Selected Papers in Asian Studies: Western Conference of the Association for Asian Studies

Volume 1
Number 53 *A Competitive Advantage Analysis of The Air Emissions Control Industry In The People's Republic of China*

Article 1

1995

A Competitive Advantage Analysis of The Air Emissions Control Industry In The People's Republic of China

Jonathan Harrington

Yiqi Wu

Selected Papers in Asian Studies

NEW SERIES # 53

JONATHAN HARRINGT
AND WU YIQI

A COMPETITIVE AD-
VANTAGE ANALYSIS
OF THE AIR EMIS-
SIANS CONTROL
INDUSTRY IN THE
PEOPLE'S REPUBLIC
OF CHINA

Western Conference
Of The Association
For Asian Studies

Western Conference of the Association For

Asian Studies

Selected Papers in Asian Studies

New Series

Paper No. 53
1995

A Competitive Advantage Analysis Of The Air Emissions Control Industry In The People's Republic of China

by

Jonathan Harrington and Wu Yiqi

Jonathan Harrington is currently studying for his Doctorate in Political Science at Loyola University Chicago, Illinois. Mr. Harrington's current research centers on the evolution of environmental interest and related policies in South-East Asia.

Wu Yiqi is a veteran of the Shanghai Foreign Affairs Office where she worked as a translator and delegation organizer. She is currently a consultant for China-American Cultural Business Center in Chicago.

A Competitive Advantage Analysis of the Air Emissions Control Industry in the People's Republic of China

In recent years international trade has expanded at near double digit rates worldwide. It has expanded even faster in Asia in countries such as Japan, South Korea, Thailand, and the "Greater China" states of Hong Kong, Taiwan, Singapore and, most recently, the People's Republic of China. A major reason for this fast expansion is that each of these states has aggressively pursued export growth strategies. The strong growth of these Asian competitors has created new challenges for the United States which has, since the early 1980s, consistently experienced large trade deficits with several of the above listed nations. One bright spot for United States firms, however, in this otherwise negative climate of expanding trade deficits is the expansion of U.S. exports of pollution control technologies to Asia.

There are a number of reasons why demand for U.S. environmental goods and services is increasing. Since the passing of the Clean Air Act of 1970, polluting industries have spent tens of billions of dollars on pollution control devices. The U.S. market makes up fully half of total worldwide demand for environmental control goods and services. [1] This demand, in turn, has led to the development of environmental control industries which are considered by many to be the most technologically advanced and competitive in the world. One case in point of the competitiveness of U.S. firms in the environmental control market in Asia is their penetration of the Taiwanese market over the past 15 years. Exports of pollution control technologies and equipment have grown from next to nothing in 1980 to over two billion dollars in 1993. These exports have had a significant impact on the United States still large, but shrinking trade deficit with that island nation.

Worldwide, the trade in pollution control goods and services is one area where the United States maintains a significant trade surplus. Judging from the overall competitive success of United States environmental firms worldwide, it seems reasonable that both the government and the private sector should develop the potential that trade in this industry could have in reducing the United States fast growing trade deficit with the People's Republic of China.

The purpose of this study is to examine the competitive advantages of U.S. environmental technology firms vis a vis Chinese firms and major foreign competitors in the area of air pollution control for the energy industry in the P.R.C. I predict that, despite many challenges and barriers the U.S. firms will face in opening up the China market, there is significant long term potential for growth in environmental goods and services exports to the P. R. C.

This study examines various factors, both business and non-business, that impact market penetration potential for U.S. air pollution control firms. Competitive advantage analysis is used to evaluate the Chinese market.

Background

During the past 12 years the economy of the People's Republic has gone through a significant transformation. The implementation of capitalist-like economic reforms such as the freeing of price controls, increasing government-owned firms autonomy, and allowing the development of private economic sectors have all stimulated impressive economic growth.[2] China's economy has grown at an average rate of over 10 percent per year for the past 12 years and is now one of the largest economies in terms of G.N.P. in the world. This growth, however, as has

been the case in most industrializing countries, has caused enormous air, water and related pollution problems. The primary culprit for this pollution in China is the country's energy industry. Around seventy-five percent of all electricity in China is produced by coal fired plants. Pollution control technologies used in these plants are generally rudimentary at best. Additionally, most coal used for electricity generation is "soft" coal, high in sulfur and, consequently, more damaging to the environment. [3] The problem is becoming so serious that expanded coal-based electricity generation and resulting air pollution problems could endanger the long term development of the P.R.C..

Sino-U.S. trade has greatly expanded over the last 15 years. In 1992, the P.R.C. racked up an 18 billion dollar surplus with the United States. The Chinese government, fearing retaliation, has made a conscious effort to expand government procurement of a variety of U.S. made capital goods, especially in the telecommunications and aerospace industries. [4] This political situation should also create opportunities for U.S. companies in the air pollution control market.

There are a number of other reasons why Chinese firms might be interested in expanding their purchases of pollution control technology. There is increasing public awareness of the seriousness of the pollution problem in the P.R.C.. International environmental organizations are putting pressure on China to clean up its energy industry. This industry is becoming one of the world's major contributors to the buildup of greenhouse gases in the atmosphere and the destruction of the ozone layer. At China's current rate of growth, by 2020 it will produce more air pollution than the United States, Canada and Japan combined. International aid organizations such as the World Bank and the Asian Development Bank, which have long supported development projects without regard for their environmental impact, are now putting greater emphasis on these impacts

when planning new projects. [5] In China there seems to be a movement to strengthen enforcement of environmental laws already on the books and to establish tougher pollution standards, especially in large urban areas. The Chinese government has shown that it is indeed interested in doing something about these problems by setting aside billions of dollars in its latest five year plan, adding up to .9% of GNP, and setting new standards stating that 10% of all investment in future energy production projects should be put aside for energy conservation. [6]

There are also hard economic reasons for the Chinese to take action in the area of energy conservation and related environmental protection. In 1993, according to Chinese statistics, P.R.C. oil imports increased by 41%, exacerbating China's 12 billion dollar trade deficit. [7] These factors that could affect Chinese demand for pollution control equipment will be discussed in greater detail later in this paper.

Overview of the paper

The first part of this analysis will discuss various cultural, political, social and legal factors that affect foreign pollution technology firms in the P.R.C.. It will also examine the current state of the P.R.C.s domestic power generation industry and the types of technologies that are currently used in China for air pollution control. Because of the technical nature of air pollution control equipment, this section will also summarize some of the technical aspects of these technologies. The second part of this analysis will discuss the competitive advantages of both Chinese and other international competitors such as Germany and the Netherlands and the impact that they might have on the ability of U.S. firms to develop the China market.

Theory

Competitive advantage analysis will be used to determine the strengths and weaknesses of Chinese and U. S. manufactures. Competitive advantage analysis requires one to examine the strengths and weaknesses of potential competitors, which can range from looking at individual firms to a country's entire industrial sector. Doing this allows firms to identify opportunities in and strategies for the Chinese market. Competitive industry analysis has four components.

First, one must examine the boundaries of an industry, including information about what it does and does not produce. Defining industry boundaries allows firms to clearly delineate the scope of the market in which they are competing. This can be done in a very narrow or broad sense depending on the nature of the industry. [8] The nature of the energy production process includes, for instance, mining and extraction of raw materials, mostly coal, coal processing and transport, combustion processes, power transmission and emissions control. This work will discuss each of these industrial activities but will specifically concentrate on the competitive advantage of China's air pollution emissions control producers vis a vis their U.S./ counterparts.

The second component of competitive advantage analysis involves defining the structure of an industry. It is important to know the level of integration of these related activities and to examine how integration can affect competitive advantage. In this analysis, understanding integration involves asking three questions about an industry. First, is there vertical integration, on the part of specific firms, of the entire process of energy production from coal extraction to emissions control? Second, does government regulation and/or planning encourage coordination of firms supplying

different inputs all along the production cycle from extraction to emissions control? Third, is the industry monopolistic, oligopolistic or freely competitive and does government intervention encourage one or more of these market structures? In China, the first question is generally answered in the affirmative with some qualification that will be discussed in a later section. The second question can also be answered in the affirmative up to but not including emissions control equipment, at least up until very recently. To understand why the second question is answered in the affirmative requires an understanding of government policy and how it has affected the development of domestic air emissions control firms as well as future demand for such services. This will be discussed in a later section of this paper. Finally, the answer to the third question is both yes and no. The energy generation industry is essentially monopolistic, at least in major markets, because each market essentially has only one producer. Also, with reference to emissions control equipment, before 1978 government policies encouraged the development of single suppliers for each province. After 1978, however, market opening reforms have allowed cross-provincial competition among suppliers. The underdeveloped and highly segmented nature of the industry, however, make it unlikely that most firms have either the resources or capital to expand into markets beyond their own province or region. Except for the cities of Shanghai, Tianjin and Beijing, each province has only a few producers of control equipment and they mostly produce simple mechanical collectors, such as cyclones. Many firms, in fact, produce their own collectors in house. This is especially true of smaller rural based firms that do not have capital resources to purchase equipment.

The third component of competitive advantage analysis is that competitors must be clearly defined. [9] This is a difficult task to accomplish because the Chinese government itself has no standard for defining the scope of the industry. Also, many firms, without outside help, develop their own rudimentary air emissions control devices.

Fourth, one must discover the major determinants of competition. This involves looking at such things as direct and indirect market barriers, government import substitution policies, and demographic/social factors that affect firm competition. [10] Determination of price is also an important aspect of this and holds special meaning for China. [11]

In this case, the analysis examines Chinese industry while U.S. firms are looked upon as competitors to this industry. Because of a lack of quantitative data on specific Chinese firms, their sales and market shares, this analysis will approach the Chinese pollution control industry in a rather broad and general way.

Why use competitive advantage analysis to examine possible opportunities for United States Environmental technology firms in China? Comparative advantage analysis is widely used in international trade circles as well as by specific firms in specific industries. This type of approach is also used by government organizations interested in discovering policies that encourage market penetration for domestic firms. In the early 1990s for instance, the United States embarked on developing an integrated policy to promote the export of environmental technologies. This policy implementation process involved a very similar strategy to the one outlined above. Two good examples of this approach are the Department of Commerce's "Environmental Technologies

Exports Strategies: Framework for U.S. Leadership: A National Agenda" and the "Clean Coal Technology Demonstration Program." [12]

Chinese energy policy 1978-1994

The quasi-government organization that produces most of China's power, China Power, has struggled to keep up with demand. Between 1978 when economic liberalization policies were first enacted and 1985, demand far outstripped supply and widespread shortages developed, especially in large cities and in industrializing rural areas which, under past regimes were never expected to develop power hungry sideline industries. During this period the government attempted to follow a policy of "10 to 1," that for each dollar invested in energy production, ten cents would be invested in conservation and pollution control.

