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World bank energy projects in China: influences on environmental protection

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Abstract

A study of the World Bank's energy-related project portfolio in China reveals several areas where World Bank assistance has clearly influenced broader trends in energy and environmental protection in China. This paper reviews the World Bank's 36 energy-related projects approved from 1984 to 1999 in the context of these broader trends. Projects helped accelerate development of large-scale efficient coal power plants, hydropower, state-of-the-art technologies for controlling power-plant emissions, and international-best-practice environmental assessments of energy projects. The World Bank has just begun to fund several promising initiatives for energy efficiency and renewable energy. At the same time, some opportunities for the Chinese government and the World Bank to jointly promote environmentally sounder energy development are only just now being addressed, such as natural gas distribution and utilization, rural energy and development, wind power, energy efficiency of heat supply and buildings, energy efficiency in industry through performance contracting, and greater support for clean energy options within ongoing electric power sector reform.

Keywords: Electric power; Air pollution; Energy efficiency; Multilateral assistance strategies

1. Introduction

China has borrowed the most money from the World Bank for energy projects of any country in the world. From 1984 to 1999, the World Bank provided about $7 billion for 36 energy-related projects, and the Global Environment Facility provided an additional $90 million in co-financing for energy efficiency and renewable energy projects.[1] How has this assistance helped China address pressing energy and environmental problems? How has it not? What have been the main influences of this assistance on environmental policies, energy technologies, and direct environmental emissions in China? To answer these questions, this paper presents a framework of 15 important strategies for reducing the environmental consequences of energy use in China, and analyzes the historical influence of World Bank assistance within each of these 15 strategies.

The findings presented here are based on a review of the World Bank's energy-related project portfolio in China carried out in 1998 and 1999 by the Operations Evaluation Department of the World Bank. The author served as a consultant for that evaluation. During that period, the author conducted interviews with approximately 80 people, including World Bank staff, Chinese government officials, utility managers, private-firm managers, project personnel, academic researchers, representatives of other donor agencies, and representatives of non-governmental organizations.[2] This paper provides a summary of the author's findings. The views expressed are strictly those of the author and do not necessarily reflect the views of the World Bank or the Chinese government.

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[1] The Global Environment Facility has also provided $38 million in grants for energy efficiency and renewable energy projects in China through the United Nations Development Program. See Martinot and McDoom (2000).

[2] Chinese interviews took place in six cities (Beijing, Chengdu, Shanghai, Hangzhou, Wuxi, and Yantai) during September 1999.

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2. Energy and environment in China

China has had double-digit rates of economic growth for much of the past two decades. This growth has had huge implications for energy consumption and environmental impacts. For example, with growing income and affluence, urban households are dramatically increasing their material consumption — and demand for energy (Ikels, 1996). The total stock of refrigerators went from 4 million in 1985 to 60 million in 1996 and refrigerators now account for half of residential energy consumption. Energy consumption in the residential sector grew by 16 percent annually on average from 1980 to 1994 (UNDP, 1997). Air conditioners are now becoming ubiquitous in urban areas as well. Private automobile ownership, at one time illegal, grew to 4 million in 1996 and is now rising by an estimated one million cars annually (Walsh, 2000; World Bank, 1998b). The environmental consequences of this economic growth are staggering, as accelerating air and water pollution threaten public health, damage ecosystems, and add to global climate change (Bardeen, 1995; Ryan and Flavin, 1995; Kam, 1996; Byrne *et al*., 1996; Smil, 1997; World Bank, 1997c; Lin, 1998).

Even so, China has been praised by many for expanding its economy while restraining the growth of energy consumption. While the economy grew by an average rate of 12 percent/year from 1980 to 1995, primary energy consumption only grew by an average of about 4 percent/year during the same period — an unprecedented situation for a developing country. Energy consumption in 1995 would have been 2.2 times greater had the economy consumed energy at the same intensity in 1995 as it did in 1977, according to Sinton and Levine (1998).[3] This situation has been attributed to policies directed at energy efficiency, particularly reductions in industrial sectoral intensities (Levine *et al*., 1992; Yang *et al*., 1994; Zhang, 1995; World Bank, 1997a; Sinton and Levine, 1998). It has also resulted from a concerted drive away from central planning and towards a market economy, which has raised energy prices (often within a two-tier system of co-existing "state prices" and "market prices") and forced enterprises to begin to think about profitability and cost-minimization like never before (Hamburger, 1995; Cao *et al*., 1997; Morita and Zaiki, 1998).

Energy efficiency in industry and power production remain the highest priority in continuing to reduce the energy intensity of the economy, although energy efficiency in the residential and transport sectors becomes more important with each passing year. In 1995, industry accounted for 75 percent of electricity use, agriculture for 6 percent, residential consumers for 10 percent, municipal and commercial consumers for 7 percent, and transport and communications for 2 percent (World Bank, 1997a).

Many have looked at China's large dependence on coal — coal provides 75 percent of China's total primary energy consumption — and proposed alternative energy solutions that would be more environmentally sound (Lenssen, 1993; Johnson, 1995; Wu and Li, 1995; China State Council, 1996; Martinot *et al*., 1997; Chandler *et al*., 1998; Logan and Zhang, 1998). Indeed, other energy forms are entering the picture, including oil, natural gas, wind power and other renewable energy sources. Still, coal remains among the cheapest forms of energy in most parts of China. Coal prices have historically been distorted due to explicit and implicit subsidies for coal mining and rail transport of coal — but price increases in conjunction with the transition away from central planning and towards a market economy have begun to alter the picture (Yang *et al*., 1994; Cao *et al*., 1997).

The power sector in China has featured prominently in China's modernization drive over the past two decades, and China has become the second largest producer of electricity in the world. Electric power production increased by an average of 8 percent/year from 1980 to 1995 (World Bank, 1998b).[4] Three-quarters of that production comes from burning coal. Older coal plants (especially pre-1990) often use coal relatively high in sulfur content and lack end-of-pipe pollution abatement equipment. The remaining 25 percent of power comes from hydropower, with continuing efforts are underway to develop hydropower — most notably now with the massive and controversial Three Gorges project (Chau, 1995; Chinese Academy of Sciences, 1995; Lu, 1996). The need for investment in the power sector has consumed Chinese officials' priorities, and they have turned to foreign sources, including foreign multinational firms and multilateral assistance agencies like the World Bank (Blackman and Wu, 1998; Murray *et al*., 1999; World Bank, 2000).[5]

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[3] Sinton and Levine (1998) note that contrary to many claims, decreases in sectoral energy intensities (energy per unit of economic output in a specific sector) were much more important than structural change (shifts in the sectoral shares of total output) in the decline in overall energy intensity (energy per unit of GDP).

