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Richard K. Lester and Edward S. Steinfeld

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292 Main Street, E38-104
Cambridge, MA 02139-4307
P 617-253-7522
web.mit.edu/ipc/www

THE COAL INDUSTRY IN CHINA (AND SECONDARILY INDIA)[1]

Richard K. Lester and Edward Steinfeld
Industrial Performance Center
Massachusetts Institute of Technology

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Introduction

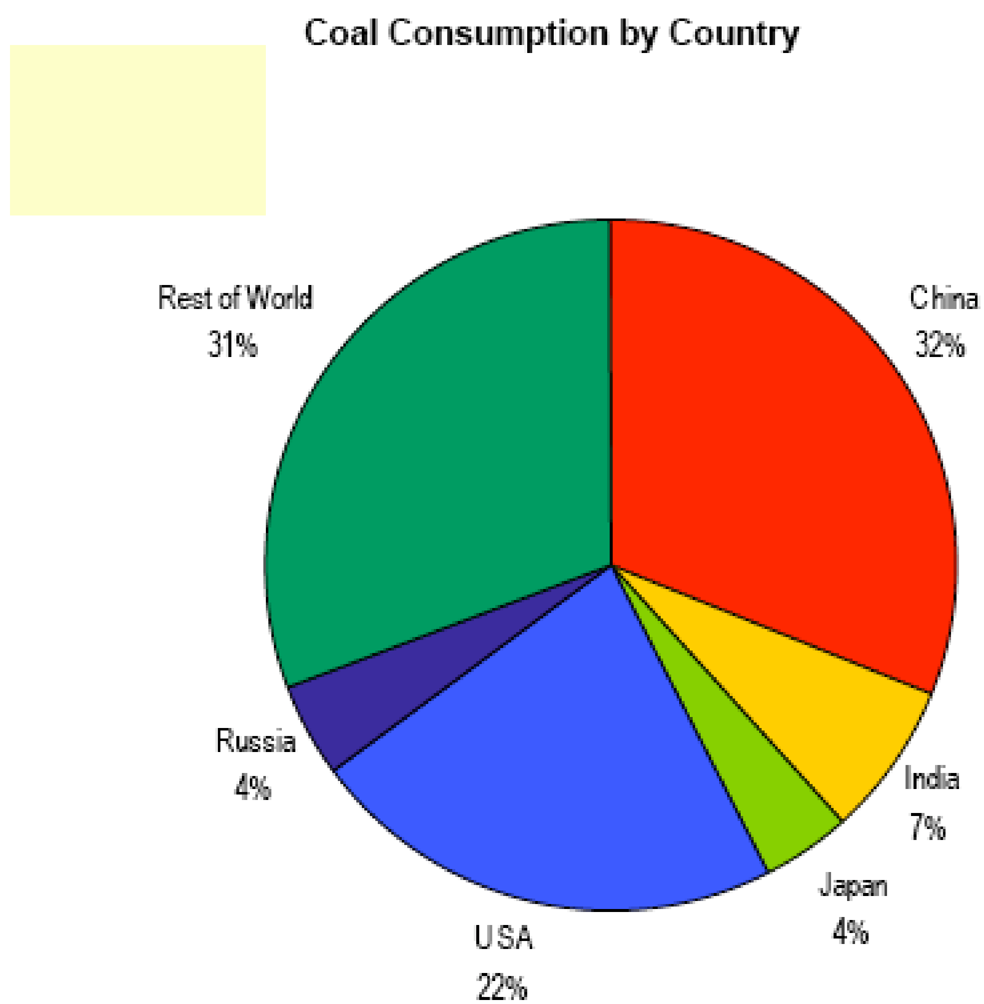
China is expected to account for more than half of global growth in coal supply and demand over the next 25 years. The implications for the global environment are both complex and substantial. This chapter explores the circumstances under which China might constrain its carbon emissions from coal significantly below the currently forecast range. India, with a population comparable to that of China, a rapidly growing economy, and large domestic coal reserves, may one day come to rival China as a source of carbon emissions from coal. Like China, India derives over half of its commercial energy from coal, and together the two countries are projected to account for over 68% of the incremental demand in world coal through 2030.[1] Today, however, India consumes only about a fifth as much coal as its neighbor, and for the foreseeable future the consumption gap between the two countries will remain wide. The main focus of this chapter is thus on China, but in the final section we briefly compare patterns of coal use in the two countries.

Coal is today China's most important and abundant fuel, accounting for about two thirds of the country's primary energy supply. Coal output in China rose from 1.30 billion tonnes in 2000 to 2.23 billion tonnes in 2005,[2] making China by far the world's largest coal producer (the next largest, the United States, produced 1.13 billion tonnes last year). All but a few percent of this coal is consumed domestically, and China's coal use amounts to nearly a third of all coal consumed worldwide (see Figure 1). Electricity generation accounts for just over half of all coal utilization in China, having risen from

[1] This paper appears as Chapter 5 of *The Future of Coal: Options for a Carbon-Constrained World*, an interdisciplinary MIT study, MIT, March 2007.

22% of total consumption in 1988 to over 53% in 2002.[3] Coal currently accounts for about 80% of China's electricity generation, more than 50% of industrial fuel utilization, and about 60% of chemical feedstocks. Forty-five percent of China's national railway capacity is devoted to the transport of coal.[4] The central government has announced its intention to reduce the country's reliance on coal, but for the foreseeable future it will remain China's dominant fuel, and will very likely still account for more than half of the country's primary energy supplies in the year 2030. The largest contributor to future growth in China's demand for coal will be the electric power sector.

Figure 1



The recent growth of the Chinese power sector has been dramatic. Electricity generation grew at a rate of 15.2% in 2003, 14.8% in 2004, 12.3% in 2005, and 11.8% (on an annual basis) in the first quarter of 2006.[5] Total generating capacity increased by nearly a third in the last three years and is expected to double between 2002 and 2007. In 2005, about 70,000 MWe of new generating capacity was brought into service. A similar completion of new plants is projected for each of the next two years.[6] At this rate, China is adding the equivalent of nearly the entire UK power grid each year. Most of the existing and new generating capacity is fueled with coal, and China's coal-fired power plants are the main cause of the rapid increase in its greenhouse gas emissions, which are already the world's second largest after the United States.

Chinese energy statistics – including those pertaining to coal consumption and power generation -- suffer serious problems of reliability. Data reported by both official and unofficial sources exhibit substantial variation and numerous inconsistencies. Indeed, an array of figures for annual coal consumption are noted in this chapter and in Chapter Two. But there is no dispute about the general trend exhibited by the data: Chinese energy consumption is trending rapidly upward.

The supercharged recent growth rates in the power sector may moderate in coming years, but the general trend of strong growth is likely to continue for a long time to come. Electricity consumption per capita in China, at about 1,700 kilowatt hours per year, is still only 20% of the average per capita consumption in the world's advanced economies. Rapid economic development is changing the lifestyles and energy needs of hundreds of millions of Chinese citizens. Future demand growth on a large scale seems assured.