From the mid-1980s up to 1990, China Power finally began to catch up with demand, at least in many urban areas. One reason why they were able to do this is that China's economic growth slowed in 1986 and again in 1989. Another reason utilities were able to catch up was a significant change in government policy which encouraged increased production at all costs. Environmental pollution and conservation became secondary priorities as both China Power and thousands of small communities, on their own, rushed to add production capacity. This shift from previous polices which called for "10 to 1 investment," has had disastrous effects on the environment.

In 1990, Li Peng, Prime Minister of the P.R.C., called for a return to the policy of "10 to 1" investment stating that, in the long run, it would lead to greater levels of energy production and

mitigate residual effects of energy production including the production of air pollution. In that same year the government also passed a law requiring that all new polluting equipment should be built with pollution control devices. General technology guidelines were developed for various industries, including the power industry. The government also called for expanded development of other energy resources including hydro-electric power and nuclear power generation. It is interesting to note that when government officials and experts discuss pollution control they usually are motivated to do so primarily by the desire to achieve greater efficiency and energy conservation. The actual installation of external pollution control devices is seen to be of secondary importance. Pollution control, therefore, is not seen as an end in itself but is seen as one possible benefit from increased efficiency and conservation. Also, increased interest in conservation and efficiency are related to expectations about the lifting of price controls and subsidies given to coal producers, energy producers and consumers. As prices are rationalized, semi-autonomous producers will show more interest in improving production methods and efficiency. [13]

Another significant change that might have an effect on development of the Chinese environmental market is recent efforts by the Chinese government to clearly define how its overall economic strategy fits in with environmental protection. This was done in the context of the "Earth Summit" which was held in Rio de Janeiro in 1992. Li Peng, in a keynote speech to the United Nations Conference on Environment and Development assembly, traced five key principles he believes are necessary to worldwide environmental protection These include: "Economic development should be pursued parallel with environmental protection.... Protecting the environment is a common task of mankind as a whole but economically developed nations should

bear a greater responsibility..., International cooperation should be based on respect for state sovereignty...environmental protection and economic development would be impossible without world peace and stability and that in tackling environmental problems, consideration should be given to both the immediate interests of various countries and the long term interests of the whole world. " [14] A large propaganda campaign was launched in conjunction with the "Earth Summit" in China to "increase the awareness of the Chinese people of the problem of environmental protection" [15] One major justification that the Chinese government has given for this heightened interest in environmental problems is its connection with the population issue. The government wants people to see the connection between having more children and environmental destruction. It is hoped that this will give Chinese an added incentive to keep family sizes down. [16] These concerns have culminated in China's first real effort to fully integrate environmental concerns into overall developmental plans. In April 1994 the State Council officially approved its "Agenda 21 plan," not coincidentally named after the joint document that came out of the Rio conference. The agenda calls for integration of policies relating to natural resource management, population control, industrialization, education, consumption, social services, poverty, health care and sustainable growth. [17] The problems of environmental protection and the need for government action are also increasingly echoed in state-run newspapers. [18]

Effects of 1990s policy changes

It is difficult to tell exactly how these official polices have affected the actions of producers. As the economy has decentralized and the central government has allowed state-run firms to

become financially autonomous, many firms have shown less and less interest in implementing government directives, including those related to pollution control. Widespread government corruption creates numerous opportunities for enterprising managers to find ways around government directives. Technology and air quality standards are, in many cases, too general and even firms interested in improving their pollution control performance do not know what standards they should meet or what technologies they should use. Managers in the energy industry have, on the average, the equivalent of a third-grade education. This hampers their ability to understand both the need for and the technology used for air pollution control. China's equivalent of the U.S. Environmental Protection Agency is understaffed and has limited enforcement powers. [19] Usually, enforcement of pollution control laws is left up to local governments, which can be more easily swayed by the wishes of large local firms. Another problem that inhibits enforcement is the nonexistence of air pollution monitoring facilities, even in large cities. The city of Shanghai, China's largest and most industrialized city, did not develop any permanent air monitoring capability until 1993, and this new system is only experimental. When laws are enforced, fines imposed on firms are so minuscule that they do not act as a deterrent. The only real and effective deterrent that has been sporadically used by local governments is to criminally prosecute mangers of seriously polluting firms. This method is usually used when public outcry becomes so great that local officials, in order to appease their constituents, take action. Provincial governments also use these highly public methods to "scare" other polluters into compliance.

Despite these problems, much new productive capacity built since 1990 by large state-run electricity producers does have some form of pollution control built into its construction

specifications. These mainly include power plants in large metropolitan areas that already have serious air, water and land pollution problems. Widespread public dissatisfaction and the explosive growth of pollution related diseases along with complaints from expatriates and foreign investors have motivated metropolitan governments to take action. Increasing public awareness in industrialized nations, including the U.S. and E.U. countries, of the global effects of green house gas emissions has motivated governments to pressure third world polluters, of which China is the largest, to improve their pollution records. Development aid and government to government aid projects sponsored by international organizations, after decades of encouraging environmentally destructive policies, now require that most aided projects make provisions for pollution control in development projects.

Many of the above mentioned factors point to a growing awareness of pollution problems and related needs to increase efficiency and conservation. It does seem evident, however, despite continuing problems, that as energy production capacity is added, there is going to be increased demand for air and other related pollution control equipment. [20]

Out into the air--Sino-United States standards

To understand market opening potentialities it is useful to examine Chinese experiences in a comparative context. Doing this will show the applicability of U.S. technology to the China market.

In the United States, a variety of air pollution control devices are used by energy utilities. Types used largely depend on location and age of the plants and the type of coal and burning

processes used by each firm. In 1991, the United States passed the sweeping Clean Air Act of 1991 which sets strict air pollution guidelines. Major components of this law include: expanded monitoring, increased fines for offenders, higher overall particulate and gaseous emission standards and a "pollution quota system" for various industries. Certain pollution quotas are established for each firm. If a firm produces less pollution than it is allowed to, it can "sell" its polluting rights to other firms that cannot quickly meet tougher clean air standards. This law allows firms that have older equipment in place to put off purchasing new controls until they can afford it. Polluting rights costs, however, are sufficiently expensive to influence cost polluting firms less in the long run to install new equipment. This new law, like the Clean Air Act of 1970 and other legislation have pushed U.S. technological advances in the area of air pollution control devices. The Department of Commerce estimates that there are between 45,000 and 60,000 firms in the U.S. that deal in some way with environmental protection. [21]

As stated before, China also has general guidelines for air pollution but they are often not enforced. Air pollution is especially difficult to combat because no comprehensive monitoring systems are used except in large cities. Few if any plants have their own monitoring systems so it is difficult to pinpoint exactly which factories exceed standards in industrialized areas. In 1988, spot experimental studies were done by foreign experts in China's major cities. Their preliminary findings showed that particulate pollutants in major metro areas exceed Chinese legal standards by 78%, dust standards by 91% and SO^2 standards by 14%. [22] China, like the United States has discussed the possibility of developing a pollution "quota" system, but these discussions are only in

the planning stages. In any case, it would take many years for China to develop a monitoring infrastructure that would make such a system workable.

This next section will discuss in more detail how China's state energy monopoly, China Power, and the Chinese government have tried to meet the challenge of increasing electricity production while dealing with the issue of environmental control. It will also consider the potential for U.S. market penetration in the P.R.C.

From the mine to the plant

As has been stated, 75% of China's energy is produced by coal fired plants. The air pollution dangers of coal mining are many but the three most important pollution problems resulting from the mining have to do with the type of coal mined, the way that is it cleaned, stored and transported and the way that it is shaped and processed for final use.

There are essentially two general coal types, high sulfur and low sulfur. In the U. S., most coal resources located East of the Mississippi are high in sulfur, and when burned, emit large amounts of sulfur-dioxide and other sulfur byproducts into the air. These negative byproducts, gasses and particulates increase green house gasses, decrease visibility and air quality and, when burned in large quantities over a long period of time, can create acid rain. In the early 1970s the United States, partly in response to Canadian demands and to general public outcry, passed a series of laws which set strict pollution standards for all polluting industries. [23] The power industry, in response, has spent billions of dollars on pollution control equipment. This government imposed

demand greatly stimulated growth of U.S. pollution control industries and also forced most power producers to switch from high sulfur to low sulfur coal in the production process. Fortunately, most of the United States remaining coal reserves are composed of low sulfur coal so this switch was not a painful one. China, however, has no such luck. While China's coal reserves are the largest in the world, the great majority of this coal is high in sulfur, and consequently, more dangerous to the environment. While it is possible to remove 99% of sulfur and particulate emissions resulting from high sulfur coal burning, it requires extremely sophisticated and expensive technology, technologies that even many U.S. companies can not afford. [24]

There are ways, however, that pollution can be significantly reduced to levels that would not result in serious economic hardship or excessive pollution emissions for firms. One way to do this is to put coal through a "washing process." Simply, the coal is sprayed with water mixed with certain chemicals that reduce the sulfur content of the coal. Coal washing and processing also allows firms to separate high and low sulfur coal. Mines then can sell coal to firms based on the composition and quality of coal desired. In China, only a tiny percent of coal is treated in such a manner. When coal is not washed it also creates serious local pollution problems including: coal dust emissions from uncovered train freight cars and ground and water contamination. [25] The production of dangerous pollutants happens twice, once during the burning process and once after the pollutants enter the environment. [26]

Another process that can be used to increase btu output, increase efficiency and decrease pollution is to "shape" coal in special ways. Shaped coal generally has a relatively hard surface because of the "packing" process that it goes through and, therefore, creates fewer particulate

problems in transport. It has been proven that the burning of shaped and washed coal cuts both gaseous and particulate pollution 20-30% in comparison to unprocessed coal. $C0_2$ and SO_2 emissions from coal burning can be cut by 80% and 40% respectively. [27] Like washing, only a small percentage of coal produced goes through this process in the P.R.C. [28]

The technologies involved at this stage are relatively inexpensive and low tech and could be developed and implemented by domestic producers as demand increases. The same is true of methods used to transport coal. The government can easily produce more covered rail cars to decrease localized pollution problems. At the present time, about 20% of mined coal in China is washed. Additionally, about 10% of coal ash is processed. A much smaller percentage is shaped. [29] There is a movement in the P.R.C. to develop the coal processing industry so that in ten years 50% of all coal mined will be washed, shaped or selected according to quality. Chinese coal experts are calling for the increasing of total investment in the coal extraction industry into coal processing technologies from 7% to 10% of total investment. [30] This situation should open up direct short term opportunities for U.S. firms. The United States is the world's leader in "Clean Coal" technologies.