[4] This rapid growth rate has faltered in the late 1990s. In 1998, electric power production growth was reportedly only 2.6 percent (World Bank, 2000).

[5] The decrease in electric power demand growth in 1998–2000 has led to a drop in coal use during this period.

3. World bank energy-related assistance to China

China has sought international assistance to help with its drive towards modernization and with the energy development and environmental challenges mentioned above. During the early 1980s, the World Bank was called upon to help promote China's reintegration with the global economy following years of isolation. China tapped the technical expertise and financial resources of the Bank and exposed officials to international practices for project evaluation and preparation, such as financing and competitive bidding and procurement procedures. "By the end of the 1980s, China had, to a large extent, exposed successfully its already well-trained and disciplined manpower to the technology and knowledge available outside its borders" concluded the Bank's recent country assistance strategy for China.

From 1984 to 1999, the World Bank approved 36 energy-related investment projects in China, most of these focused on the power sector:

- 12 coal-fired power plant projects.[6]
- 11 hydropower projects.
- 4 energy efficiency projects (efficient boilers, energy-service companies, fertilizer plants).
- 3 urban environment projects with district heat-supply components.
- 2 power transmission projects.
- 2 industrial pollution control projects.
- 1 natural gas development project.
- 1 renewable energy project (wind power and off-grid solar photovoltaics).

Total Bank lending has been $3.5 billion for coal power plants, $2.7 billion for hydro projects, $430 million for the stand-alone energy efficiency projects, and $100 million for the one renewable energy project.[7] The Bank has also leveraged $90 million total in co-financing grant contributions from the Global Environment Facility for the two most recent energy efficiency projects and for the renewable energy project.[8]

World Bank energy lending consistently draws public controversy. Three of the main public criticisms of the bank's power sector work in China contend that there should have been: (i) more end-use energy efficiency relative to supply expansion (i.e., demand-side management), (ii) more emphasis on "integrated resources planning" to consider energy supply and demand in an integrated fashion; and (iii) more consideration of alternative fuels and technologies for reducing environmental impacts of energy production and use. Some of the biggest criticisms of the Bank's activities in the power sector in China have come from international environmental advocates, who have severely chastised the Bank for lending so much for "dirty" coal-fired power plants (Flavin, 1997; Institute for Policy Studies, 1998).

One of the Bank's standard responses to such criticism is that half of its energy lending in China has been for hydroelectricity.[9] Regarding the other half for coal, a typical response by Bank managers is that "the Chinese will use coal no matter what we do; we have helped the Chinese to greatly improve the efficiency of coal utilization, thereby reducing the environmental impacts of coal use — primarily through larger and more efficient power plants and advanced technologies". One Chinese official echoed this idea: "The World Bank has greatly contributed to the development of the power sector by helping us utilize advanced and efficient technology". Another said "the project mix selected (coal vs. hydro) was not the Bank's problem .... The Chinese government

[6] The 23 power-plant projects (12 coal and 11 hydro) represent installed capacity of roughly 19 GW. About half of this capacity is coal and half is hydro. Total installed electric capacity in China was 254 GW in 1997.

[7] The total cost of these projects is much greater than these figures, as substantial co-financing by the Chinese government, and other domestic and international investors exists in the majority of projects. For example, the total cost of the 1999 renewable energy project is $444 million, with $100 million from the World Bank, $35 million from the GEF, $112 million from domestic commercial banks and other international financial institutions, and the remainder from domestic companies and power utilities (World Bank, 1999); the total cost of the 1997 Waigaoqiao thermal power project is $1.9 billion, with $400 million from the World Bank (World Bank, 1997b).

[8] In the 1990s, the Chinese government and the World Bank also sought policy changes in the energy sector. Among the policy and reform goals of the Bank's assistance to China have been to enact and implement a National Electricity Law (passed in 1995); to further commercialize and corporatize operating entities and competition among them; to assist regional and provincial power companies in transition to autonomous business-oriented entities; to promote privately financed infrastructure projects outside of just the southern provinces; and to adjust power tariffs to reflect long-run marginal costs of production countrywide so that long-run costs are more fully covered from revenues (ESMAP, 1993; World Bank, 1994; World Bank, 1995; Shao *et al.*, 1997). This paper does not consider the results of these policy dialogues and reforms. The subject of how energy-sector reform and restructuring have affected environmental impacts and energy technology choice around the globe is an extremely complex subject with unfortunately very few definitive lessons or studies yet produced for developing countries (USAID, 1998; Kozloff, 1998; Hirsh & Serchuk, 1999).

[9] Serious environmental and social impacts of hydroelectricity development have also been the subject of harsh criticism of the Bank historically (Rich, 1993). Such impacts are not included in this review. See World Bank (1998a) for an evaluation by the Operations Evaluation Department of hydropower resettlement for two projects. In general, the Bank appears to be moving away from financing large hydropower projects where resettlement is an issue, towards micro- and mini-hydropower for off-grid rural development.

decided what it wanted the Bank's money for, both as a source of capital and as a way to attract other foreign investment".

The projects have also been justified on least-cost grounds. Chinese power planning institutes have used analytical models to develop least-cost power development strategies — what types of power plants and in what sequence represent a least-cost path to meeting expected future power needs in a particular province. The Chinese have provided the results of these models as justification for various power projects put forth for Bank assistance, and the Bank has generally agreed to the conclusions of the models. A 1995 Bank study on China's coal and electricity sector said that "the substantive conclusions of the study have also helped support the Bank's lending programs to China.... All the power sector projects in the bank's lending program were selected as part of the least cost strategy in the medium demand scenarios" (World Bank, 1995, p. 45). But "least-cost" decision-making has generally ignored the costs associated with air pollution and other environmental impacts.[10]

Perhaps the Bank could have been more proactive in taking a strategic point of view in the energy sector, said other Chinese interviewed. "The Bank has just been a seller of goods [requested by the government]" said one. "The Bank should rethink its assistance and reorient its thinking from a strategic point of view.... For example, the Bank could have provided more assistance for planning and use of natural gas and coal-bed methane resources". In turn, Bank staff point to a long-standing dialogue with the Chinese on promoting natural gas, energy efficiency and renewable energy, and say that much of this effort is just now paying off as Chinese government priorities are shifting to consider environmental protection much more seriously than in the past.