A full understanding of China's current energy situation – including the types of fuels being consumed, the kinds of technologies employed, the effectiveness of environmental regulation, and the international reach of its enterprises – starts with three key characteristics of the Chinese system.

- *First, especially at the national level, China's energy-related governmental bureaucracy is highly fragmented and poorly coordinated.* Responsibility for energy pricing, for the approval of infrastructure projects, for the oversight of state energy companies, and for long-term energy policy is spread across many agencies, most of them seriously understaffed, and some of which – given their very recent emergence on the scene – are notably weak in relation both to other agencies and to the players they are supposed to be regulating.

- *Second, under these conditions the state energy companies – the national oil corporations and the national power generating groups – are the most coherent entities.* These are the organizations that are most capable of defining their own interests and that are most likely to act, making decisions that their ostensible state regulators and overseers can barely keep up with and sometimes do not even monitor. At the same time, and reflecting China's increasingly deep integration with the global economy, these corporate entities are hardly simple organizations themselves. Listed on both domestic and foreign stock exchanges, the state energy corporations encompass complicated groupings of stakeholders, including state-appointed senior executives, domestic and foreign corporate board members, major financiers from the global investment banking community, and international institutional investors. Textbook examples of shareholder-driven corporate governance they are not, but neither are they simple puppets of the state – in no small part because the state itself is so fragmented and lacks a clear voice on energy policy. In essence, the central government in Beijing today has neither a coherent national energy strategy nor much capacity to monitor, support, or impede the actions of state-owned energy companies – actions that are often misunderstood by outsiders as merely echoing government policy.

- *Third, and most important, the remarkably rapid growth of energy consumption in China has been possible because a host of infrastructural issues are being resolved very quickly by individuals and organizations* *operating well below the level of national energy corporations.* Almost daily, actors at the grass roots level are making key decisions about China's physical and technological infrastructure – decisions with profound consequences for its long-term energy development.

Thus, it is a mistake to attribute China's aggregate energy demand growth – or even the actions of the state-owned energy companies – to central government agendas or geopolitical strategy. What many outsiders see as the deliberate result of Chinese national 'energy strategy' is in fact better understood as an agglomeration of *ad hoc* decisions by local governments, local power producers, and local industrial concerns. These local actors are primarily motivated by the need to maintain a high rate of economic growth and few, if any, have the national interest in mind. They are rushing to fill a void left by the absence of a coherent national-level energy strategy. Amidst surging energy demand and frenetic local decision-making, agencies and individuals in the central government are scrambling simply to keep abreast of developments on the ground. China's astonishingly rapid energy development may well be spinning the heads of outsiders, but it is vexing, perplexing, and even overwhelming to Chinese governmental insiders too.

Methodology

The main conclusions of this chapter are based upon fieldwork conducted in China by a team based at the MIT Industrial Performance Center beginning in 2002, but concentrated primarily in 2005. Our goal was to study decision-making in the Chinese power and coal industry sectors. The study primarily employed a case-based approach, supplemented by extensive interviews at various levels of Chinese governmental, academic, and commercial circles. The cases center primarily on the electric power sector and they were selected to represent three general modes of energy-related problem solving in the Chinese system: (1) relatively standard coal-fired power generation by municipal-level plants; (2) "within the fence" self-generation (co-generation) by industrial users or other commercial entities operating outside of what is generally understood as the energy sector; and (3) more future-oriented regional efforts by China's wealthiest coastal provinces to build a natural gas infrastructure.

(1) In the municipal power utility category, we focused our efforts on two sites, the 250 MWe Xiaguan Power Plant in Nanjing (Jiangsu Province) and the 1,275 MWe No. 1 Power Plant in Taiyuan (Shanxi Province). The Xiaguan facility, though formally owned by the national Datang Enterprise Group, is managed and administered primarily at the provincial and municipal levels. The facility is located in the downtown area of Nanjing, the capital of Jiangsu Province and a city of 1.8 million persons (the city has an additional 3.5 million suburban residents). Jiangsu, located on the east coast of China and encompassing much of the Yangtze River Delta, is among the most prosperous and industrialized regions of the country. Industry accounts for over 77% of provincial electricity consumption and (including the power sector) 92% of coal consumption, with residential following a distant second at 11% and 4.2%, respectively.[7] Jiangsu is a center for numerous clusters of domestic and foreign-owned manufacturing operations, and relies primarily on coal imported from interior regions of China to meet its needs. In 2003 about 79% of the province's total coal supply was imported.[8] Nanjing consumes one quarter of Jiangsu's electricity supply.

Nanjing's Xiaguan Power Plant dates originally from 1910, but underwent a substantial rebuild from 1998 to 2000. Approximately 30 percent of the rebuild costs were devoted to the installation of a LIFAC (Limestone Injection into Furnace and Activation of Calcium oxide) flue-gas desulfurization system. At the time of our research, three such systems were operating in China, two in the Nanjing facility and one in a 125 MWe power plant in neighboring Zhejiang Province. Xiaguan's system was supplied by the Finnish firm POCOTEC Pollution Control Technologies, and was financed by soft loans from the Finnish government and grants from the Jiangsu provincial government. The system produces no secondary wastewater, and the fly ash is used for road construction and cement production. The Xiaguan plant generally burns coal with a sulfur content of 1.0 to 1.5 percent. The LIFAC system has achieved a 75% sulfur removal rate, and for the first five years of operation averaged more than 95%

availability. Though a loss maker commercially over the past three years -- a condition not unusual for Chinese generators -- the plant has become something of a model nationally for advanced emissions control.

The second case in this category, the No. 1 Power Plant on the outskirts of Taiyuan City, Shanxi Province, is a more typical facility along a number of dimensions. Taiyuan is the capital of Shanxi, a landlocked province in North China and the largest coal-producing region in the country, supplying 27% of China's coal in 2003.[9] Mining is far and away the largest industry in the province, though a concentration of traditional, state-owned heavy manufacturing is clustered in Taiyuan City. The province, among the poorest in China in terms of urban income, has gained notoriety as the center of some of the country's worst environmental problems, especially atmospheric pollution and acid rain. Approximately 70 percent of annual provincial production of energy resources are exported and sold to other provinces. Taiyuan City, with an urban population of about 2.3 million, consumes 40% of the province's electricity supply. The city is covered in soot and has been ranked as having the worst air quality (particulates and sulfur dioxide) of any city in the world.[10] In 2002, despite various regulatory efforts, reported average daily SO2 concentrations in Taiyuan equaled 0.2 milligrams per cubic meter (mg/m3), over three times the PRC's Class II annual standard (0.06mg/m3).[11]

The Taiyuan No. 1 Power Plant, one of the largest sources of airborne pollutants in the city, went into operation in 1954, though the six units currently in operation – four 300 MWe generators, one 50 MWe generator, and one 25 MWe generator – date from the 1990s. The plant sources all its coal from within Shanxi province, and reports an inability to secure low-sulfur and low ash content coal. Flue-gas desulfurization facilities (wet limestone and gypsum spray injection systems imported from Japan) have been installed only on the 50 MWe unit and one of the 300 MWe units. The plant reports sulfur dioxide emissions of approximately 60,000 tonnes annually, about 20 percent of Taiyuan municipality's annual total. The local Environmental Protection Bureau has routinely assessed emission fines on the No. 1 Power Plant which, when combined with low tariffs for power delivered to the grid, makes the facility uneconomic. Nevertheless, the facility is planning a major expansion, involving the addition of two 600 MWe generators. This expansion is driven in part by electricity shortages both within the inland province itself and in the Northern coastal areas to which power generated by the plant is dispatched. Shanxi Province exports approximately 25 percent of its electric power to coastal areas, with generators in the province facing particular pressure to dispatch to the distant, but politically powerful cities of Beijing and Tianjin. Our team also interviewed the state-owned Shanxi Grid Corporation to examine issues surrounding dispatch.