<u>In the power plant--furnace efficiency and emissions</u>

Industrial furnace technology has developed quickly in the P.R.C. In China, there are 282 different kinds of industrial furnaces. About one dozen different kinds are used for coal-based energy production. One general problem that these furnace technologies have is their poor heat generating efficiency. It is estimated that, on average, furnaces used in power production achieve

efficiency ratings of approximately 55%. This is over 20% lower than that of industrialized countries. The consequences of lower efficiency include: increased coal waste, lower levels of energy production and increased air, water and waste pollution. [31]

The Chinese government is aware of serious waste problems associated with energy production. It is estimated that if China's energy production industry were able to increase furnace efficiency by 10% that 50,000,000 tons of coal could be saved annually. [32] While this is the case, one must ask why the energy industry has not done more to alleviate waste. One major reason is that since both coal and electricity prices are set by government organs at artificially low levels, there is little incentive for local plant managers to ask for permission to make extensive capital investments in improved furnace technologies. [33]

An even more important consequence of low furnace technology is its effect on particulate and gaseous concentrations in smokestack plumes. Alexander Economopoulos, in a recent study on hourly concentrations of particulate and gaseous matter around power plants, explains the relationship between, furnace efficiency, heat, plume velocity, stack height and particulate dispersion. Geographical and meteorological factors also affect particulate dispersion. [34] Economopoulos states that "Plume rise takes place due to momentum or buoyant forces stemming from the high velocity or high temperatures, respectively, of the exhaust gas. This momentum, or thermal plume rise is an important parameter in dispersion calculations." [35] In other words, the more efficient a furnace is, the hotter it burns. The hotter it burns, the more buoyant and the greater velocity of the thermal plume. Less particulate matter is carried into the air and particulates that do enter the air achieve higher altitudes and, therefore, can be dispersed more effectively by natural

forces. Also, the hotter the furnace the more coal and dangerous trace elements such as lead and mercury are burned and therefore do not enter the environment. Also, hotter, higher velocity plumes produce less solid waste. [36]

The major problem for U.S. firms interested in entering this market is price. One Chinese expert estimates that comparable high tech furnaces produced in China are about 1/3 of the cost of those imported from industrialized countries. He recommends that high technology be imported from industrialized nations. [37]

Air pollution control technologies

As far as specific technologies used by utilities go, there are many variations. When considering the effectiveness of these technologies a number factors must be considered. First, one must look at tons of coal used per megawatt ratios to determine the size and type of equipment appropriate to each firm. Second, industrial density must be considered. Areas that are highly developed and, therefore emit large amounts of particulate and gaseous pollution in per sq\m, require more effective controls that those located in isolated areas. Third, one must determine the effects that large pollution equipment investment will have on the operation of specific firms. Fourth, does the firm have trained personnel that are capable of installing and maintaining control equipment? This is a particularly challenging problem in the P.R.C. where educational levels of technical personnel are low. Fifth, the firm must decide along with regulatory agencies exactly what kind of emissions it wants to combat, particulate, gaseous emissions or both. Dealing with both usually requires purchasing two or more types of equipment to deal with each type of pollution.

Finally, as stated before, other factors such as the type of coal used and the type of furnace that will be used to burn the coal impact the amount of emission control needed by firms. [38] Understanding these questions is crucial to producers so that they then can develop specific products for Chinese customers.

In the P.R.C. plants vary greatly in size and level of technological development and management and engineering prowess. This analysis will primarily consider air control technologies used in large state-run coal fired electric plants. It is these plants that are most often scrutinized by central government authorities and local populations. They also often have the capital and technical ability to install and maintain pollution control devices. In most rural areas in fact, small coal fired power plants do not use any form of pollution control at all beyond smokestacks and simple stack filter systems. Most of these types of plants are conveniently located along waterways so that (untreated) waste waters from production can be conveniently disposed of.

Technologies commonly used in the P.R.C.

The most common form of pollution device used in the P.R.C., besides simple smoke stacks, is called the cyclone. Cyclones are one type of mechanical collector, a device that separates suspended particles from gases by causing the gas stream to change direction when the particles, because of their inertia, tend to continue in their original direction and are separated from the gas. [39] Cyclones generally have one or two tubes through which gaseous plumes travel. Multiple tube devices are more expensive but are also more effective. Newer plants are moving in the direction of multiple tube technology purchases in the expectation of future higher emissions standards. [40]

Cyclones are favored because of their low cost, easy maintenance (they have no moving parts) and small space requirements.

Another common classification of air pollution control device used by large utilities is the "baghouse." These fabric filter dust collectors are among the oldest of currently used pollution control technologies. [41] Despite their generally simple construction and relatively low construction costs baghouse technology, when properly maintained, effectively removes 95%+ percent of particulate matter from plumes. [42] Baghouses create few problems with liquid waste disposal and are versatile because bag types can be changed depending on changing needs. They are also simple to operate.

A less common, but still effective technology used in the P.R.C. is the "wet scrubber." There are only a few firms that produce "wet scrubbers" in the P.R.C. There are three types of wet scrubber used in the P.R.C., Spray towers, Venturi scrubbers and Cyclonic scrubbers. The most commonly used scrubber is the cyclonic scrubber. Cyclonic scrubbers are essentially cyclones with water spray nozzles built in. In some cases water is sprayed from a spray manifold located in the center of the cyclone. In other cases, spray nozzles are located on the sides of the tower. [43] These types of wet scrubbers have many advantages including their small space requirements, their ability to collect gases as well as small particulates and their ability to handle high temperature gas streams. [44] Negative problems include water disposal challenges, corrosion, acid buildup and high maintenance costs. Wet scrubbers are generally built into stack systems in the P.R.C.

Other technologies

The above technologies are often used separately, or in combination with one another or with other technologies that power utilities are experimenting with in the P.R.C. Various types of adsorber technologies have been developed and used, mostly in the chemical industry. Adsorbers use various types of solid or liquid materials, liquid gels, activated aluminum and the like, to adsorb various gaseous emissions. Some firms are also experimenting with electrostatic precipitator technology. Electrostatic precipitation is the most common method in use in the United States for removing fine solids and liquids from gas streams. [45] Electrostatic precipitators have prohibitive cost and high technological requirements that preclude the ability of most firms to use this technology. Also, its high efficiencies are more than is what is needed for most firms to meet P.R.C. emission standards.

One technology that government officials would love to get their hands on is "Liu hau chuang" or circulating air burning technology. This furnace technology is especially appropriate when burning low BTU generating coal (burning at lower temperatures). This technology reaches burning efficiencies of up to 99% and furnace efficiency of over 85%. This process also removes over 90% of sulfur for coal. This technology results in very low quantities of smoke and dust discharge. Combined with other air pollution control equipment, pollution discharge can virtually be eliminated. [46] U. S. firms lead in the development of this technology. Other cutting edge technologies will be discussed in the next section.

Extraction to Emission: Vertical Integration of the Process?

One final question regarding the emissions control industry in China is its level of integration with the overall energy production process. First of all, determining the level of vertical integration in the industry is not an easy task. In one sense, one could say that because most of the significant firms involved in raw materials extraction, transport and power generation are classified as state owned firms (as opposed to collective or private firm types) and technically come under the direct management of central government bureaucratic organs they are highly integrated. Theoretically, China Power and many of its subsidiaries throughout China do have administrative control over the various levels of production from mineral extraction to processing to power generation itself. This relative monopolistic control, however, has recently deteriorated as individual firms have used their new found autonomy from bureaucratic control to enrich themselves in various ways, often at the expense of economic efficiency. This creates chaos in the processing pipeline which is still largely controlled by government set quota pricing strategies.

What is conspicuously absent from this vertical integration is emissions control products and services. One important exception to this that was alluded to earlier is the tendency of firms to provide their own "in house" emissions control equipment. These conditions have two effects on the structure of the Chinese emissions control industry. First, since emissions control was not a high priority among government planners in its vertical integration of the energy production industry, an emissions control industry essentially did not develop. Second, firms' tendency to take care of pollution control "in house" creates a barrier for both fledgling Chinese as well as foreign suppliers. As mentioned in an earlier section, however, trends towards increasing regulation and higher air

emissions standards will be a disincentive to firms that choose following "in house" strategies because of their generally low level of technology and effectiveness.

This section has discussed the current state of air pollution policy and technology in the P.R.C. Reference has been made to United States policies and technologies so that the applicability of United States technology and know-how can be better evaluated. The energy production process, from the mine to the stack, was examined as were technologies currently in use in the P.R.C. by large state-run energy utilities. The next section will discuss the applicability of current United States technology and know-how, the current market presence of U.S. firms and the state of foreign competition for utilities in China.

The competitive position of U.S. firms in the P.R.C. market

As has already been stated, there are many factors which affect the Chinese firm's ability to acquire U.S. technology and equipment. There are also challenges which U.S. businesses must overcome if they are to establish a competitive position in China's pollution control technology market. This section will use competitive advantage theory to examine these markets and explore at which point U.S. firms, if any, have an existing or potential competitive advantage over their Chinese and foreign competitors. [47]

The major question that one must analyze has to do with demand. It has already been stated that various socio-economic factors such as inadequate educational levels, weak legal codes and enforcement and general misunderstanding of the need for pollution control affect demand for pollution control equipment. For most Chinese firms, pollution control is seen to be a residual effect

of conservation rather than the other way around. In the P.R.C. there are also political determinants that can affect demand. These include international pressure, especially from aid organizations and the development of increasingly pluralistic tendencies both within and outside of the government. There seems to be a general lack of knowledge about which control devices are appropriate to specific circumstances and there is a shortage of trained personnel to run and maintain these devices. Also, because China's economy is still underdeveloped and firms have a relative shortage of capital vis a vis firms in industrialized nations, demand is relatively price sensitive.