For example, an energy conservation study and a major GEF-financed greenhouse-gas emissions control study in 1994 led to new dialogue between the Bank and China on energy efficiency and renewable energy (World Bank, 1993; NEPA *et al*., 1994). This dialogue resulted in a country strategy for stand-alone energy efficiency and renewable energy projects, three of which are now being implemented (World Bank, 1996b, 1998c, 1999). The availability of GEF grants strongly influenced the Chinese willingness to pursue these types of Bank activities, according to interviewees. Before the greenhouse-gas study and availability of GEF grants, the Chinese had earlier rejected the notion of loans for energy efficiency and renewable energy, partly because of the perceived technological and institutional risks. The renewable energy project has also been facilitated by more recent studies on renewable energy applications for both rural and on-grid applications in China (ESMAP, 1996; World Bank, 1996a; Taylor and Bogach, 1998).

Other so-called "sector work" has also been a strong and important aspect of the Bank's involvement in the Chinese energy sector. The Bank has completed with the Chinese a total of 14 energy-related sectoral studies, as well as two workshops and several discussion and policy working papers. This volume of intellectual work has been much greater for China than for any other recipient of World Bank assistance. Chinese nationals have been major participants and managers of the sector work, which has enhanced uptake and ownership. In general, many interviewees believed the sector work has facilitated Chinese interest in and commitment to new environmentally preferable strategies for energy sector development, and strengthened the ability of Chinese scientists and policy-makers to push for new environmental strategies in the energy sector.

The question of Bank assistance for the power sector in the future is still important, but perhaps less so than in the past, at least in terms of direct provision of capital. As China's domestic financial sector has strengthened, private-sector financing has grown in recent years. Foreign direct investment, prohibited until just a few years ago, reached $40 billion in 1999 for all sectors (UNCTAD, 2000). "We don't need the Bank's money [now]; we can get domestic loans for 6 percent and electric power capacity is in balance" said one official.[11] In the 1980s the Bank's money was important for attracting foreign investment to China. By the late 1990s, it had become less so. For example, by 1998, private investment in power development was approaching an installed capacity of 26 GW (operational or under construction), more than the total from all the Bank's previous assistance (World Bank, 2000).

4. Environmental protection in China's energy sector and influences of the World Bank

This section outlines 15 key strategies for reducing the environmental impacts associated with the energy sector (summarized in Table 1), and considers how World Bank energy-related projects have had an influence in each of these areas.

[10] Analytical models increasingly provide analyses of the environmental impacts and costs of different options, but such costs have historically not been incorporated into economic decision making.

[11] Nevertheless, domestic loans are usually only available for shorter periods, like 5–7 years, whereas Bank loans are available for up to 20 years.

Table 1
Fifteen key strategies for environmental protection in China's energy sector

1.	Construct large-scale efficient coal power plants
2.	Locate coal power plants at the mine mouth
3.	Construct hydropower plants
4.	Retire smaller, less-efficient power plants
5.	Wash coal at the mine before transport
6.	Install high-efficiency electrostatic precipitators, flue–gas desulfurization and low-NO_x burners in power plants
7.	Set and enforce quantitative emissions targets (by plant, city or province)
8.	Develop advanced "clean coal" technologies for power plants
9.	Expand natural-gas production and imports
10.	Construct gas-fired power plants and gas-distribution systems
11.	Make industrial energy-efficiency improvements
12.	Promote performance contracting as a commercial model for energy efficiency
13.	Construct wind power plants
14.	Promote the use of photovoltaic, small hydro, wind and biomass technologies in rural areas
15.	Construct cogeneration and district heating systems

4.1. Construct large-scale efficient coal power plants

Coal-fired electricity generation in China is still based on relatively small, less efficient and more polluting power plants relative to plants in other countries that utilize coal. More efficient utilization of coal for power generation has become one of China's priorities, particularly with the rapid growth of small coal-fired power plants in unit sizes of 50 MW or less. Compared with a large state-of-the-art plant, these small plants consume up to 60 percent more coal per unit of electricity produced, resulting in higher sulfur dioxide emissions. Particulate emissions from the small plants are proportionally even higher due to use of inefficient particulate control technology. Although China's current power development program emphasizes addition of 300- and 600-MW units, over one half of China's thermal power capacity was sized below 200 MW in 1995. Only about 12 percent of the total installed capacity was in units of 300 MW or more, compared to typically 60–80 percent in industrialized countries. In the mid-1990s, local governments continued to invest in large numbers of new small plants, largely due to difficulties in mobilizing the necessary investment resources for financing larger ones (World Bank, 1997a).

The review suggests that the Bank has successfully accelerated development of the market for large-scale efficient coal power plants over the past 15 years. For example, a project completion report for one plant completed in the early 1990s stated: "the project provided a fully integrated state-of-the-art 600-MW coal-fired unit that set technical and economic performance standards for a series of same size units that were subsequently installed in China .... This was the first such unit designed, constructed and operated by [the local power utility] and only the third in China. As such, it represented a remarkable technical achievement".

The Bank's projects gave domestic manufacturers additional motivation and urgency to develop these technologies themselves. A number of Chinese boiler manufacturers are now producing 600-MW units with almost comparable performance and quality to international models. These technology development efforts have included technology transfers from foreign manufacturers, involvement in Bank-financed projects, and active promotion by government. Large-scale (300- and 600-MW) coal units can now be considered "mainstream" and recent Chinese policies to limit development of smaller-size plants can be linked to this 15-year development trend. For example, in the next few years, the State Power Corporation plans to limit further investment in units less than 300 MW, according to one official. The Bank has also been among the first to finance high-efficiency 'supercritical' coal power plants, notably a 900-MW unit in Shanghai, which will be the first supercritical unit of that size in China.[12]

4.2. Locate coal power plants at the mine mouth

Most of China's coal exists in deposits in the Northern part of the country, while demand for coal exists along the southern coastal provinces. Thus China has suffered from coal transportation capacity shortages as huge volumes of coal are transported southward. The situation has led planners to embark upon a "mine-mouth" coal development strategy, in which power plants are constructed at the coal mine, and electric power transmission lines are constructed to urban demand centers (World Bank, 1995).