(2) In the category of co-generation for primary power by industrial firms, the research team focused on the coastal Southern Chinese province of Guangdong, where much development of this type has taken place. Guangdong, arguably the first Chinese province to undergo economic reform, is now one of the most economically liberal and internationally integrated regions of China. The province includes a number of major manufacturing clusters, many of which emerged only after the onset of economic reform and thus have avoided many of the historically-rooted problems of China's northern and northeastern industrial 'rust belt' regions. The research team focused on two primary cases in this region.

One of the cases is a major Guangdong subsidiary of a Hong Kong-based global apparel concern. This subsidiary employs 23,000 individuals in a major production site in the city of Gaoming. The company's factories in Gaoming and nearby Yanmei consume about 170 thousand megawatt-hours of electricity and 600,000 tonnes of steam annually, accounting for 8-9% of total operating costs. The firm was confronted with electricity shortages which were constraining its expansion, and in 2001 elected to build its own 30 MWe coal-fired co-generation plant. The plant became operational in 2004. The plant burns low sulfur coal sourced from Shanxi and Inner Mongolia. Coal costs for the company have risen substantially over the last two years (from 330 RMB/ton to 520 RMB/ton), making the in-house plant's electricity costs only marginally lower than grid electricity. Unlike the grid, however, the in-house plant provides reliable energy, as well as substantial quantities of steam, which avoids the need for costly and environmentally problematic heavy oil burners.

The second self-generation case involves the Guangdong manufacturing site of a U.S. consumer products company. This firm faced similar energy constraints, albeit on a smaller scale, at its production facilities outside the provincial capital, Guangzhou. The bulk of the site's energy use is accounted for by the heating, ventilation and air-conditioning requirements of its climate-sensitive manufacturing facilities. In the last two to three years, the firm has routinely received electricity-shedding orders from the regional grid company, requiring a shift in production schedules to avoid periods of peak power consumption. The shedding orders have ranged from 30 to 70 percent of total load, thus challenging the firm's HVAC requirements and threatening its manufacturing operations. Fearing further energy-related disruptions, the firm elected to purchase dual Perkins diesel-fired generators, each rated at 1.8 MWe.

To supplement these case studies, the team conducted interviews with major multinational suppliers of diesel generators to the China market, as well as with industrial and governmental purchasers of diesel generators in North China, a region in which these generators are usually employed as back-up sources of power.

(3) Members of the research team have also undertaken a multi-year effort into the third category of energy decision-making, gas infrastructure development in coastal East China. Interviews and discussions have been conducted with a variety of involved entities, including overseas fuel suppliers, Chinese national oil and gas majors, port facility and pipeline development companies, national and local governmental development agencies, domestic bank lenders, and overseas investors. This is a large topic that extends beyond the scope of the chapter. However, we include it as an important illustration of the politics of energy-related issues in China, as an important indicator of future energy infrastructure trends in the country, and as a bridge between China's domestic energy imperatives and global energy markets.

Capacity Expansion in the Electric Power Sector.

Capacity expansion in China's electric power sector provides us with some of the clearest evidence of how energy-related decisions are actually being made on the ground. On paper, the story is straightforward. Most power plants belong to one of five major state-owned national energy corporations, enterprise groups that in theory answer upward to the central government while issuing orders downward to exert direct financial and operational control over their subsidiary plants. This chain of command should mean that for a new power plant to be built, the state-owned parent must secure the necessary central government approvals, and demonstrate that the new project meets relevant national technical standards, stipulations about what fuels to utilize, and, once the plant is up and running, national operational requirements, including environmental regulations.

The reality, however, is far more complex. For example, as central government officials themselves acknowledge, of the 440,000 MWe of generating capacity in place at the beginning of 2005, there were about 110,000 MWe of 'illegal' power plants which never received construction approval by the responsible central government agency (the Energy Bureau of the National Development and Reform Commission, a part of the former State Planning Commission.)[12] These plants were obviously all financed, built, and put into service, but nobody at the center can be sure under what terms or according to what standards.

Local government dynamics are critical to an understanding of China's fragmented energy governance. In China today, localities in high growth industrialized regions like the coastal provinces Zhejiang and Guangdong desperately need electricity. Local officials, long accustomed to operating in a bureaucratic system that for all its confusion has consistently emphasized the maximization of economic growth and consistently tolerated 'entrepreneurial' ways of achieving that goal, are the key players in power plant construction and operation. For example, the parent national energy corporations provide only about 25% of the capital required for new power plant investment. Much of the remainder comes in the form of loans from the municipal branches of state-owned banks. These banks in theory answer to a headquarters in Beijing, but in practice are likely to respond to the wishes of local governmental officials, partly because local officialdom exerts substantial control over personnel appointments within local bank branches. Another important source of capital is even more directly controlled by the locality. These are municipally-owned energy development corporations -- quasi-commercial investment agencies capitalized through various fees and informal taxes levied by local government.

Thus, regardless of formal ownership ties running up to the center, power plants built for the urgent purpose of meeting local demand are often built with locally-controlled financing. It should not be surprising, then, to find municipal governments providing construction approval to get the plants online as quickly as possible, while simultaneously shielding them from the need for further approvals from the center that might well require stricter technical, environmental, or fuel standards. Similarly, parent power firms and local governments will often break apart plant investment filings in an attempt to lower artificially the plant's recorded capacity and therefore avoid the need for central government approval. The fact that 110,000 MWe of installed capacity is 'illegal' means neither that the plants are hidden in a closet nor that they lack any governmental oversight. What it does mean is that they are not part of a coherent national policy, that they frequently operate outside national standards, and that they often evade control even by their ostensible owner at the national corporate level.