Socio-economic determinants of competition

Many U.S. businessmen that travel to China are mystified by the complexity of management, supply and demand relationships that exist parallel to one another. Theoretically, most firms in the power industry are owned by the state but the level of autonomy firms have varies greatly. Firms run under the state budget, collectives at various levels and private firms operate simultaneously. In addition, various types of foreign ownership structures in China including equity joint ventures, cooperative ventures and wholly foreign-owned enterprises exist in the P.R.C. Because of the importance of the power industry in the P.R.C. most power producers and input suppliers are strongly influenced by government directives. [48] Prices for energy inputs such as coal and oil, transportation to and from plants and energy produced are subsidized and heavily regulated. One major reason why power production is so inefficient and is unable to keep up with demand is that subsided prices give firms little incentive to increase efficiency. All these factors create structural barriers which may inhibit U.S. firms' ability to get a foothold in the P.R.C. A shortage of

technical personnel capable of understanding and operating advanced pollution technology is another problem that inhibits demand for U.S. products.

Energy output is still inadequate to meet current needs and energy. Input supplies, especially oil supplies are not being developed fast enough to meet China's high rate of economic growth. [49] Again, subsidized prices and relatively unadvanced technological inputs inhibit exploration and expansion of raw materials supplies. China is rich in hydro-electric power potential but this is also underdeveloped for similar reasons. Also, while hydro power is less expensive and cleaner in the long term, large initial capital investments and long production times have motivated policy makers to favor coal fired thermal power production. [50]

As was already stated, weak legal codes and enforcement also inhibit emissions control. While the Chinese government has passed a number of laws and often makes explicit statements about the need for pollution control and increased efficiency in the government's Eighth Five Year Plan, it is difficult to tell what effect these actions have had on demand for pollution control devices and related technology. [51] The plan also calls for the continued construction of a nationwide monitoring network which will have 74 meteorological monitoring stations. Also individual cities have taken steps to develop their own monitoring networks. Shanghai's Pudong Special Economic Zone, a pilot monitoring project led by a group of foreign aid organizations and technical advisors is being developed. More important than these laws, however, is the government's stated goal to continue movement away from central economic planning and related administrative structures which will lead to price and market liberalization.

The Chinese government has taken limited actions to increase the population's understanding of the need for environmental protection. As was stated before, the 1992 Rio de Janeiro Environmental Conference was extensively covered in the Chinese press and Li Peng himself attended. [52] Many universities now offer courses to future managers in environmental protection. The central government regularly praises the work of firms that have made contributions in the area of environmental control or conservation. [53] Also, there have been a number of highly publicized cases of serious environmental violations described in the Chinese press. [54] Premier Li Peng himself recently "wrote" and published a book on environmental protection. [55]

For Chinese users, another important consideration is whether pollution control equipment simply controls emissions or also increases efficiency. Related to this is the potential cost for current serious polluters that do have installed pollution equipment to improve performance of these instruments through better management procedures or additional hardware. [56] There often is, in fact, no direct relationship between initial capital cost and ultimate costs. More expensive and technologically advanced equipment often means greater durability and lower maintenance costs. The converse might be true for equipment that involves low initial capital costs. [57] In figure 4 in the appendix some major cost factors that affect the purchase and operation of pollution control equipment are summarized. Some of these include capital cost of equipment, maintenance and operation, fuel and electricity, raw materials and chemicals, installation, materials and supply, control hardware and land use.

China's competitive edge

This leads one to the question, does China's current pollution control technology industry have a strong competitive advantage over its foreign competitors? Certainly, structural barriers discussed earlier favor domestic competitors. Knowing which government bureaus to talk to and what their priorities are can be quite challenging. Many bureaucrats still distrust foreign entrepreneurs and do not fully comprehend the profit motives that drive foreign investors and sellers. These barriers are especially daunting in the energy industry which still functions under the watchful eyes of the state. Also, government authorities usually favor Chinese firms in the awarding of infrastructure projects.

In the area of pollution control law, standards and enforcement are not sufficiently stringent to encourage firms to invest in many high technology devices that U.S. industry produces. Lower level technologies, however, that are still in use in the U.S. might find a market in the P.R.C.

The primary problem that U.S. firms do and will have in the Chinese market has to do with price. At almost every stage of the pollution equipment production process, from production input prices to transportation to installation, Chinese firms hold an enormous advantage. For instance, when "Liu hua chuang" technology was mentioned earlier in the paper the Chinese author cited stated that the hardware for this technology could be produced in China at about 1/3 the price that it is produced in the United States. Present cost benefit ratios, especially for new technologies, seem to be too low for Chinese firms to purchase new equipment produced in the United States. This situation, however, is slowly changing as prices free up and reflect true supply demand ratios. U.S. firms already export about 250 million dollars in environmental goods and services to China.

(1993) The current price situation, however is not favorable to most U.S. firms interested in straight export to China.

The question of price is especially complex because of the myriad equipment that is used for air pollution control, differing price calculation techniques and differing technological standards. Machinery commonly used in the U.S., for example might only be used on an experimental basis in China. Differing regulatory standards are a major reason for these disparities. Machinery that is seen to be necessary in the U.S. might be viewed as "overkill" in the P.R.C. where more lax standards and weak enforcement prevail. Also, the cost of control hardware itself makes up less than half of initial capital outlay. Each type of coal fired generation plant requires different types of equipment depending on location, age, type of furnace and turbine technology used types of pollutants emitted, and types of coal used in the combustion process. Systems are usually custom assembled.

These problems can be illustrated by describing one type of setup marketed by Bayliss-Trema Inc. Let us take the example of a small ten MW coal fired power plant. This hypothetical power plant requires equipment to control both particulate and $S0^2$ emissions. In this instance Bayliss-Trema recommends that the plant purchase a venturi scrubber capable of removing 50,000 actual cubic feet of flow gas (ACFM). The equipment itself costs $1,000,000 and installation is an additional $1,000,000. The reason for the high installation cost is that they must customize and assemble the unit on-site. To control particulate emissions the company recommends a cyclonic dryer for an additional $600,000 including installation. In another example, Dust Collection Industries recommends combining a power cyclone with a wet baghouse filter system. This

combination including installation runs about $1,000,000. At first glance it seems as though the second system is more cost effective but when you calculate the long-term operating and maintenance costs of the baghouse system, overall outlays are fairly close.

Because of the importance of maintenance costs to overall cost, many firms look at price per megawatt produced or price per ACFM removed. Figure 5 shows how these costs are calculated for three different types of technologies.

As mentioned before, most firms use no more than chimneys with simple steel filters for pollution control. These structures can be built for a few thousand dollars. Some newer firms have dry cyclonic collectors that primarily remove particulate matter. For an equivalent power plant in the P.R.C. management might spend anywhere from $10,000 to $100,000 to purchase and install such equipment. This equipment, however, might only remove 70% of particulate emissions versus 90% percent for U.S. products. A similar situation exists in the case of a Chinese firm that purchases a wet scrubber or baghouse technology to control gaseous emissions. Initial capital outlays might be 1/10 of the cost of equipment produced in the U.S. but is also less effective in controlling emission levels. Because installation and maintenance is very labor intensive, Chinese firms have a tremendous advantage over U.S. exporters. Average wages in China for skilled labor are approximately 2500 Yuan or $500 per year whereas the wages for similarly skilled personnel in the U.S. are twenty times higher. Few Chinese technicians, however, have the ability to properly install and maintain pollution control devices. Although, U.S. firms can mitigate wage and production price deficiencies by producing products in the P.R.C., developing this capability and training local personnel can take years.

Competitive advantages of U.S. firms

U. S. firms have four major competitive advantages over their Chinese counterparts. First, the Chinese pollution control industry is relatively small and underdeveloped while the U.S. industry is the largest in the world. Second, U.S. firms have much more advanced technology to offer their customers. Third, U.S. pollution technology is highly respected in the P.R.C. Fourth, much newer U.S. air pollution control technology emphasizes energy conservation as well as emission control. Fifth, the U.S. government has taken a more active role in the development of new technologies and the marketing of domestic environmental goods and services.

The significance of these advantages varies considerably. The first advantage is unarguable based on much evidence presented in this paper. The second advantage, however, is a small one because of the low cost of labor inputs in the P.R.C. Most new technology that is currently used and is being developed in the U.S. is very capital intensive, whereas Chinese firms are more likely to favor technologies that allow them to use their own natural labor cost advantages. For instance, cyclone and baghouse hardware is relatively cheap but labor inputs needed to maintain them are higher. Conversely, many U.S. utilities favor electrostatic precipitation technology which requires large initial capital investments but is relatively easy to maintain.

The third advantage that U.S. firms seem to have, reputation, is also more and more suspect because of strong efforts by foreign competitors to promote their own technologies. Japan's government actively uses aid and loan assistance to introduce Chinese consumers to Japanese technology, and aid projects that involve pollution technology often require that technology be

purchased from Japanese manufacturers. [58] Also, Japanese investments in infrastructure projects such as coal extraction and energy production are much greater in the P.R.C. than that of U.S. firms. This gives Japanese manufacturers such as Matsushita and Fuji a head start in competing for future business. The German government has followed a similar strategy, promoting the technology of such companies as Siemeins and Dalemer Benz. [59]

The fourth advantage that U.S. firms have over their Chinese counterparts is a significant one, that newer U.S. technologies are more geared towards energy conservation as well as emissions control. There is an increasing movement towards not only reprocessing emission gasses and particles but more directly to integrating boiler and emissions technologies. The greatest emissions benefits from these technologies are gained when high sulfur coal is used, which is in abundance in China. [60] Some of these technologies include: Limestone Injection Multistage Burners, Low NO_X Burners, and Advanced Silicate Burners. The last technology seems to be the most promising. It is able to achieve 90% removal at 50% of the cost of a wet scrubber. Each of these technologies can usually be retrofitted onto existing boiler configurations. The new technology that is most widely in use today and that works especially well with high sulfur coal is wet flue gas desulfurization technology. Some firms involved in the development of these technologies include: W.R. Grace, MK-Ferguson, various utilities, General Electric and Fluor. [61]