The Bank has financed one mine-mouth coal-fired power plant (in Inner Mongolia) and two projects that construct electric power transmission lines from coal producing areas. These projects reduce air pollution in the urban areas where electric power is consumed (at the expense of greater air pollution at the coal mine) and ease the burden on rail transportation systems for coal. One of the electric power transmission projects has been completed. The completion report stated: "On the whole, the accomplishments of the project have played a positive role in developing and utilizing coal resources, promoting construction of mine-mouth power stations, mitigating the power supply shortage in East China, and promoting industrial production and regional economic development". However, there has been no significant

[12] There are two existing supercritical power plants in China, one with 300- and one with 600-MW units.

"mainstreaming" trend within China for these types of plants.

4.3. Construct hydropower plants

Hydropower projects have long been a priority for the Chinese government, despite the need to resettle large numbers of local residents from reservoir sites. From 1984 to 1997, 34 GW of new hydro capacity was brought on-line (China Electric Power Information Center, 1998). Since the early 1990s, the massive Three Gorges project has captivated international attention due to its sheer scale (18 GW in total) and the number of people expected to be resettled — estimated at 1 to 2 million (Chinese Academy of Sciences, 1995; Chau, 1995). Still, the share of hydropower in China's overall energy mix has been steadily declining as coal-fired capacity has expanded faster than hydro capacity.

The bank provided China with needed foreign exchange for hydropower development starting in 1984, and about 10 GW of hydro capacity has been financed by the Bank (including pumped storage facilities), or about 30 percent of the total increment during that period. Without this foreign exchange, the Chinese would likely have developed more thermal power and less hydropower, according to several interviewees. In recent years, however, Chinese willingness to borrow from the Bank for hydropower has diminished, as China's resources and attention have turned to the Three Gorges project, in which the Bank is not participating. Nevertheless, additional mini-hydropower and pumped storage projects are being developed with the Bank.

4.4. Retire smaller less-efficient power plants

The Chinese government, placing more emphasis on environmental protection in recent years, has begun to emphasize larger, more-efficient power plants. In the 1990s, rapid expansion of power demand made it difficult to consider retirement of smaller, dirtier plants because severe power deficits remained in most provinces. By the late 1990s, however, power surpluses were beginning to appear and shortages became less acute. Enabled by these conditions, in 1999 the government made a decision to retire all small power plants less than 50 MW in size by 2002.

The national electric power utility and provincial power utilities have made efforts to close down their smaller units and some have managed to do so. But the majority of smaller plants are owned by municipal governments, who generally want to continue to operate the plants because they are cheap to run — prevailing power tariff structures make electricity from these plants "cheaper" to produce than power from newer, more efficient plants, and pollution emissions fines for these dirtier plants are usually left uncollected or simply result in "pocket to pocket" transfers of funds within the same government. The central government and national utility have so far had difficulty enforcing any requirements for small plant retirements, said some officials.

Bank staff have claimed that the large units financed by the Bank have allowed retirement of smaller, less-efficient power plants. But no Bank projects have explicitly specified or required small plant retirements. Nevertheless, small plant retirements are starting to occur in some provinces as indirect effects of the capacity additions of the past several years and the recent decline in electric power demand growth. Some provincial utilities where Bank projects are taking place appear serious about these retirements. For example, most of the smaller plants owned by the Shanghai municipal electric power company (about 360 MW total) were retired from 1993–1999 — although a much larger number of small plants owned by the Shanghai government are still operating. The government is seeking ways to enforce mandated retirements among municipal governments, and the Bank has started to provide technical assistance for this purpose.

4.5. Wash coal at the mine before transport

Coal washing at the mine before it is transported can result in reduced transport energy consumption and more efficient combustion at the power plant. There are other environmental impacts of coal washing, however, as large volumes of water are needed and water treatment of run-off can be an issue. The bank has not addressed this issue in any lending operations, nor has it attempted to assist with coal-sector policy reforms that would promote the general practice of coal-washing at mine mouth. Partly this was because the Chinese didn't want to borrow from the Bank in the coal sector. Said one former Bank manager, recalling the 1980s: "We tried to work with the coal sector…. The coal sector didn't want to import technology…. In the early years if you didn't earn foreign exchange [in China] you couldn't borrow it…. This was an obstacle to lending [to the coal sector]".

The Bank's ongoing sector work may produce some influence on coal washing in the future. In reviewing the 1995 coal and electricity system study, a conference report concluded: "By recommending least-cost strategies, the modeling effort feeds into a policy dialogue with the Government of China to identify and remove institutional barriers and price distortions that may stand in the way of the free market adopting these optimal solutions. For instance, coal washing has long been held back by a host of problems. Coal price reform, longer-term contracting, environmental regulation and taxation of pollution all would encourage enterprises to produce and buy washed coal" (World Bank, 1995, p. 45).

4.6. Install high-efficiency electrostatic precipitators, flue–gas desulfurization, and low-NO_X burners in existing and new power plants

In large- and medium-scale plants, China has made substantial progress in controlling particulate emissions through deployment of electrostatic precipitators (ESPs). For controlling sulfur dioxide emissions, China is just beginning to employ flue–gas desulfurization (FGD) in areas with especially poor air quality. In some regions (i.e., the southwest), thermal power plants often burn coal of over 4 percent sulfur content (e.g., 5–10 times the level typical throughout most of north and east China), and sulfur dioxide control strategies are becoming particularly urgent in these areas. A nationwide law under consideration would require all power plants burning high-sulfur coal (sulfur content greater than 1 percent) to have an FGD. Sulfur emissions fees do exist and in fact keep increasing, but enforcement of the fees is uneven and weak or non-existent in many regions (Tavoulareas and Charpentier, 1995; Lieberthal, 1997).

The review showed that all Bank projects have included high-efficiency ESPs (from 99.3 to 99.7 percent). Many interviewees seemed to agree that the Bank has been directly responsible for Chinese adoption of high-efficiency ESP specifications in all new power plants in China, which has greatly contributed to reductions in particulate emissions. Another such definitive influence has been on the use of low-NO_x burner technology. This technology has been specified in all Bank projects and has become widespread throughout China and standard in all new power plants. These are two of the most definitive cases of Bank influence suggested by the review.