In this system, the lines of operational accountability and responsibility are often blurred. On the one hand, power plants that are supposed to be controlled by a parent national firm end up dealing with the parent at arms length. Some investment and working capital funds are provided by the parent to the plant, and some profits are returned upward. In accounting terms, the financial performance of the plant is subsumed within the integrated financial statement of the parent corporation. On the other hand, financing and project approval come primarily through local agencies that are intent on ensuring power delivery regardless of the commercial ramifications for the plant or the parent group. Thus, power plants can and do operate at a loss for years on end, further complicating incentives for plant managers. Indeed, because of the lack of clarity in the governance structure these operators sometimes themselves engage in creative financial and investment strategies. Central officials acknowledge that it is not unusual for power plants to operate sideline, off-the-books generating facilities, the profits from which can be hidden from the parent energy group and thus shielded from upward submission. As one Chinese government researcher recently observed, the electric power sector may be a big loss maker on the books, but people in the sector always seem to have a great deal of cash. Of course, the high rates of capacity increase mentioned earlier could not happen without local government compliance, if not outright encouragement. China's fastest growing cities are effectively pursuing a self-help approach to meeting their power needs, and they are abetted in this by blurred lines of governance and accountability.

Environmental Regulation.

Chinese environmental administration is also characterized by a pattern of de facto local governance. For example, the central government has established extensive legal restrictions on emissions of sulfur dioxide. The 1998 and 2000 amendments to China's Law on the Prevention and Control of Atmospheric Pollution set stringent national caps on total sulfur emissions and required coal-fired power plants to install pollution-reducing flue gas desulfurization systems[13]. To promote the utilization of these technologies, which add significantly to plant capital and operating costs, the central government imposed mandatory pollution emission fees on power plants. Yet today, the central government estimates that only about 5,300 MWe of capacity has been equipped with FGD, a small fraction of the total capacity subject to the anti-pollution laws. Another 8,000 MWe with FGD is currently under construction, but even once completed, the resulting total will still only equal about 5.4% of thermal capacity.[14] Even more troubling, researchers could only guess at how often the equipment is actually turned on.

Once again, the fragmented, *ad hoc* system of energy-related governance in large part explains how this could happen. Environmental policy at the national level is primarily the responsibility of the State Environmental Protection Agency (SEPA), a relatively weak organization, though one that has been gaining authority recently. But implementation and enforcement come under the authority of provincial and municipal-level arms of SEPA. As with the local bank branches, personnel appointments in these local environmental bureaus are for the most part controlled by local governmental officials rather than by the parent central agencies. If the locality's main goal is to achieve economic growth, and cheap electric power is needed to fuel that growth, then environmental enforcement will play a secondary role. Local environmental officials who take a different view are likely to run into career difficulties. Moreover, budget allocations for local environmental bureaus are very tight, so bureau officials are often forced to resort to self-help mechanisms of financing just to survive. To keep up staffing levels and ensure that their employees are paid, they must rely either on the collection of local pollution emission fees or on handouts from the local government. In practice, this translates into incentives for local environmental regulators either to allow emitters to pollute (as long as they compensate the local SEPA office with the payment of emission fees) or to accept payment from the local government in return for ignoring emissions entirely.

Within-the-fence generation.

In the fastest-growing and most power-hungry areas of China the self-help approach goes right down to the level of the industrial enterprises that account for so much of the growth in electricity demand. In provinces like Guangdong and Zhejiang, major industrial cities have grown up out of what only recently were small towns or villages. In the absence of adequate municipal or regional power infrastructure, large numbers of manufacturers in these areas have been installing their own diesel-fired generators. The diesel fuel is expensive, and the electricity is more costly than from a large coal-fired power plant. But the factories have little choice. Many of them are tightly integrated into global production networks and are scrambling to meet overseas demand for their products. They cannot afford to shut down for lack of power. Some of them operate sensitive production processes that do not tolerate power interruptions. The scale of such activities is considerable. In Zhejiang province, for example, it is estimated that 11,000 MWe is off-grid. China is now the world's largest market for industrial diesel generators, and the country's consumption of diesel fuel, much of it produced from imported crude, has climbed substantially. Generator manufacturers estimate that ten percent of China's total electric power consumption is supplied by these 'within-the-fence' units. Local officials have generally tolerated and in some cases actively supported such solutions, and environmental regulation of these diesel generators has lagged behind that of central station power plants.

The Path Forward: Coal versus Oil and Gas.

The complicated, fragmented governance of China's energy sector will also have a major bearing on one of the most important aspects of its future development: the relative roles of coal, on the one hand, and oil and natural gas, on the other. The vast scale of China's demand suggests that all economic energy sources, including nuclear power and renewables, will be used heavily. But in China, as in the world as a whole, fossil fuels will dominate the supply side for the foreseeable future. (China's ambitious plans for nuclear power underscore this point. If current plans come to fruition, and nuclear generating capacity is increased from its current level of about 9,000 MWe to 40,000 MWe by the year 2020, more nuclear plants will be built in China over the next 15 years than in any other country. But even then, nuclear energy will still only provide about 4% of China's generating capacity. Fossil-fired plants will account for much of the rest. [15])

The inevitable dominance of fossil fuels in China is not good news for the global climate. But the severity of the problem will depend on the proportions of oil, gas, and coal in China's future energy mix, and that is much less certain. In one scenario, China, like almost every country that has preceded it up the economic development ladder, will rapidly shift from reliance on solid fuels towards oil and gas, with gas playing an increasingly important role in electric power generation, in industrial and residential heating, and potentially also in transportation.

In an alternative scenario, China will remain heavily dependent on coal for electric power, for industrial heat, as a chemical feedstock, and increasingly, for transportation fuels, even as demand continues to grow rapidly in each of these sectors. The prospect of continued high oil and gas prices make the coal-intensive scenario more plausible today than it was during the era of cheap oil.

These two scenarios pose very different risks and benefits for China and for the rest of the world. For the Chinese, the heavy coal use scenario would have the merit of greater energy autonomy, given China's very extensive coal resources. It would also mean less Chinese pressure on world oil and gas markets. But the impact on the environment would be substantially greater, both locally and internationally. In the worst case, the heavy environmental toll inflicted by today's vast coal mining, shipping, and burning operations, already by far the world's largest, would grow much worse as China's use of coal doubled or even tripled over the next 25 years. More optimistically, China would become the world's largest market for advanced clean coal technologies, including gasification and liquefaction, and eventually also including carbon dioxide capture and storage. But these technologies will add considerably to the cost of coal use, and, in the case of carbon capture and sequestration, are unlikely to be deployable on a large scale for decades.

The high oil and gas use scenario would not prevent these problems, but it would make them more manageable. A modern gas-fired electric power plant is not only cleaner than its coal-fired counterpart, but also emits 70% less carbon dioxide per unit of electrical output. A petroleum-based transportation system emits only about half as much carbon dioxide per barrel as it would if the liquid fuels were produced from coal. But the high oil and gas scenario would also force China, with few resources of its own, to compete ever more aggressively for access to them around the world. In that case, the recent tensions with Japan over drilling in the East China Sea and the flurry of deal making in Iran, Africa, Central Asia, South America, and elsewhere may in retrospect come to seem like a period of calm before the storm.