A final advantage that has recently developed is that the U.S. government is beginning more active involvement in developing the domestic environmental industry and promoting exports. The Department of Commerce's "Environmental Technologies Exports Strategies: Framework for U.S. Leadership: A National Agenda" discusses this strategy. Some aspects of this strategy include:

interagency coordination of export promotion and market development, expansion of government trade tied aid financing to energy industries, identification of specific technologies that have the best export prospects and active involvement in the development of new domestic technologies. [62]

Competitive advantages of other foreign suppliers

As mentioned before, the U.S. government is not the only one actively encouraging environmental exports. Japan, Germany, Italy and other nations offer many incentives to both suppliers and consumers of these products that in many cases far exceed U.S. incentives. The Japanese government, for instance subsidizes both its domestic environmental industry, as well as firms that export environmental products. These subsidies can range from tax breaks to low cost loans to outright government grants. These benefits allow medium sized and small firms to control the high costs associated with establishing an overseas market presence. The Japanese government also offers government assisted financing to foreign customers. This is especially important to cash strapped Third World countries such as China. The proliferation of these types of programs has, in a sense, created a buyers market in which government and individual firms can shop around for the cheapest total pollution control "package." The U.S. has made some progress in promoting these types of package deals but still lags in this area of market penetration. Also, Japanese and German firms are more oriented towards exporting than are U.S. firms. For instance, only 10% of total production of U.S. environmental goods and services is exported. [63]

Breaking into the P.R.C. market

Judging from the above competitive advantage analysis, it seems as though it will be difficult for U.S. firms to export assembled U.S. pollution control hardware to China in the short term. There are, however, a number of ways that firms can mitigate the competitive advantages of Chinese competitors as demand for pollution control and related equipment increases. One of the most common ways of doing this is for U.S. firms to enter into joint ventures with domestic producers. A number of U.S. environmental firms have already taken this path. This allows them to take advantage of lower labor costs and personal business relationships and to benefit from established Chinese firms and government organs. This has, in fact, been done by boiler technology firms, especially in the area of steel production. This strategy is favored by Chinese companies because they usually can benefit from preferential tax provisions extended to foreign investors and capital investment infusions, as well as technology transfer from U.S. businesses.

U.S. firms do have a presence in the P.R.C. but their pollution services are only peripheral to their planning, engineering and production efforts. It does seem likely that firms that offer a diverse array of services have a better chance of success in marketing U.S. pollution technology than companies that specialize in environmental technology alone. One way that firms specializing in environmental technology can take advantage of this situation is to enter into joint marketing agreements with multi-nationals already in China. [64]

Another way that air pollution control firms can market their wares is by entering into cooperative technology sharing agreements with Chinese producers. In these kinds of agreements, a cash price is paid over a period of years to the company that supplies a particular technology. This

strategy is also favored by Chinese companies that do not have the capital resources or incentive to develop new technologies on their own.

Establishing wholly owned foreign subsidiaries in the P.R.C. is another possible option. This option allows foreign firms to maintain control over technology, know-how and management. The larger capital investment involved in this strategy, socio-economic and structural barriers and the underdeveloped nature of the marketplace, however, might make this a less desirable option. [65]

Other opportunities for United States firms

Despite U.S. environmental firms' current problems related to the sale of air pollution technology in the P.R.C., there are many other stages of the energy production process, both directly and indirectly related to environmental protection at which U.S. firms can, and do compete. U.S. businesses are leaders in the areas of coal and energy exploration. Chevron, Unocal, Occidental and other major U.S. energy producers have investments in the P.R.C. In the area of coal mining and extraction, Bechtel, Fluor and Dravo Wellman have extensive business interests in China. In the area of pollution monitoring equipment, Honeywell and Johnson Controls have established a presence in the P.R.C. U.S. steam generating and boiler technology is also in demand in the P.R.C. U.S. products in these areas are highly efficient and as Chinese input and output price structures are liberalized, U.S. presence should increase. It is also possible that there may be opportunities for marketing used pollution control equipment to Chinese firms.

The areas, however, that offer the greatest near-term advantage to U.S. firms are infrastructure planning, consulting and related environmental services. Firms such as China Energy

Ventures and Foster Wheller Corporation offer extensive advisory services to Chinese firms and to the Chinese government. P.R.C. firms realize that they need Western technology and know-how so U.S. service firms have a significant competitive advantage over their Chinese competitors. One major barrier, however, that still stands in the way of greater market penetration by U.S. service firms has to do with different Chinese perceptions about the monetary and practical value of services. Many Chinese firms are mystified as to why they must spend millions of dollars just to plan large projects. As capitalism takes root in China and China's own service industries develop this psychological barrier should become less formidable.

Of course the market for U.S. services is not limited to Chinese customers. Thousands of foreign manufacturers dot the Chinese countryside and are in need of pollution control services as well.

Long term benefits of market penetration

None of the above market penetration strategies should be undertaken without careful long term planning. Establishing a presence in the P.R.C. requires great patience and a significant up-front capital investment. Firms should not expect short term returns from their efforts.

This section outlines the scope of the Chinese air pollution control industry. Various types of technologies in wide use in the P.R.C. including wet scrubbers, baghouses and cyclones are discussed in reference to U.S. technologies and their applicability to the Chinese market. The energy production process, from the mine to combustion and emissions are discussed to show the complexity of the production process and to examine other possible opportunities for U.S.

investment in pollution control. It seems evident that Chinese firms are interested in acquiring U.S. technology but various factors discussed above put U.S. firms at a competitive disadvantage vis a vis Chinese firms.

Despite these drawbacks, this section discusses various actions that U.S. firms can take to improve their competitive position and break into the P.R.C. market. Some of these actions include: 1. Encouraging the U.S. government to actively promote U.S. technologies, 2. Establishing joint ventures with P.R.C. environmental control firms, 3. Establishing alliances with U.S. multinationals already involved in planning, engineering, infrastructure and construction projects in the P.R.C. so that these firms can market their technologies and, 4. Expand marketing efforts to foreign firms that have manufacturing facilities in the P.R.C.

Conclusion

This analysis attempts to develop a strategy for analyzing present and future export opportunities for U.S. environmental firms in the area of air pollution control for the energy production industry in the P.R.C.. Competitive advantage analysis is used to discover boundaries, strengths and weaknesses of the Chinese air pollution control industry and to look at these in the contexts of U.S. technologies and experiences. Because of a lack of quantitative information on specific firms, their sales and market shares, this analysis reaches broad and general conclusions about market penetrations and offers general recommendations to U.S. firms interested in expanding in the P.R.C..

Summary of findings

Competitive advantages of Chinese firms

There are a number of advantages that Chinese firms have in their own home market. Differing U.S. and Chinese views on acceptable pollution control levels favor Chinese companies. Weak legal codes and enforcement of laws inhibit demand for more effective technologies. Shortages of trained personnel to maintain technologies add cost to U.S. equipment purchases. A general lack of knowledge about the effects of pollution on the environment among firm managers and the general populace inhibits demand for more effective technologies. Various structural barriers such as import substitution policies, vertical integration of the energy industry, weak patent protection, cultural differences, corruption, currency control and government investment directives stand in the way of U.S. firms wanting to break into the market. Slow movement on the part of government organizations regarding the issue of pollution control limits demand for new technologies. Another important barrier is that most Chinese firms do not have adequate capital resources to invest in new pollution control equipment. Most U.S. products manufactured in the U.S. are too costly to justify investments by Chinese firms. Cheaper labor costs encourage firms to favor labor intensive technologies. U.S. technologies are more capital intensive. Finally, continued input and output subsidies which artificially decrease the cost of production and consumption discourage firms from purchasing new technologies.

Competitive advantages of foreign firms

There are a number of advantages that foreign firms have that can affect the ability of U.S. firms to penetrate the Chinese air emissions control devices market. Many other industrialized nations, especially Germany and Japan, have mature pollution control industries. These and other governments use foreign aid political influence to encourage adoption of their respective technologies.

Competitive advantages of U.S. firms

Despite these challenges from both Chinese and foreign firms there are some advantages that the U.S. emissions control industry has that could help its long term move into the Chinese market. For one thing, the Chinese pollution control industry is underdeveloped. U.S. technologies are more advanced than those of their Chinese counterparts. They are also, on the whole, at least equivalent to and in many cases, technologically superior to their other foreign counterparts. Development of this industry has been strongly enhanced over the past few decades by increasingly stringent government regulation of air pollution standards. Another important advantage is that U.S. pollution control technology is highly respected in the P.R.C. This reputation and visibility will be enhanced by the already extensive involvement of U.S. engineering, mining and construction firms in China which have also gained a high reputation in Chinese industry and government circles. As mentioned before, the U.S. government's targeting of environmental technology products as a major area of future export growth should also enhance the visibility of and sales of U.S. products

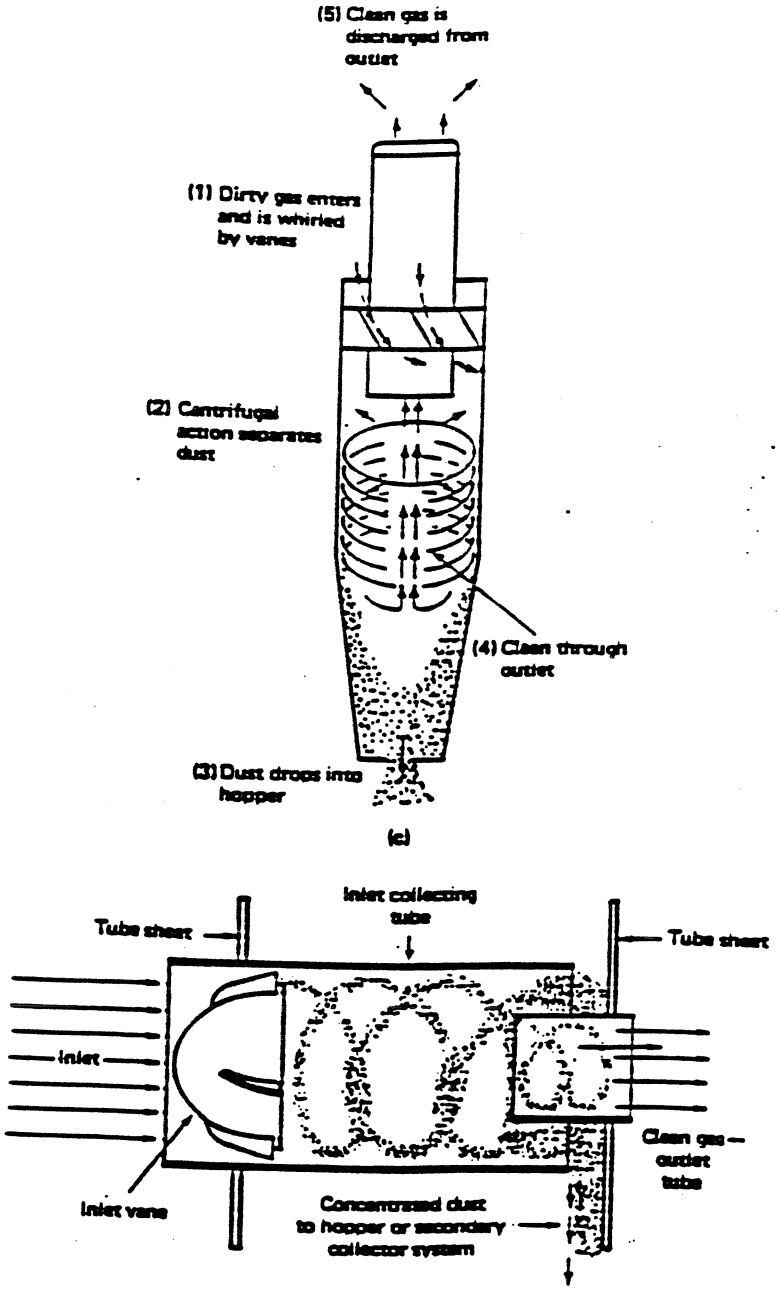
in this area. Finally, newer U.S. pollution control technologies put strong emphasis on resource conservation and production efficiency as well as pollution control.