So far, one Bank project has invested in FGD technology, in response to a local government mandate. Indirectly, the Bank has made local governments more aware of environmental considerations and this awareness is translating into investments in FGDs in some regions — particularly because of new environmental monitoring systems provided in a few Bank projects.[13] In fact, environmental monitoring systems have been one of the most useful aspects of the Bank's assistance in one province, said the provincial utility. With an environmental monitoring network, the local government now pays much more attention to environmental conditions and environmental performance of power plants, and has adopted a new policy of zero net increase in sulfur emissions over the current level. Several power plants in that locality are being retrofitted or installed with FGDs, at least partly because of this policy.

All Bank power plant projects have required the use of low-sulfur sources of coal (containing typically 1 percent sulfur or less). However, one can argue whether the low-sulfur coal would better be used in applications where pollution control is more difficult — such as in dispersed small coal boilers and furnaces. The unit costs of sulfur reduction in these sources are likely to be higher than those of an FGD on a large power plant — although institutional barriers can prevent such cross-sectoral "optimization" of sulfur abatement costs.

4.7. Set and enforce quantitative emissions targets

Recently, the Chinese government has initiated serious efforts to curb air pollution related to the burning of coal and particularly to reduce the power sector's contribution to the problem. Measures under development or being strengthened include emissions limits, emissions taxes, emissions trading, environmental fines, and imposing FGD requirements on new plants in some provinces. Emissions limits may be imposed for specific facilities or as a "cap" for a city as a whole. However, implementation of these measures requires adequate formulation and enforcement of national regulations at local and provincial levels. Local governments are usually more concerned with economic growth and employment than they are with adhering to national environmental mandates, and therefore implementation and enforcement of environmental measures at local level is often lacking. Even if fines are assessed they may not be paid. Finally, emissions limits may have the lower status of "administrative mandate" rather than the status of a law, although the status may change in the future (Lieberthal, 1997; World Bank, 1997c; Chandler *et al*., 1998).

The Bank appears to have had little influence on these trends, as it has not worked very much with the State Environmental Protection Agency (SEPA), the body responsible for national environmental regulation. (The Bank's main counterparts have been the energy companies and utilities themselves.) One Bank project piloted an emissions trading scheme — a so-called "bubble concept" — in which a new power plant was allowed to be constructed without an FGD in exchange for installation of an FGD retrofit on an existing plant in the same area. It turned out an FGD could more cost-effectively reduce emissions if installed at the old plant than at the new one. This model may have some replication potential.

4.8. Develop advanced "clean coal" technologies for power plants

Advanced fluidized-bed combustion (FBC) and integrated-gasification combined-cycle (IGCC) technologies

[13] Most Chinese cities have stationary air pollution monitoring stations that measure overall ambient conditions, but mobile monitoring systems provided in a few Bank projects have allowed greater understanding of emissions patterns from particular point sources. This equipment has allowed utilities to monitor their own emissions, in addition to the stationary monitoring done by local governments.

for coal power plants promise cleaner burning and more efficient utilization of coal. The Chinese have conducted research on both technologies and both show promise for the future (Tavoulareas and Charpentier, 1995; Cheng, 1996; Chandler *et al*., 1998). The State Development Planning Commission (SDPC) has taken a strong interest in using these technologies in the next generation of power plants. Even just a few years ago, FBC boilers were still firmly in the research and development stage. Now they are going commercial in increasing sizes, although they are still not competitive with conventional technologies at the large-power-plant size (i.e., 300 MW and up). Few countries utilize these technologies so the Chinese see domestic development as critical. Two of the Bank-supported energy efficiency projects contain subprojects that address commercial FBC boilers in smaller sizes for industrial uses. The Bank has not made substantive contributions to the development of larger FBC boilers for power plants, although new studies on advanced clean coal technologies were underway in 2000 under the Bank's "clean coal initiative" (World Bank, 1996c).

4.9. Expand natural-gas production and imports

Traditionally, natural gas was seen by Chinese economic planners as a marginal fuel whose primary use was as a feedstock for fertilizer production. Partly as a consequence, natural gas makes up just 2 percent of China's primary energy supply. Many studies have advocated greater use of natural gas for electricity production and for replacing coal-fired heating boilers in urban areas with gas-fired boilers and other cogeneration technologies (Yang *et al*., 1996; Chandler *et al*., 1998). Now Chinese planners are rethinking gas use. In 1999, the first natural-gas-fired power plant in China to be supplied by liquified natural gas (LNG) was approved in Guongdong, with imported gas to arrive via a new LNG shipping terminal constructed as part of the project. Other high-population coastal areas, for example Shanghai, are considering similar imported-LNG and power-plant schemes. Other ideas exist for international pipelines to bring gas from the Russian Far East, the Middle East, and Central Asia (Paik and Choi, 1997; Tussing, 1998; Paik and Lan, 1998; Dorian *et al*., 1998). "Now is the right time to push for gas" said one official.

Some see China's new emphasis on natural gas as coming too late and fault the Bank for not pressing the Chinese more strongly on gas production and utilization issues. It appears that the gas sector has historically been unable or unwilling to borrow from the World Bank, partly because it has lacked foreign currency with which to repay foreign loans. The Bank's one gas-sector project, in Sichuan province, was somewhat of a special case because of serious safety concerns and leakages in the gas transmission network that required urgent attention and foreign equipment.

The Sichuan project did make a substantial contribution to increasing gas reserves and gas production capacity in that province, as well as improving safety and environmental protection throughout the province's gas transmission network. The project increased the proven reserves from 400 bcm in 1993 to 554 bcm in 1998 and increased annual production capacity from 6.5 to 9.3 bcm over the same period. Supplemental grants by the Global Environment Facility helped to reduce pipeline leakages and introduced the process of leakage detection and repair to the gas company for the first time. The company had not realized the importance of pipeline monitoring and had to bring in new analytical tools and gain new skills, including the establishment of a new pipeline monitoring and rehabilitation center. As a result of the project, system leakage rates went from 3.6 percent in 1996 (the first time leakage had ever been monitored) to 1.5 percent in 1998.