Much is riding, therefore, on which of these scenarios China will follow more closely. There are already some indications of which way China will go. China's coal is for the most part located inland, far from the major energy consuming regions along the coast. So a clean-coal-based development strategy would require a national-scale energy infrastructure, with large-scale, technologically-advanced, highly efficient power plants and 'polygeneration' facilities (producing a mix of chemical products, liquid transportation fuels, hydrogen, and industrial heat as well as power) located in the coal-rich areas of the north and west, and linked to the coastal regions via long-distance, high-voltage transmission networks. But although numerous demonstration projects have been proposed or even in some cases started, both participants and other domestic advocates frequently express frustration at the slow pace of development and inconsistent government support for these efforts. Despite years of deliberation, many of the highest profile projects are still held up in the planning or early construction phases.

A major obstacle is that these clean-coal-based strategies require a strong central government role, centralized funding, and substantial cross-regional coordination, all of which are lacking in China's energy sector today. Instead, China's most-developed coastal regions, rather than waiting for a national strategy to emerge, are moving forward with their own solutions. Many municipalities are simply building conventional coal-fired power plants as fast as they can, often with subpar environmental controls. While they are willing to import coal from the poorer inland provinces, they are not willing to invest in the large-scale infrastructure that would make them dependent on electricity generated in those interior regions. It is commonly observed that in China everybody wants to generate power, and nobody wants to rely on others for it.

More developed provinces like Zhejiang and Guangdong, or provincial-level municipalities like Shanghai, under pressure to provide adequate power supplies but also facing growing demands by an increasingly sophisticated public for a better environment, recognize the need for cleaner approaches. However, these wealthier regions are investing not in clean coal, but rather in a burgeoning natural gas infrastructure, based mainly on liquefied natural gas (LNG) imports. In this, their interests coincide with those of the state petroleum companies, which have become significant investors in – and builders of – the infrastructure of port facilities, terminals, LNG regasification plants, pipelines and power plants, frequently partnering in these projects with the energy development arms of the municipalities and provinces. Since the viability of these investments depends on the availability of natural gas, the state petroleum companies have recently been focusing their overseas acquisition activities at least as much on gas as on oil. CNOOC's recent bid for Unocal, for example, was motivated as much or more by Unocal's natural gas reserves than by anything having to do with oil.

In effect, commercial and quasi-commercial interests at the local and national levels – almost always in cooperation with international investors – are moving China's coastal regions, if not China as a whole, down a natural gas-intensive path. Recent increases in the price of gas are playing a key role in these decisions, but that role is by no means straightforward. As noted previously, many of the key decision-makers – particularly those at the grass-roots level who are influencing national policy through 'fait accompli' commercial deals and investment programs – often simultaneously play the roles of policy designer, regulator, investor, commercial operator, and commercial fuel supplier. At times, their commercial stakes extend across the supply chain, from ownership of overseas fuel assets to management of shipping and logistics, investment in domestic port and infrastructural facilities and ownership of power generation. Thus, a given decision-maker may simultaneously view the prospect of higher-priced gas imports negatively from a regulatory perspective and positively in commercial terms.

In fact, more than any other players in the Chinese system, those who are participating in the gas and petroleum supply chains are the organizations with cash, commercial sophistication, links to global partners, access to global fuel supplies, and ready entrée to downstream infrastructure and major energy consumers. It is they who are making national energy policy, whether by design or – simply by virtue of the speed with which they are executing commercial strategies – by default. And none of them – not the national fuel and power firms nor the decision-makers in the leading coastal provinces – has much incentive to advocate advanced coal-based solutions or technologies. For the state petroleum firms, which increasingly see themselves as gas companies and hold substantial cash reserves, coal is a substitute for their products and the coal industry a competitor. Large-scale clean coal solutions are unlikely to be much more appealing to the national power companies, the nominal parents of most of China's coal-burning plants. Large-scale clean coal is associated with power generation at the mine mouth, which in turn is associated with control by the mining industry, and the power companies have little interest in yielding control of their industry to mining concerns

Finally, even though price will surely be important in the long run, powerful provincial and municipal governments along the industrialized coast, facing rapidly growing local power demand and able to draw on substantial investment resources to meet it, seem at present to be opting for dependence on foreigners for gas over dependence on interior provinces for coal. The Shanghai government last year banned the construction of new coal-fired plants, while at the same time working to build an LNG infrastructure. Some coastal municipalities have little choice but to rely on coal from the interior in the near term, though even here they maintain control over power generation through the exercise of financial and regulatory power, and by building new coal plants scaled to serve only local or intra-provincial needs. However, the real trend-setters over the long term, the richer and more advanced municipalities like Shanghai, are pursuing self-help on a grand scale by investing in natural gas infrastructure. In effect, they are tying themselves to overseas natural gas supplies while maintaining a regulatory and financial stake in the downstream gas infrastructure. As they partner in these projects with national energy companies, they become at once investors, producers, consumers, and regulators of the natural gas business. This is all done in lieu of national-scale advanced coal solutions which would remove from their control not only the fuel but the power generation business as well.

Conclusions

In light of this fragmented system of governance, what can the West expect of China in those aspects of its energy development that matter most to us? What, if anything, might be done to influence China's energy development in a favorable direction?

First, we should recognize that the Chinese government's capacity to achieve targets for reducing hydrocarbon consumption or pollutant releases, or Kyoto-like limits on greenhouse gas emissions, is in practice quite limited. Neither louder demands for compliance by outsiders nor escalating penalties for non-compliance are likely to yield the desired results. China's national leadership may eventually be prepared to enter into such agreements, but if so those undertakings should be understood primarily as aspirational. China's system of energy-related governance makes the fulfillment of international commitments problematic. Nevertheless, those commitments can serve as an important source of domestic leverage for leaders seeking to strengthen internal governance in the long run.

The Chinese central government's recently announced goal of increasing national energy efficiency by 20 percent over the next five years can be understood in analogous terms. Key actors within the central government have grown increasingly aware of China's energy vulnerabilities and of the urgent need for more sustainable utilization of energy resources. Public commitments to efficiency targets, by putting the central government's reputation on the line, suggest at the very least serious aspirations – probably a necessary condition for real change to occur, though by no means a sufficient one. The question now is whether, given the nature of governance obtaining across the system – vast decentralization, ambiguous boundaries between regulatory and commercial actors, and overriding norms of economic growth maximization – there exists systemic capacity to meet the center's aspirational goals.

Second, the authoritarian nature of the Chinese state does not mean that the state itself is internally coherent or effectively coordinated. Indeed, even with regard to the recent energy efficiency targets, substantial differences of opinion persist among various agencies and actors at the central level. One result of China's particular path of reform is that the boundaries between state and non-state, public and private, commercial and non-commercial, and central and local have all become blurred. China's increasingly deep integration into the global economy is even blurring the distinction between foreign and domestic. The Chinese energy companies are majority-owned by the state (though who actually represents the state is open to debate), but they also list on overseas stock exchanges, have foreigners among their corporate directors, and receive financing and guidance from international investment banks. As a practical matter, the number of actors exercising de facto decision-making power over energy outcomes in China is large, and they are not exclusively confined within China's borders. We should not reflexively invest the actions even of the ostensibly state-owned Chinese energy entities with geostrategic intent. Nor should we assume that those in the center who do think in terms of crafting a national energy policy actually can control the very large number of entities whose actions are often driving energy outcomes.