While opportunities for environmental technology companies seem limited at the moment, as the Chinese economy grows and pollution problems become more severe, China's underdeveloped pollution control industry is going to be hard put to deal with increasing demands for better controls and technologies. This author believes that that there is enough evidence to show that U.S. firms do have some competitive advantages over the long term, especially if they establish joint ventures in the P.R.C..

One only needs to look to the experience of China's Asian neighbors, Japan, South Korea and Taiwan to see how social, political and economic costs of waste and pollution have forced these countries to take action to improve their environmental records and technical efficiency. It seems that in each of these cases, the growth of democratic institutions and avenues for expressing dissent are also directly linked to environmental control. While the leadership of the P.R.C. remains largely authoritarian, there is widespread evidence that the P.R.C. is becoming a much more pluralistic society, a society which is less and less afraid to express its views regarding the destruction of their environment. [66]

Despite existing barriers and challenges, U.S. firms, with government help, must forge ahead in developing the Chinese market. As stated before, the Asia-Pacific region is the fastest growing export market in the world and the U.S. must actively develop this market if it is going to maintain its own economic growth. If it does not act quickly, other nations will fill the environmental goods and services void in the region.

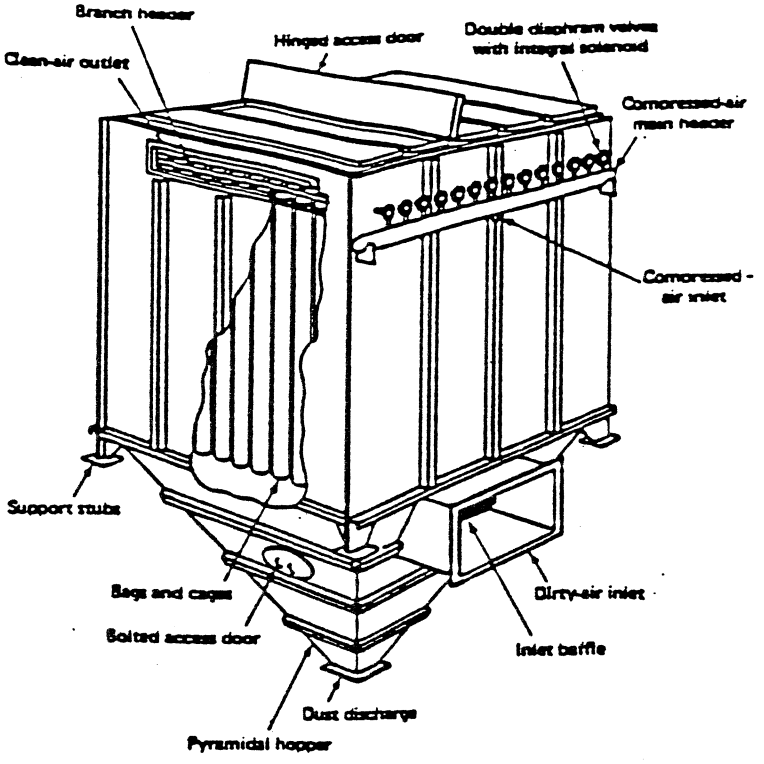
China's developmental path is in many ways similar to that of industrialized nations. Fifty years ago, the United States also had similar pollution problems and inadequate legal provisions for their control. There, however, is one major difference. The sheer size of China's population and economy and its dependence on coal will have long term environmental consequences that former environmental blunders by the industrialized world did not have. In as little as ten years P.R.C. production of greenhouse gases could surpass that of the United States. Can the world environment sustain such high levels of pollution? If the P.R.C. and the world community do not do more to combat this serious threat, we will all suffer from the consequences.



Cyclone

Figure 1

Figure taken from Air Pollution Control Equipment, p. 179



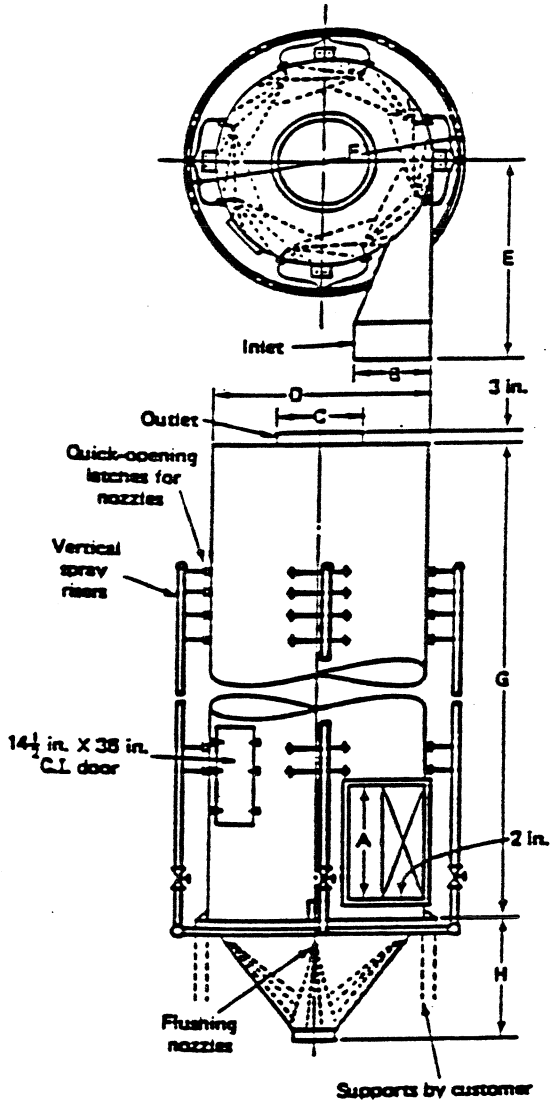
Pulse-jet cleaning—parameters.

Frequency	Usually, a row of bags at a time, sequenced one row after another; can sequence such that no adjacent rows clean one after another; initiation of cleaning can be triggered by maximum-pressure-drop switch or may be continuous
Motion	Shock wave passes down bag; bag distends from cage momentarily
Mode	On-stream in difficult-to-clean applications such as coal-fired boilers, off-stream compartment cleaning being studied
Duration	Compressed-air (100 psi) pulse duration 0.1 sec; bag row effectively off-line
Common bag diameter	5–6 in.

Pulse Jet Baghouse

Figure 2

Taken from Air Pollution Control Systems, p. 203.



Cyclonic Wet Scrubber

Figure 3

Taken from Air Pollution Control Equipment, P. 241.