Also as part of the Sichuan project, the Bank's dialog with the state planning commission was credited by some with helping to bring about policy changes in gas prices in 1997 that could end up spurring production in the gas industry. Prior to the project, gas well-head prices were regulated at levels below production costs, a situation that was remedied by the policy changes. Still, the gas industry in general suffers from monopoly behavior and a lack of gas demand — which in turn is not encouraged because of production constraints and lack of real markets and competition in gas supply.

4.10. Construct gas-fired power plants and gas distribution systems

One difficulty encountered in the Sichuan project described above was that the gas utility was unable to sell all the gas it could produce. In fact, despite the increase in annual production capacity to 9.3 bcm, actual production in 1998 was only 7.5 bcm, as the gas company struggled to market gas to a greater number of customers. Customers in Sichuan have been unwilling to increase their consumption of gas for a variety of reasons and sales to neighboring provinces have been transmission-capacity constrained.

This situation highlights the fact that gas utilization for power and heat production in China is still virtually unknown, despite large environmental benefits from using more gas and less coal (Logan and Zhang, 1998). The infrastructure simply does not exist — in terms of long-distance transmission pipelines, local-gas distribution networks, and gas-fired boilers and other end-use equipment. The use of gas for power generation appears to be growing in acceptance within the Chinese government in recent years, including the "repowering" of existing coal-fired plants to burn natural gas instead. For example, Shanghai power authorities said in 1999 that their power-sector development plan calls for 40 percent of new power capacity to be gas-fired.

The Bank has not contributed directly to the development of natural-gas power plants. Bank managers insist they have tried to interject thinking about natural gas utilization in past dialogues with the Chinese, but the Chinese just were not interested. As one Bank manager said, “we can choose *not* to do things in China, but we cannot choose by ourselves *to* do things in China.” Still, the Bank could have tried to be more proactive in pushing a natural gas agenda within the government, said some observers.

Indirectly, Bank studies and dialogues may have had or will have some effect. For example, a Bank-supported study of LNG in 1997–1998 was credited with having some influence on central government planning and interest in gas. And as part of one Bank-supported power project, provincial electric utility officials went on study tours abroad and visited LNG terminals and gas-fired power stations. This utility subsequently proposed it’s own LNG/gas-fired-power plant project to central government authorities. “There is now strong support for LNG within the government” said the utility, which also noted that increased use of gas in other countries has also influenced China’s thinking. In 2000, a joint study on natural gas utilization was underway by the Bank and Chinese government.

Also indirectly, the Sichuan gas rehabilitation project appears likely to contribute to gas-fired power generation in neighboring Hubei province. The increased gas production capacity in Sichuan led to a proposal for construction of a gas pipeline to Hubei and construction of gas-fired power plants there. Market studies of gas demand in Hubei showed that a pipeline could recover construction costs within just a few years. Total pipeline capacity is planned at 2.1 bcm/yr, half of which would be used for power generation, including a new 120-MW combined-cycle gas-turbine (CCGT) plant and the repowering with gas of three existing coal power plants with combined capacity of 1000 MW. A planned 0.4 bcm/yr would go to residential customers and 0.6 bcm/yr would replace fuel oil in the chemical industry.

The irony of greater gas utilization in China is that gas for local distribution and consumption by the commercial and residential sectors will produce the greatest improvement in urban environmental conditions (as small coal boilers are replaced, for example), but financing for the necessary gas supply and transmission may come primarily from increased gas use in power generation, where the environmental benefits are lower.[14] The above example of the pipeline to Hubei shows how the two might go hand in hand.

[14] Credit for this thought goes to Todd Johnson of the World Bank.

4.11. Make industrial energy-efficiency improvements

Medium- and small-scale coal-fired industrial boilers account for a whooping one-third of the total coal consumption in China (World Bank, 1996b). Chinese industrial boiler technology still lags substantially behind international levels in terms of efficiency and performance. The 1996 World Bank/GEF Efficient Industrial Boilers project has been the first large-scale infusion of international technology for small coal-fired industrial boilers to China since the 1940s, when technologies were transferred from Russia, according to Bank staff. This project has targeted an important area for industrial energy-efficiency improvements, particularly since there is no central authority whose mandate includes advancing the state of Chinese boiler technology. Nine competitively selected boiler manufacturers are participating in the project.

This project appears to be indirectly accelerating industry-wide efforts to improve industrial boiler efficiencies, but the effectiveness of the project remains uncertain. Technology needs by Chinese boiler manufacturers are becoming a rapidly moving target, driven more and more by environmental considerations, and manufacturers may not be able to obtain the most relevant technologies under the original project concept. The market has overtaken the project in other ways, as boiler firms who are not participating in the project — but initially were anticipating technology dissemination from it — have stopped waiting for the project to finish (because of slow implementation progress) and have set out on their own to obtain the technologies they need. The rise in coal prices has made it easier for all boiler makers to contemplate producing higher-priced high-efficiency boilers, although lack of financing and the creditworthiness of boiler manufacturers could still hinder technology development.

Other important areas for energy conservation and efficiency, such as certification, labeling, efficient lighting, and efficient motors, have so far been left to the Chinese or other donor agencies.[15] Energy efficiency in town and village enterprises (TVEs) is another important priority that the Bank has not addressed, in part because the UNDP is doing so with a GEF-supported TVE energy-efficiency project. Demand-side management (DSM) programs within electric utilities have been popular with governments in other countries, but the Chinese have not been interested in this approach, said World Bank managers. The Bank worked hard to convince the Chinese to accept a $10 million DSM component that was included

[15] For example, the UNDP and GEF approved a “green lights” project for efficient lighting in China in 2000. See www.gefweb.org. The UNDP/GEF also initiated an efficient refrigerators project in China in 1997; see UNDP (1997).

in a 1997 thermal power project, but the project was subsequently canceled for unrelated reasons.

Early experience in the 1980s with two fertilizer plant rehabilitation projects was favorable. According to one project completion report, "the project has demonstrated the potential that exists in the Chinese fertilizer industry for efficiency improvements in both production and energy .... Encouraged by the attractive benefits experienced under the project, the Ministry of Chemical Industry and some individual enterprises have followed the models established and introduced similar rehabilitation schemes in other plants." But these types of projects were not repeated in the 1990s, as both the Bank and Chinese determined that other financing sources were available for such industrial projects.