For those outside China who have a stake in the direction of China's energy development, the governance situation we have described here has both positive and negative implications. On the one hand, this is not a system that is capable of responding deftly to either domestic or international mandates, particularly when such mandates call for dramatic near-term change, and particularly when such change carries economic costs. Indeed, the response by subordinate officials to dictat from above is more likely to come in the form of distorted information reporting than actual changes in behavior. The response by local officials in the late 1990s to central mandates for closure of locally-owned coal mines – a response that generally involved keeping local mines open but ceasing to report output to national authorities – is indicative of how the system reacts to dictat. The many players, diffuse decision making authority, blurred regulatory and commercial interests, and considerable interest contestation in the energy sector combine to make dramatic, crisp changes highly unlikely. It is illusory to expect that the world's carbon problem can somehow be solved by wholesale changes in Chinese energy utilization trends.

On the other hand, this is also system in which players are emerging at every level who have a stake – whether political or commercial – in achieving more sustainable energy outcomes. That some central agencies have been able to establish more stringent national energy efficiency targets, that citizens in China's more advanced cities like Shanghai (a municipality with a per capita income comparable to Portugal's) are demanding cleaner air, and that domestic energy companies are positioning themselves commercially for an environmentally-constrained market are just some of the indicators of this. Although these players are not well coordinated, and often represent competing interests themselves, they are frequently looking outside, particularly to the advanced industrial economies, for guidance and models to emulate. Moreover, they are doing so in the context of a system that is highly integrated into the global economy, to the point that foreign commercial entities are often deeply involved in domestic decision making. This is particularly apparent with respect to corporate strategy (including the strategies of the state energy companies), investment preferences, and technology choices. In short, there may be significant opportunities, especially through commercial channels, for foreign involvement in China's pursuit of sustainable energy development.

Perhaps most important, for all its faults the Chinese system is highly experimental and flexible. Those entities that are seeking more sustainable energy solutions in many cases actually have the ability to pursue experimental projects, often on a large scale and often involving foreign players. For example, several municipalities, including Beijing itself, have taken advantage of aspects of the national Renewable Energy Law to establish cleaner, more efficient, large-scale biomass-fueled power plants. The specific terms of such projects – who pays for them, who designs and controls them, and so on – are always subject to ambiguity, negotiation, and ad hoc interpretation. This is, after all, a nation that has an institutional tolerance for "systems within systems" and a wide array of quasi-legal, gray area activities. Experiments on the sustainable energy front are certainly possible, and in some cases are beginning to happen. Those most likely to succeed will not be national in scale, but localized, replicable, and able to propagate to other localities. These experiments should also be consistent with trends in advanced economies, and indeed, should be supported by players from those economies.

China’s economic and commercial development is now so dependent on global integration that it will not be an outlier in terms of its energy system.

Finally, we should recognize that China’s energy system is in its own way as politically complex, fractured and unwieldy as our own. And we would be unwise to expect of the Chinese what we do not expect of ourselves.

Afterword: China and India Compared

India, with a population almost as large as that of China (1.1 billion compared with 1.32 billion) and with a similarly rapid rate of economic growth, will also be a major contributor to atmospheric carbon emissions. Like China, India has extensive coal reserves (see Figure 2.1), and it is the world's third largest coal producer after China and the United States. Coal use in India is growing rapidly, with the electric power sector accounting for a large share of new demand. However, India's per capita electricity consumption, at 600 kWe-hr/yr, is only 35% of China's, and its current rate of coal consumption (460 million tonnes in 2005) is about a fifth that of China.

India's total installed generating capacity in the utility sector in 2005 was 115,000 MWe, of which 67,000 MWe, or 58%, was coal-fired. Coal currently accounts for about 70% of total electricity generation. (The comparable figures in China were about 508,000 MWe of total installed capacity, with coal plants accounting for over 70% of installed capacity and about 80% of generation.) In India, as in China, self-generation by industry is also a significant source of coal demand.

A large fraction of future growth in the electricity sector will be coal-based. Current government plans project growth in coal consumption of about 6%/year.[16] At this rate, India's coal use would reach the current level of US coal consumption by about 2020, and would match current Chinese usage by about 2030. This suggests that there may be time to introduce cleaner, more efficient generating technologies before the greatest growth in coal use in the Indian power sector occurs.

Further information on India's patterns of coal use is provided in the Appendix to this chapter.

Appendix to Chapter 5

Introduction

India is the world's second most populated country, after China, with 1.1 billion people.[2] With its higher population growth rate, India is projected to equal China's predicted population of 1.45 billion people in 2030. India's economy, with a real growth rate of 7.8%, lags that of China, which has a real growth rate of 9.2%.[3] India also lags China in terms of electricity consumption with an average per capita consumption of 600 kW_e-h/yr, compared with China's 1700 kW_e-h/yr and about 14,000 kW_e-h/yr in the U.S..[4] India is also plagued by chronic electricity shortages. To address these problems, India has put in place policies to speed up generating capacity additions and growth in the power sector. The Indian central government plays a large role in electric sector development, presenting an opportunity for an effective single source of leadership.

Power Generation

Background: Until recently, India maintained a relatively closed economy and focused on indigenous or indigenized technologies. In the electricity sector the key players were the National Thermal Power Corporation (NTPC), the central government's power generation company, and Bharat Heavy Electricals Limited (BHEL), the primary boiler and steam turbine manufacturer and turn-key plant constructor. The central Government owned nuclear and hydroelectric plants and large thermal plants (NTPC) that supplied substantial electricity across state boundaries. The remainder of the Indian electricity sector was historically under the control of vertically-integrated State Electricity Boards (SEBs) which built, owned and operated the local electricity infrastructure (generation and distribution), and set rates and collected tariffs. In an effort to promote food production and increase the rate of agricultural growth in the late 1970's, farmers were

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[2] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, http://esa.un.org/unpp, 12 February 2006.

[3] "The World Factbook." CIA. <09 February 2006> Online: www.cia.gov/. GDP per capita is $3400 in India and $6200 in China in 2005 at purchasing power parity.

[4] BP statistical_review_full_report_workbook_2005. Based on gross output.
Population based on July 2005 data from CIA World Factbook. www.cia.gov

given free electricity for irrigation. The state-controlled SEBs used this and other related programs as a political instrument whereby the state governments could introduce subsidies for political gain. As a result of this and the lack of effective control over illegal connections to the grid, by the mid-1990s about 30% of the electricity produced was un-metered or not paid for. Even for the metered portion low tariffs were set for many poorer consumers and largely cross-subsidized by higher tariffs charged to commercial and industrial users. The gross subsidy per unit of electricity generated increased from 0.75 Rupees/kW_e-h (2 ¢/kW_e-h) in 1997 to 1.27 Rupees/kW_e-h (2.6 ¢/kW_e-h) in 2002.