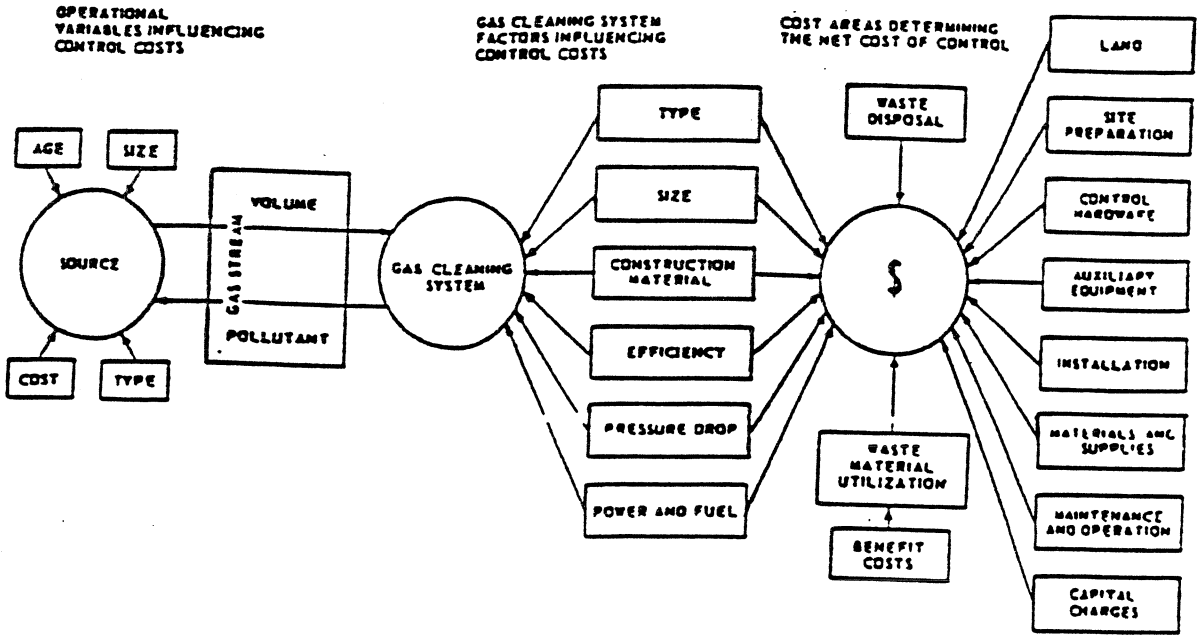
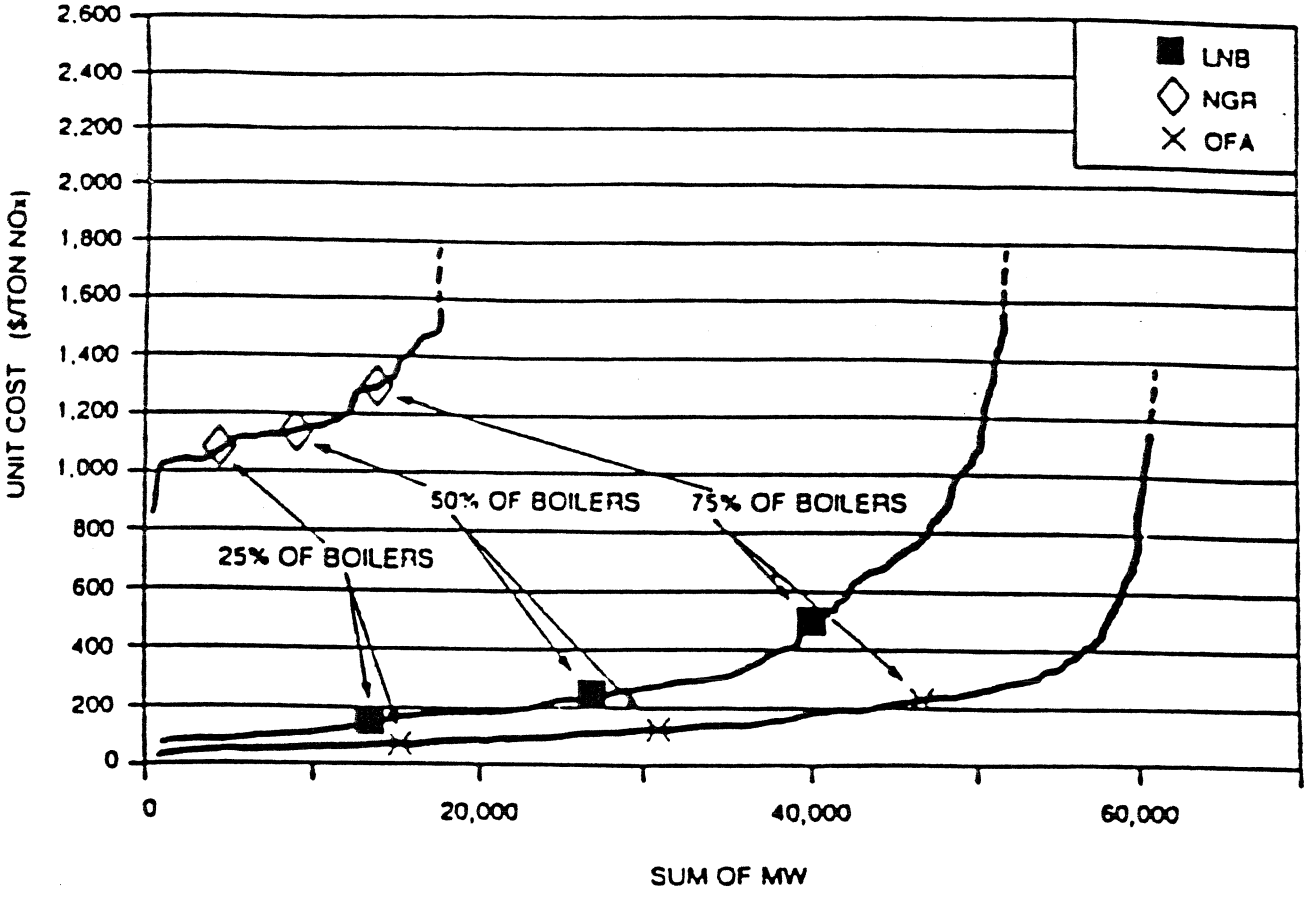


Diagram of cost evaluation of a gas cleaning system

Figure 4

Figure taken from Process Engineering and Design for Air Pollution Control, p. 25.



LNB = Low Nox Burners

NGR = Natural Gas Burners

OFA = Overfire Air

Summary of cost per ton of Nox removed from low Nox combustion.

Figure 5

Endnotes

[1] United States Department of Commerce, National Trade Data Bank, (Washington D.C.: Department of Commerce, 1993a), 2.

[2] Ezra Vogel, One Step Ahead in China: Guangdong Under Reform (Cambridge: Harvard University Press, 1989), 1-50.

[3] William Porter, "Is China on the Road to Destruction?" World Watch (April 1993): 93.

[4] Stephen Lippet, "China Expands U.S. Purchases to Avert Trade Actions," Wall Street Journal, 23 Jan. 1993, A4.

[5] Porter, 97.

[6] Porter, 98.

[7] Liang Chao, "Deficit Soars as Trade Grows 18.2%," China Daily 10 Jan. 1994, 1.

[8] John Pearce and Richard Robinson, Formulation, Implementation and Control of Competitive Strategy (Boston: Irwin Publishing, 1991), 96.

[9] Pearce and Robinson, 101.

[10] Lawrence Jaunch and James Townsend, Cases in Strategic Management and Business Policy (New York: McGraw Hill Publishing, 1990), 9.

[11] J. V. Koch, "Industry Market Structure and Industry Price-Cost Margins," Industrial Organization Review (June 1994): 186.

[12] United States Department of Commerce, National Trade Data Bank, "Clean Coal Technology Demonstration Program" and "Environmental Technologies Export Strategies: A National Agenda," (Washington D.C.: Department of Commerce 1993).

[13] Weimin Cheng, "Coal Tries to Get Back into Black," China Daily, 12 June, 1992, 7.

[14] Dizhong Liu, "Li Cites Five Key Principles," China Daily, 13 June 1992, 1.

[15] Baoxia Zhu, "China More Aware of Ecology Problems," China Daily, 6 June 1992, 4.

[16] Zhenggong Gao, "Last Chance to Control Population Explosion," China Daily, 1 June 1992, 4.

[17] Shonggun Sun, "Government Reveals Agenda for the Nation's Development," China Daily, 16 April 1994, 1.

[18] Geping Qu, "Pollution Remains Serious Problem Despite Environmental Cash," China Daily, 16 March 1994, 1. Also see Ransheng Yong, "Laws on Environment Now Require Amendment," China Daily, 31 Jan. 1994, 4.

[19] Yong, 4.

[20] Hanchao Liu, "Large Energy Producers Should Pay More Attention to Energy Conservation," (Chinese) Energy in China (Nov. 1991): 28-30.

[21] United States Department of Commerce, "Environmental Technologies Export Strategies: Framework for U.S. Leadership: A National Agenda," 1-12.

[22] Hancheng Wang, Air Protection and Energy Utilization, (Chinese) (Beijing: China Environment and Science Publishing House, 1992), 5-12.

[23] Gary Lindgren, Managing Industrial Hazardous Waste, (Ann Arbor: Lewis Publishers, 1989), 16-20.

[24] Peter Bibbo, "Electrostatic Precipitators," in Air Pollution Control Equipment ed. Louis Theodore (Ann Arbor: Lewis Publishers, 1989), 283.

[25] Ian Huchison and Richard Ellison, Mine Waste Management: Resource for Mining Industry Professionals, Regulators and Consulting Engineers, (Ann Arbor: Lewis Publishers, 1992), 141.

[26] Jieming Hao and Guangda Ma, Air Pollution Control Engineering, (Chinese) (Tianjin: Tianjin University Press, 1992), 5.

[27] Xinrong Qian, "Technical Countermeasures for Decreasing the Environmental Impact of Coal Utilization," (Chinese) Energy in China (April 1992): 43-46.

[28] Liangdong Zhu, "Establish the Conditions for Improving Environmental Pollution By Enhancing Coal Utilization Rates," (Chinese) Energy in China (Aug. 1992): 9-12.

[29] Yuying Zhao, "Preliminary Approach to Technical Development of Chinese Energy Conservation in the Last Ten Years," (Chinese) Energy in China (Oct. 1990): 12.

[30] Zhao, 9.

[31] Zhu, "China More Aware of Ecology Problems," 12.

[32] Zhu, "China More Aware of Ecology Problems," 10.

[33] Ying Chen, "Attaching Great Importance to the Value of Coal is the Premise for Enhancing the Economic Benefits of Coal Enterprises," (Chinese) Energy in China (Feb. 1992): 1-3 and 27-32.

[34] Alexander Economopoulos, "A Model for the Critical Hourly Concentration, Receptor Distance and Meteorological Conditions for Point Sources with Momentum-Dominated Plume Rise," Environment International 18 (Spring 1992): 73-85.

[35] Economopoulos, 76.

[36] Louis Theodore and Anthony Bunicore eds., Air Pollution Equipment: Selection, Design and Maintenance, (Englewood: Prentice Hall, 1982), 223.

[37] Yi Chao, "Burning Coal and Pollution Control," (Chinese) Energy in China (April 1993): 1-4.

[38] Wang, 12.

[39] Herbert Kaplan, "Mechanical Collectors," in ed. Louis Theodore, Air Pollution Control Equipment, 171.

[40] Shanghai Chaojing Dust Removal Device Factory Promotional Materials, 1992.

[41] John Mckenna, "Baghouses," in ed. Louis Theodore, Air Pollution Control Equipment, 195.

[42] Hao and Ma, 263.

[43] Hao and Ma, 243.

[44] Hunan Chanshan Dust Collector Factory promotional materials, 1992.

[45] Bibbo, 284.

[46] Liangdong Zhu, 11-12.

[47] Pearce and Robinson, 48.

[48] Price Waterhouse, Investors Guide to the People's Republic of China, (New York: Price Waterhouse, 1990): 193-196.

[49] Economist Intelligence Unit, Economist Intelligence Unit Country Profile: China 1992-1993, (London: The Economist Publications, 1992), 17-22.

[50] Economist Intelligence Unit, 36.

[51] Economist Intelligence Unit, 38.

[52] China Statistical Bureau, People's Republic of China Yearbook, 1991-1992, (Beijing State Statistical Bureau, 1992), 27-28.

[53] China Statistical Bureau, 456.

[54] "Li Peng Attends Rio Conference," Foreign Broadcasting Information Service: China, (15 July 1993): 22. Also see Xinhua, "State Crackdown Aims to Protect Environment," Foreign Broadcasting Information Service: China, (18 April 1994): 3.