4.12. Promote performance contracting as commercial model for energy efficiency

China has over 10 years of experience in the active promotion of energy conservation, with a solid record of achievement (Sinton and Levine, 1998). Success has been based on a well developed set of institutions. For example, provincial energy conservation centers have provided assistance and expertise to industry for energy efficiency improvements and monitoring. Traditionally, energy conservation programs were based on centrally designed energy conservation policies and heavily subsidized administrative programs. However, faced with constrained fiscal revenues, the government began in the late 1990s to promote a shift in energy conservation programs to rely more on market-based incentives and introduce innovative and commercially-based contractual and financing mechanisms.

The 1998 World Bank/GEF China Energy Conservation project is a step in this direction (World Bank, 1998c). A small European Union (EU) project first introduced the energy-service company (ESCO) concept in China. Three demonstration ESCOs were established in late 1996, with the aim of piloting energy performance contracting for the first time in China.[16] The $150 million Bank/GEF project was designed to extend this effort. By 2000, the three ESCOs had signed approximately 100 subcontracts for energy efficiency investments valued at $25 million, with a combination of financing from the EU, World Bank, GEF, and other domestic sources. All projects are based on performance contracting. Actual energy savings from the projects under implementation was exceeding estimates and had repaid more than half the value of these projects by 1999.

Indirect influences were also apparent. In the early stages of project preparation the project achieved substantial influence over government thinking and thinking among local and provincial energy conservation centers throughout China. In fact, the government subsequently dictated to all 200 of the provincial energy efficiency centers that they should consider how to become profit-making market-based entities through the use of performance contracting, drawing upon the experience of the Bank/GEF project (as government support for these centers declines or their financing needs increase). Nevertheless, the ultimate viability of this model will remain untested until the project is much further advanced; there are clear obstacles to performance contracting and commercial financing has yet to be mainstreamed.

4.13. Construct wind power plants

China is at a critical crossroads for action on renewable energy development. Action is urgently needed to develop market infrastructure, improve information access, improve renewable energy capabilities, and put in place policies necessary to enable expansion of commercial markets. China has taken up this challenge in various ways, including preparation of the "New and Renewable Energy Development Program 1996–2010" by the State Development Planning Commission (SDPC), the State Economic and Trade Commission (SETC), and the State Science and Technology Commission (SSTC). Provision for renewable energy development was also made under the Electricity Law of 1995 (SETC, 2000; SDPC, 2000).

Wind power is a relatively new but growing priority within China. About 230 MW is currently installed, but government plans now call for 1000–3000 MW by 2010 (Shi, 2000; SDPC, 2000). The Bank is making a substantial contribution in this area through the Renewable Energy Development Project, approved by the Bank in 1999 (World Bank, 1999). This project funds the first large wind power plants not subsidized through bilateral assistance; essentially the first "commercial" wind farms.[17] Four new wind power companies, jointly owned by the State Power Corporation and provincial or municipal power utilities, will construct 190 MW of wind farms and enter into commercial-style power-purchase agreements.

A major benefit from the project is that it will use standards and international methods for resource

[16] ESCOs in this project are officially designated as "Energy Management Companies" (EMCs).

[17] Wind power wholesale tariffs are set based on wind-power production costs. Since these costs are still greater than the costs of conventional electricity generation in most regions of China, wind-power purchase arrangements increase the recipient utility's costs and thus still entail an implicit cross subsidy by the customers of the utility purchasing the wind power.

assessment, competitive bidding, and feasibility studies. Another influence will be to push wind power development to larger scales, such as 100-MW size wind farms. Historically, bilateral assistance for wind projects has resulted in many smaller-size farms — 15 MW or less. Another influence will be to bring international experience for feasibility studies and power purchase agreements and competitive bidding. Finally, the project has created more credibility for wind among government policymakers.

However, tariff setting, cost-recovery for wind-power developers, power purchase arrangements, and transmission wheeling are still important unresolved issues for wind power in China (Lew, 2000). Despite a tariff policy requiring utility purchases of wind power on a "cost-plus" basis, as utilities increasingly act as commercial businesses they may be less inclined to purchase higher-priced wind power because of the growing burden on overall utility costs as more wind power is developed. Provincial utilities still appear willing to purchase wind power from local developers on their own territory. But cross-provincial power purchase agreements are another matter. For example, in the World Bank project, problems arose in 2000 over a planned 100 MW windfarm component in Inner Mongolia, because that province's utility proved unable to convince other, restructured, provincial utilities to sign power sales agreements for the wind power. This issue is significant because the best wind resources are often not located near areas of high electricity demand.

4.14. Promote photovoltaic, wind, biomass and small hydrotechnologies for rural areas

China has had substantial success promoting rural use of renewable energy technologies, such as small-scale wind turbines, family-size biogas plants for lighting, and improved use of biomass and other fuels in cookstoves (Qui *et al*., 1990, 1996; Smith *et al*., 1993; Li, 1996; Deng *et al*., 1996; Byrne *et al*., 1998). Since the 1980s, the UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) has assisted some of these efforts by providing field studies, training, and energy planning methodologies. The earliest work focused on rural energy and township and village enterprises and developed courses in integrated rural energy planning for local officials. These efforts, and the cadre of Chinese experts trained, played an instrumental role in the development and implementation of China's "hundred counties" program for rural energy planning and development (ESMAP, 1989, 1994, 1996, 1999; Leach and Foley, 1996; Li, 2000).

An evaluation of the ESMAP rural energy work stated: "In China, a number of linked ESMAP activities have clearly had a major and beneficial impact on the Chinese approach to integrated rural energy planning … all three projects have involved … the effective transfer of expertise and skills to substantial numbers of Chinese personnel …. ESMAP also introduced a number of important concepts such as least-cost analysis and cost-benefit analysis into rural energy planning. These have been adopted and integrated into huge Chinese initiatives such as the current and expanding 'hundred counties program' on rural energy planning and development" (Leach and Foley, 1996, p. 2).