The result was that many SEBs were effectively bankrupt, deeply indebted to the central government financing institution, and unable to honor payments to generators or to finance new capacity. This has been a primary root-cause of depressed growth in new generating capacity additions over the last 20 years and the resulting power shortages. Today, the unmet electricity demand is 7.6% and the peak demand deficit is 10%.[5] This does not take into account the fact that 40% of Indian households are not yet electrified or connected to the grid and rely primarily on biomass for their energy needs.[6]

In the mid-90s the Indian economy began to be opened up. To address the increasing electricity shortages the Indian government encouraged independent power production (IPPs). However, because of the poor financial state of the SEBs and their inability to pay for power purchased, most IPPs either failed or never materialized.

Today: India's installed generating capacity in the public or utility sector was 115,550 MW_e in 2005. Of this, coal generating capacity was 67,200 MW_e or 58% of total installed capacity. These plants accounted for almost 70% of India's electricity

[5] Ministry of Power, Government of India. Installed capacity of power stations on 31.12.2005. http://powermin.nic.in/JSP_SERVLETS/internal.jsp
[6] Dickel, Ralf. Head, Energy Diversification Division, International Energy Agency. "Coal and Electricity Supply Industries in India: Key Issues". Conference on Coal and Electricity in India,
New Delhi, India. 22 September 2003

generation (Figure 5.2). India's coal consumption was about 360 million tonnes in 2000 and increased to 460 million tonnes per annum in 2005 or an increase of about 5.5%/yr. Recently, total electricity generating capacity growth has averaged about 3.3% per year whereas the economy has been growing at over twice that rate; thus, the increasingly severe electricity shortages.

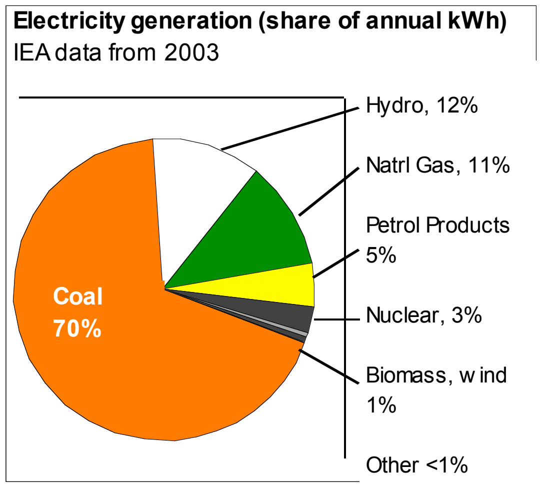

Figure 5.2 Share of India's Total Electricity Generation by Energy Source

In addition to the public or utility generating capacity, Indian companies have resorted to captive power to ensure the availability of consistent, quality power. Captive power generation is within-the-fence generation that provides the primary power needs of the facility and is not connected to the local grid. Indian captive power grew from 8.6 GW installed capacity in 1991 to 18.7 GW installed capacity in 2004.[7] [8] At this level it represents almost 25% of the public or utility thermal generating capacity in India. The fuel mix for captive power is about 45% coal, 40% diesel and 15% gas.

The Indian government, recognizing the problems inhibiting growth, began addressing them through policy reforms in the 1990s, culminating in the Electricity Act of 2003. This legislation mandated the establishment of electricity regulatory commissions at the state and central levels, and the development of a National Electricity Policy. Emphasis was placed on financial reforms and on unbundling the SEBs into separate generating,

[7] Shukla
[8] CEA. "general Review 2005".

transmission, and distribution companies. To date, eight of 28 states have unbundled.[9] The legislation opened the electricity sector to private generating and private distribution companies, gave increased flexibility to captive power generators, and gave open access to the grid.

The ability to meet electricity demand and to increase electricity supply will depend on the success of financial and economic reforms in the power sector. The payment structure to generators was reformed to create incentives for generating companies to improve plant efficiencies and to increase operating load factors. This, combined with the restructuring of the SEBs, had the purpose of improving the financial health of the sector to ensure payments to the generating companies and improve payment collection from consumers. This would attract more private sector development, particularly by IPPs.

During the 1990s the central sector, particularly NTPC, began to play a larger role. It developed an engineering center that successfully improved plant operating factors and efficiency and began to offer engineering services to the SEB-operated plants. These activities helped improve plant performance and during this period the all-India average plant operating load factor increased from 64% in 1997 to almost 75% in 2005. This load factor improvement has been responsible for about half of the power generation growth that India achieved during this period. Economic incentives to improve plant efficiency are sufficiently recent that the all-India effect is still small. Operating efficiency improvements are harder to achieve than improvements in plant load factor.

The Electricity Act of 2003 mandated the development of a National Electricity Policy and a Plan for achieving it. These were developed by mid-2005. The National Electricity Policy calls for (a) eliminating general and peak shortages by 2012 so that demand is fully met, (b) achieving a per capita electricity consumption increase to over

[9] "Power Sector Reforms". Ministry of Power, Government of India. http://powermin.nic.in/indian_electricity_scenario/reforms_introduction.htm. Accessed 13 February 2006.

1000 kW_e-h by 2012, (c) providing access to electricity for all households, (d) strengthening the national grid and distribution systems, and (e) metering and appropriately charging for all electricity generated.

The Plan for achieving these goals calls for doubling installed generating capacity from 100,000 MW_e in 2002 to 200,000 MW_e by 2012. The goal is to meet all demand and create a spinning reserve of at least 5%. The Planning Commission's Expert Committee on Integrated Energy Policy has recommended an energy growth rate of 8%/yr to ensure continuing economic development. This would require that installed capacity increase from 115 GW_e in 2005 to 780 GW_e in 2030 and that coal consumption increase from 460 million tonnes/yr in 2005 to about 2,000 million tonnes/yr in 2030.[10] The Plan also calls for: (a) gas-based generation to be sited near major load centers, (b) new coal plants to be sited either at the pit-head of open-cast mines or at major port locations which can easily import coal, (c) thermal plant size to be increased to the 800-1000 MW_e size and (d) a shift to supercritical generating technology.

India's new capacity additions are primarily the joint responsibility of the central and state sectors, and to a lesser degree, the private sector. The process of capacity addition begins with the Central Electricity Agency (CEA), which collects and analyzes historical and annual operating data, makes forward projections of demand (both national and local) and develops recommendations of new capacity additions including fuel mix, size, and location of plants to meet these needs. These recommendations form the basis for discussions among the various players of how to meet the increased demand.