[55] Xinhua, "Crackdown on Environmental Law Violators," Foreign Broadcasting Information Service: China, (27 May 1992): 27.

[56] Jaime Benitez, Process Engineering and Design for Air Pollution Control, (Englewood Cliffs: Prentice Hall, 1993), 25.

[57] Benitez, 1-3.

[58] Xinhua, "Japan to Cooperate in Coal Desulfurication Project," Foreign Broadcasting Information Service: China, (17 May 1993): 18.

[59] Xinhua, "German Firm Plans Tianjin Economic Venture," Foreign Broadcasting Information Service: China, (14 April 1992): 22.

[60] Frank Princiotta, "Pollution Control for Utility Power Generation, 1990-2000," in Environmental Management in the 21st Century, (Englewood Cliffs: Prentice Hall, 1992), 635.

[61] J. L. Halsbeck and M. C. Woods, "Plant Test Data on the NOXSO Flue Gas Desulfurication Treatment System," in Integrating Environmental Controls and Energy Production, (Boulder: A. S. M. E. Working Papers, 1991), 11-12.

[62] United States Department of Commerce, "Environmental Technologies Export Strategies: Framework for U. S. Leadership: A National Agenda," 1-10.

[63] United States Department of Commerce, "Clean Coal Demonstration Program," 9-11.

[64] US-China Business Council. China Business Directory, (Hong Kong: China Business Publications, 1989), 8-13.

[65] Price Waterhouse, 197-98.

[66] A. Tisdell, Economic Development in the Context of China, (Armonk: M. E. Sharpe, 1993), 201-203.

Bibliography

Benitez, Jaime. Process Engineering and Design for Air Pollution Control. Englewood Cliffs: Prentice Hall, 1993.

Bibbo, Peter. "Electrostatic Precipitators." In Air Pollution Control Equipment. Ed. Louis Theodore. Ann Arbor: Lewis Publishers, 1982.

Chao, Liang. "Deficit Soars as Trade Grows 18.2%." China Daily, (10 Jan. 1994), p.1

Chao, Yi. "Coal Extraction Technology and Pollution Control," Energy in China (April 1993): 38.

Chao, Yi. "Burning Coal and Pollution Control." (Chinese) Energy in China (April 1993): 1-4.

Cheng, Weimin. "Coal Tries to Get Back into Black." China Daily, 12 June 1992, 7.

Chen Ying. "Attaching Great Importance to the Value of Coal is the Premise for Enhancing the Economic Benefit of Coal Enterprises." (Chinese) Energy in China (Feb. 1992) 1-32.

Chen Zhaoming. "USA Countermeasures and Control of SO_2 Emissions From Coal-Powered Thermal Power Stations." (Chinese) Energy in China (June 1992) 31-32.

China Statistical Bureau. People's Republic of China Yearbook: 1991-1992. Beijing: State Statistical Bureau, 1992.

Ding, Zhao. "Pondering the Comprehensive Utilization of Coal." (Chinese) Energy in China (Sept. 1992): 9-12.

Du Lian and Gao Jie. "The Coal Mining Environment Will Be Improved." (Chinese) China Environment News (Feb. 1992): 1-5.

Economist Intelligence Unit. Economist Intelligence Unit Country Profile 1992-1993. London: The Economist Publications, 1992.

Economopoulos, Alexander. "A Model for the Critical Hourly Concentration, Receptor Distance and Meteorological Conditions for Point sources with Momentum-Dominated Plume Rise." Environment International (Spring 1992): 73-85.

Gao Zhenggong. "Last Chance to Control Population Explosion." China Daily, 1 June 1992, 4.

Hao Jieming and Ma Guangda. Air Pollution Control Engineering. (Chinese) Tianjin: University Press, 1992.

Haslbeck, J. L. and M. C. Woods. "Plant Test Data on the NOXSO Flue Gas Desulfurization Treatment System." In Integrating Environmental Controls and Energy Production. Boulder: A. S. M. E. Working Papers, 1991.

Hueting, Roeffie and Christian Leipert. "Economic Growth, National Income and Blocked Choices for the Environment." The Environmentalist (Jan. 1990): 25-37.

Huang, Yicheng. "About the Management System of Hydropower Plants." (Chinese) Energy in China (June 1991): 5-8.

Hunan Chanshan Dust Collector Factory Promotional materials, 1992.

Hutchison, Ian and Richard Ellison. Mine Waste Management: Resource for Mining Industry Professionals, Regulators and Consulting Engineers. Ann Arbor: Lewis Publishers, 1992, 141.

Jaunch, Lawrence and James Townsend. Cases in Strategic Management and Business Policy. New York: McGraw-Hill Publishing, 1990.

Janicke, Martin. "Conditions for Environmental Policy Success: An International Comparison." The Environmentalist (Jan. 1992): 47-58.

Jiang, Zhenping. "Looking Back at Forty Years of Energy Policy." (Chinese) Energy in China (Feb. 1992): 9-15.

Kaplan, Herbert. "Mechanical Collectors." In Air Pollution Control Equipment. Ed. Louis Theodore. Ann Arbor: Lewis Publishers, 1982.

Koch, J. V. "Industry Market Structure and Industry Price-Cost Margins." Industrial Organization Review (June 1974): 186-193.

Leung, Chi-Keung. Resources, Environment and Regional Development. Hong Kong: University of Hong Kong Press, 1989.

Lindgren, Gary. Managing Industrial Hazardous Waste. Ann Arbor: Lewis Publishers, 1989.

Lippet, Stephen. "China Expands US Purchases to Avert Trade Action," Wall Street Journal, 23 Jan. 1993, A4.

Lippet, Victor. The Economic Development of China. Armonk: M. E. Sharpe, 1987.

Liu, Dizhong. "Li Cites Five Key Principles." China Daily, 13 June 1992, 1.

Liu Hanqiao. "Large Energy Producers Should Pay More Attention to Energy Conservation." (Chinese) Energy in China (Nov. 1991): 28-30.

Mckenna, John. "Baghouses." In Air Pollution Control Equipment. Ed. Louis Theodore. Ann Arbor: Lewis Publishers, 1982.

Pearce, John and Richard Robinson. Formulation, Implementation and Control of Competitive Strategy. Boston: Irwin Publishing, 1991.

Porter, William. "Is China on the Road to Environmental Destruction?" World Watch (April 1993): 80-93.

Price Waterhouse. Investor's Guide to the People's Republic of China. New York: Price Waterhouse, 193-196.

Princiotta, Frank. "Pollution Control for Utility Power Generation, 1990-2020." In Environmental Management in the 21st Century. Englewood: Prentice Hall, 1992.

Qian Xinrong. "Technical Countermeasures for Decreasing the Environmental Impact of Coal Utilization." (Chinese) Energy in China (April 1992): 43-46.

Qu Geping. "Pollution Remains Serious Problem Despite Environmental Cash." China Daily, 16 March 1994, 1.

Rahim, Kalid. "Internationalization of Externalities: Who Bears the Cost of Pollution Control?" The Environmentalist (Jan. 1991): 19-21.

Shanghai Chaojing Dust Removal Device Factory promotional materials, 1992.

Shu, Huifen. "Energy and Environmental Protection Should be Developed Synchronously." (Chinese) Energy in China (May 1992): 43-45.

Smil, Vaclav. China's Environmental Crisis: An Inquiry into the Limits of National Development. Armonk: M. E. Sharpe, 1993.

Sun Shonggun. "Government Reveals Agenda for the Nation's Development." China Daily, 16 April 1994, 1.

Technology Control Bureau. Emission Standards of Air Pollutants for Coal Burning Boilers. Beijing: China Environmental Protection Bureau, 1992.

Theodore, Louis and Anthony Bunicore, eds. Air Pollution Control Equipment: Selection, Design and Maintenance. Ann Arbor: Lewis Publishers, 1982.

A. Tisdell. Economic Development in the Context of China. Armonk: M. E. Sharpe, 1993.

US-China Business Council. China Business Directory. Hong Kong: China Business Publications, 1989.

United States Department of Commerce. National Trade Data Bank. Washington DC: Department of Commerce, 1993a.

-----. "Clean Coal Technology Demonstration Program." Washington DC: Department of Commerce, 1993b.

-----. "Environmental Technologies Exports Strategies: Framework for US Leadership: A National Agenda." Washington DC: Department of Commerce, 1993c.

Vogel, Ezra. One Step Ahead in China: Guangdong Under Reform. Cambridge: Harvard University Press, 1989.

Wang Hancheng. Air Protection and Energy Utilization. (Chinese), Beijing: China Environment and Science Publishing House, 1992.

Xinhua. "Li Peng Attends Rio Conference. Foreign Broadcast Information Service (F.B.I.S.): China (15 July 1992): 5.

Xinhua. "Crackdown on Environmental Law Violators," F. B. I. S.: China (27 May 1992): 27.

Xinhua. "Japan to Cooperate in Coal Desulfurization Project," F. B. I. S.: China (17 May 1993): 18.

Xinhua. "German Firm Plans Tianjin Economic Venture," F. B. I. S.: China (14 April 1992): 22.

Xinhua. "State Crackdown Aims to Protect Environment." China Daily, 14 April 1994, 3.

Yong, Ransheng. "Laws on Environment Now Require Amendment." China Daily, 31 Jan. 1994, 4.

Zhang Jingsheng. "Looking Forward to the Development of Hydropower in the Interest of Energy Development and Environmental Protection in China." Energy in China (March 1992): 1-2.

Zhang Jiwu. "Lessons From the 7th Five Year Plan Period: Coordinating Between Energy and the National Economy." (Chinese) Energy in China (Oct. 1991): 5-9.

Zhang, Zhao. "Overall Spread of "Both use Coal and Ash" Methods and the Development of the "No Waste Ash Power Plant." (Chinese) Energy in China (Jan. 1991): 12-15.

Zhao, Yuying. "Preliminary Approach on Technical Development of Chinese Energy Conservation in the Last Ten Years." (Chinese) Energy in China (Dec. 1990): 1-6.

Zhu, Baoxia. "China More Aware of Ecology Problems." China Daily 5 June 1992, 4.

Zhu Liangdong. "Establish the Conditions for Improving Environmental Pollution by Enhancing Coal Utilization Rates." (Chinese) Energy in China, (Aug. 1992): 9-12.