Following the many years of ESMAP work, the Bank began to implement one rural energy subproject (partly financed by GEF grants) for installation of 200,000 individual solar home systems in remote rural areas without access to electricity grids (World Bank, 1999; Martinot *et al*., 2000).[18] This project builds upon and expands the successes of local governments in Qinghai province to develop a private industry for such systems (in 1998, 17 companies sold 30,000 systems in all provinces in China). Other rural energy technologies, such as hybrid wind–solar–diesel systems for village-scale mini-grids, have not been addressed directly by this project, although all solar power technologies are eligible for technical assistance and subsidies under the project.[19]

4.15. Construct cogeneration and district heating systems

Buildings in Chinese cities have traditionally been heated with individual boilers or apartment stoves. Centralized district heating systems, where heat is produced in a central location (often through cogeneration with electricity) and distributed via hot water or steam to individual buildings, can result in greater energy efficiency and consequently reduced air pollution emissions given the right geographical circumstances (Johnson, 1995; Yang *et al*., 1996).

An environmental agenda for reducing urban air and water pollution resulted in three Bank-supported urban environment projects that replace stand-alone heating boilers with district-heating systems. There is now a clear recognition both within the Bank and by the Chinese that district-heating systems can provide high financial returns while improving overall energy efficiency and reducing air pollution emissions. "Local governments are doing district heating projects on their own but it is a slow process and they need help" said one Chinese observer. The technologies are simple and available domestically, but management, planning and financing issues appear to reflect the Bank's real contributions.

[18] Although service is of uneven quality, rural access to electricity is high. Still, 80 million people in rural areas remain without access to electricity (SDPC, 2000).

[19] A parallel UNDP/GEF project is providing a small amount of technical assistance and demonstrations for village mini-grid technologies.

For example, the Beijing Urban Environment project in 1992 helped to change the practices of district heating company managers by encouraging responsibility for efficient operations and maintenance. Such encouragement was made possible with the introduction of data acquisition and control systems that allowed managers, for the first time, to be informed about system performance and to have some way of controlling the system. In the city of Yantai in Shandong province, the bank has financed the first large-scale district heating system in China that has been developed from scratch, rather than patched together from smaller-scale systems. Such an integrated approach can serve as a future model for district heating planning. Besides management and planning, it appears that the Chinese rationale for engaging the Bank in district heating projects has been the need for financing. Said one Bank manager, "we agreed to do district heating because it was a local priority of the city that wanted it.... There are many existing district heating systems all over northern China, but to scale up they needed the financing".

5. Conclusions

What have been the most significant influences on environmental protection in China by Bank-financed energy projects? Projects have:

- Accelerated development of the market and domestic manufacturing capabilities for large-scale efficient coal power plants (i.e. 600 MW units) over the past 15 years.
- Promoted hydropower and facilitated the Chinese ability to harness hydropower resources as a significant source of electricity generation.
- Created new initiatives for energy efficiency and renewable energy, notably a market-oriented approach with energy-service companies that could be replicated country-wide, improvements in coal-fired boiler technologies, large-scale use of wind power on commercial terms, and support for rural markets for solar powered lighting and other uses.
- Promoted the promulgation throughout China of best-practice equipment specifications for cleaner coal combustion with low-NO_x burners and high-efficiency electrostatic precipitators.
- Led to important advances in the capabilities of Chinese personnel to conduct high-quality environmental assessments of energy projects in accordance with international practice.

What should the Bank be doing now to assist the Chinese? The six most significant opportunities for the Bank in the future are:

1. *Natural gas distribution and utilization:* The Bank could target natural gas distribution and end-use, such as replacing coal-fired furnaces with gas-fired furnaces, cogeneration and district heating. Loans to industrial and commercial entities through commercial credit lines could finance gas-based infrastructure. Loans to municipalities could help expand gas-distribution infrastructure and use of district heating systems. Policy and regulatory frameworks supportive of gas could be encouraged. The main questions are whether the Chinese see a need for foreign exchange in these activities, and whether the private sector can do much of the investment.

2. *Energy efficiency of heat supply and buildings:* A key area for the Bank will be to help improve the energy efficiency of buildings and heat supply, such as promoting improved standards and new construction materials. A greater number of district heating systems can be constructed or rehabilitated. In addition, the Bank can encourage greater responsibility for efficient operations and maintenance of district heating systems and heat supply in buildings, both through new policies and regulatory frameworks and through improved technologies for monitoring, metering and system control.

3. *Energy efficiency in industry:* The performance contracting models being developed under the Energy Conservation project could be extended to a greater number of institutions and provinces. The bank could also promote energy efficiency in town and village enterprises as part of rural development strategies — local institutions already exist for this purpose but need to be stronger and more commercial. Motor efficiency standards and other energy efficiency regulations to be made in the context of a landmark 1998 energy conservation law could benefit from Bank assistance with international experience and best practice.

4. *Rural energy and development:* Support for rural energy development could contribute to the Bank's poverty alleviation goals if rural development units within the Bank consider energy issues afresh. For example, biomass is one promising technology. Farmers are making less use of agricultural wastes for cooking and heating (as they turn to other fuels like LPG) so they could use more biomass for electricity generation and biogas production to fuel productive uses in rural areas. Small hydro, wind, and solar technologies all have potential to foster development in China's rural areas.

5. *Incorporating support for energy efficiency and renewable energy into electric power reform:* A host of potential policies can be incorporated into electric power reform that will promote a more "level playing field" for energy efficiency and renewable energy. Examples exist from both developed and developing countries that could potentially be adapted to China, such as independent-power-producer and power-purchase-agreement frameworks, transmission access and wheeling policies, renewable energy schemes mandating minimum portfolio requirements, emissions fees and trading, and use of emissions premiums in power planning.

6. *Wind power development:* Wind power is a relatively new but growing priority within China. The Bank is making a substantial contribution in this area through its Renewable Energy Development project. There is scope for much greater assistance in the future, in terms of project financing, wind turbine manufacturer support, scale-up, and especially support that addresses the regulatory and policy issues mentioned earlier.

As traditional Bank lending in the power sector is declining, it may be that some of the above opportunities will require stand-alone GEF grants in conjunction with other non-Bank sources of financing. While GEF grants have facilitated all of the Bank's energy efficiency and renewable energy projects, one day the Chinese may be unwilling to "sign a loan to get a grant" as some have said. Some areas, like gas distribution and utilization, wind power, and district-heating systems, may still be prime areas for further Bank lending. The Chinese willingness to borrow is key — and probably depends substantially on domestic capital costs and availability. The challenge for the Bank is to find ways to press ahead in most or all of the above six areas.

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