It is clear that NTPC is playing a larger role than it has in the past because it has met its capacity addition commitments and improved plant performance effectively, whereas the SEBs have routinely fallen far short of meeting their capacity addition commitments and have frequently had the lowest operating efficiency plants in the system. The worst of

[10] "Draft Report of the Expert Committee on Integrated Energy Policy". Planning Commission, Government of India. New Delhi, December 2005. http://planningcommission.nic.in/reports/genrep/intengpol.pdf

these plants have been handed over to NTPC to operate. Currently over 90 % of the installed coal capacity in India is under 250 MW_e, and all use plants use subcritical technology. NTPC has built and operates most of the 500 MW_e plants in India. NTPC currently has an effective in-house technology capability which it is further strengthening and it is greatly expanding its technology center. It has the lead on the introduction of supercritical generating technology into India and has the financial resources to build 800-1000 MW_e plants. It currently owns and operates about 32% of installed coal capacity, [11] but is destined to play a much larger role in the future.

Our assessment of the Electrification Plan is that it adequately addresses the most important problems in the Indian electricity sector. However, the most critical question is, "Can it be successfully implemented?" This is more problematic, in that the Indian bureaucracy offers many roadblocks. Coal supply is one of the most important issues, and the rate of coal industry reform will be critical.

The view from the state of Andre Pradesh (AP) offers some insight into these issues. AP unbundled its SEB about two years ago and is well into the new structure. Our discussions with the AP Environmental Protection Department, the AP Electricity Regulatory Commission, the AP GenCo, and the AP distribution company all provided a consistent understanding of the National Electrification Plan and how AP was addressing it. Such a high level of alignment is encouraging.

AP is involved in planning a couple of large generating plants, one potentially at mine mouth and one in the port city of Chennai. Negotiations are between APGenCo and NTPC. The distribution company has reduced the extent of un-metered electricity to about 20% (confirmed by the AP Electricity Commission) and has plans to further reduce it. They are installing meters at a rapid pace with the target of being fully metered by 2012 AP also has a couple of IPPs which are being paid for all the electricity they produce. In a state with a SEB in worse financial shape the story would not be as good.

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[11] Ministry of Power, Government of India. Installed capacity of power stations on 31.12.2005. http://powermin.nic.in/generation/generation_state_wise.htm

Coal-Generating Technology and CO_2

As already noted, India's PC power generation sector employs only subcritical technology. Coal is India's largest indigenous fuel resource and it has a reserves-to-production ratio of about 230 years at today's production level. To use this resource most wisely and to reduce CO_2 emissions, higher generating efficiency technology is important. NTPC is now constructing the first supercritical pulverized coal power plant in India and has plans for several additional units. The technology is being supplied by a foreign equipment manufacturer. To remain competitive the national equipment manufacturer, BHEL, has entered into an agreement to license supercritical technology from a different international equipment manufacturer. This competition should serve to reduce the costs and make it more feasible politically for Indian generating companies to build supercritical plants in the future. Ultimately, by constructing only supercritical PC power plants, CO_2 emissions could be reduced by one billion tonnes between 2005 to 2025 based on projected capacity adds.[17]

Integrated gasification combined cycle (IGCC) technology is a more distant option that requires development for India's high-ash coal. NTPC, in coordination with the Ministry of Power India, is planning to build a 100 MW_e demonstration plant either with a foreign technology or with BHEL-developed technology. One issue is that the more-proven foreign entrained-bed gasifier technology is not optimum for high-ash Indian coal. BHEL's fluid-bed gasifier is much better suited to handle high-ash Indian coal but needs further development. BHEL has a 6MW pilot plant which it has used for research. This represents an opportunity to develop a gasifier applicable to high ash coals the adds to the range of IGCC technology options.

Conclusion

India's economic development lags that of China and its power development lags even further. However, India's economic growth is likely to continue and further accelerate over time. This will require rapid growth in electricity generation, and a large fraction of this will be coal-based. This offers opportunities with respect to India in that there is time to institutionalize cleaner, more efficient generating technologies before the greatest growth in the Indian power sector occurs.

Recently, the central sector (NTPC) has successfully met its expanded capacity addition targets, has opened a power plant efficiency center, developed technology capabilities to improve plant operating factor and efficiency, is pursuing IGCC technology, and is markedly expanding its technology center. This offers the possibility for an Indian power generation sector company to develop and disseminate technology, and create standards and practices, and to be a factor in the rational development of the needed generating capacity.

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1 IEA, *World Energy Outlook* 2004, p.34.

2 Wei Yiming, Han Zhiyong, Fan Ying, Wu Gang (eds.). 2006. *China Energy Report (2006)*. Beijing, China: Science Press. (Zhongguo Nengyuan Baogao: Zhanlue yu zhengce yanjiu (2006), Beijing: Kexue Chubanshe).

3 Pu Hongjiu, Lu Yanchang, Lu Yaohua, Zhou Xiaoqian (eds.). 2004. *China Electric Power and Coal*. Beijing: Coal Industry Press. Zhongguo dianli yu meitan. Beijing: Meitanqiye Chubanshe. P. 309.

4 National Bureau of Statistics. 2005. *China's Economy and Trade Yearbook*. Beijing: China Economy and Trade Yearbook Press. p .99; UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP). June, 2004. "Toward a Sustainable Coal Sector in China", p. 4.

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http://www.sp-china.com/news/powernews/200605110002.htm.

6 State Council Information Office. June 8, 2006. http://www.gov.cn/xwfb/2006-06/08/content_303550.htm

7 National Bureau of Statistics. 2004. *China Energy Statistical Yearbook*. Beijing: China Statistics Press. p. 183.

8 National Bureau of Statistics. 2004. *China Energy Statistical Yearbook*. Beijing: China Statistics Press. p. 183.

9 National Bureau of Statistics. 2004. *China Energy Statistical Yearbook*. Beijing: China Statistics Press. pp. 34, 158.

10 National Bureau of Statistics. 2003. *China City Statistical Yearbook*. Beijing: China Statistics Press, p. 307.

11 Richard Morgenstern, *et. al.* "Emissions Trading to Improve Air Quality in an Industrial City in the People's Republic of China". Resources for the Future Discussion Paper 04-16. April 2004. p.6.

[12] A 2005 Merrill Lynch report estimated the corresponding figure at 80-140 GWe (China Daily,"Illegal Power Plants to be Cracked Down". February 15, 2005. http://www.chinadaily.com.cn/english/doc/2005-02/15/content_416510.htm.)

[13] Richard Morgenstern, *et. al.* "Emissions Trading to Improve Air Quality in an Industrial City in the People's Republic of China". Resources for the Future Discussion Paper 04-16. April 2004. p.15.

[14] National Bureau of Statistics. 2005. *China's Economy and Trade Yearbook*. Beijing: China Economy and Trade Yearbook Press. p .102.

[15] Ma Kai (ed.) *Strategic Research on the Eleventh Five-Year Plan*. Beijing: Beijing China Science Technology Press. October 2005. "Shiyiwu" guihua: Zhanlueyanjiu. Beijing: Beijing kexiejishu chubanshe.

[16] "Draft Report of the Expert Committee on Integrated Energy Policy". Planning Commission, Government of India. New Delhi, December 2005. http://plannningcommission.nic.in/reports/genrep/intengpol.pdf.

[17] Emissions forecasts from IEA.