: IEA, 1999; Figure 15.

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