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Issues in Urban Air Pollution: Review of the Beijing Case

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This is the first in a series of three case studies looking into issues related to air pollution in urban areas. The remaining two refer to Mexico City and Ankara. While the other two diagnostic case studies are based on facts-finding missions to the countries, the Beijing case is a desk exercise which draws on existing publications, research results and studies carried out in and outside the World Bank and Resources for the Future. Partial funding was provided by the Norwegian Trust Fund for health and the environment.

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ABSTRACT

This diagnostic case study is organized into three parts: the context for Beijing's air pollution problems, a detailed description of these problems, and our findings on the key issues and recommendations for future studies to help improve air quality in Beijing.

The first part includes a discussion of the economic situation in China as it affects urban air pollution problems, followed by a presentation of the physical, demographic, and economic context for Beijing's air pollution problems. Next, the report describes and offers reasons for Beijing's air pollution problems. The institutional context for addressing these problems is then discussed, paying most attention to the environmental protection laws. The implications for pollution control of China's mix of centralized planning and markets is then explored. The government's agenda for dealing with its pollution problems, and suggestions made by experts outside of China are then presented.

The second part of the report compares Beijing's air quality to Chinese and other air quality standards, examines the sources of emissions, mainly coal handling and burning, Beijing's greatest air pollution problem, and the health effects associated with exposure to air pollution. The third part presents the key issues and some straightforward options for improving environmental quality which do not necessarily imply trade-offs with economic growth, and provides brief descriptions of proposed research projects to address many of the key issues and facilitate implementation of many of the pollution control options.

ISSUES IN URBAN AIR POLLUTION: REVIEW OF THE BEIJING CASE

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BEIJING DIAGNOSTIC CASE STUDY

I. INTRODUCTION

Economic Background

During 1965-1978, China's GNP grew more than 7 percent per year while industrial production increased 65 percent. Net material product (GNP minus a major portion of the service sector) increased at 9 percent per year from 1976-1985, due primarily to productivity growth [17]. In the early 1980s China began de-emphasizing growth in heavy industry in favor of smaller scale, more decentralized production.

During this period, there was mounting concern about the inefficient use of energy and environmental degradation, from urban pollution to acid rain and global warming. As a result, the first environmental protection law was issued in 1979 and a National Environmental Protection Agency (EPA) and regional Environmental Protection Bureaus (EPBs) were created to formulate and carry out environmental regulations.

The basic premise of our analysis is that, if development strategies are defined with clear environmental objectives in sight, environmental controls do not necessarily translate into added production costs; in many cases they imply adoption of more efficient technology in the production and use of energy and other commodities.

The dual concerns over energy efficiency and environmental quality share a complementarity in policy. That is, policies that reduce energy production and use will reduce air pollution. Even if an economy is developing rapidly (a quadrupling of GNP over 1980 levels is planned for China in the year 2000), environmental protection can still be maintained or even enhanced if economic growth is achieved on the basis of large energy efficiency gains. And economic growth can provide the wealth necessary to finance further gains in environmental protection and improved social welfare.

Current economic reforms considered by the government that are relevant for the control of air pollution include: "paying attention to economic results, improving the quality of goods, reducing resource intensities in production, realizing a rational distribution of productive factors, and improving the utilization of funds and the efficiency of resources utilization" [33].

China's Mix of Centralized Planning and Free Markets

China's desire for improving the "efficiency of resource utilization" has led to a partial movement towards a market economy. From Perkins (1988), reform of the Chinese centralized planning system began after the Third Plenum of December 1978 and was given a major boost by a document released by the government in October 1980, "On the Reform of Economic Structure." This movement can be analyzed in terms of the size of the market economy, the role of the profit motive, the degree of government control over prices, tax policy and banking policy. By 1985, a large share of industrial commodities were being sold on the free market. A survey of 429 enterprises indicated that 44 percent of their product was sold on the market and that the same enterprises purchased 27 percent of their inputs on the free market. Whether market-determined prices were actually affecting decisions at the margin is unclear, however. In addition, factor markets (land, labor, and capital) are still very tightly controlled by the government.

The objective of increasing profits now appears to be more important to managers than the traditional centralized planning objective of maximizing the value of output. Nevertheless, it is not clear whether profits are being pursued through successful operation in the free market or as a result of negotiations with the government for subsidies, entitlements to certain resources, or through other means. For instance, unprofitable enterprises are not generally allowed to fail (the "soft budget constraint") and credit is obtained to a large extent through negotiation with central and local authorities.

Pricing signals are still not fully reflecting scarcities. Energy prices are held low by the government while several prices exist for the same commodities. For example, controlled prices of "in-plan" coal have risen by 80 percent in 1986 over 1978 levels, but this increase was not enough to cover increased production costs, which have risen 13 percent [32]. To mitigate the coal industry's losses, the government subsidizes coal production by at least 20 percent of the price. Consumer prices of coal are further reduced by additional subsidies. The artificially low prices for coal have several implications for environmental pollution. First, little incentive is given to coal producers to make more high quality coal available for use; therefore, emissions are higher than they otherwise would be. Second, low prices encourage inefficient and excessive use of coal, which also leads to greater emissions.

Tax policy has moved away from the requirement to turn nearly all profits back to the government in favor of use of "a corporate profits tax that allows substantial retained earnings." Yet contrary to market economies, this tax rate is very different for different enterprises.

Before 1980 enterprises obtained investment funds as grants from the central government [17]. Now short- and long-term financing come from the enterprises' own funds or from banks at interest rates set by the government. Over the 1980-84 period, 59 percent of investment funds of state-owned enterprises came from sources outside the state budget. Nevertheless, because the government holds interest rates below market clearing rates, there is credit rationing. Central and local authorities still play a major role in these decisions, with the criteria used to ration credit unclear. If investment funds are difficult to obtain, enterprises may seek to minimize initial outlays for projects rather than minimizing annualized costs. Because pollution control and energy development projects typically involve large capital costs, credit rationing may impede the technological development and diffusion of pollution control devices and processes as well as improvements in energy efficiency.

II. AIR POLLUTION PROBLEMS IN BEIJING

Physical, Institutional, and Social Context

Physical Characteristics. The Beijing municipality encompasses 16,800 km^2 and is located at the northwestern edge of the North China Plain at approximately 40 degrees N latitude and 116 degrees east longitude. Its climate is in the humid temperate zone, with winters cold (averaging -5° C in January) and summers hot (26° C in July) and rainy (annual precipitation is 685 mm, with over 30 percent in July and August) [1]. Duststorms from the Loess Plateau to the west are a frequent occurrence in Beijing, with total dustfall (including anthropogenic dust) up to 80 tons a month per km^2 when duststorms are severe, usually in late winter and spring. This natural dustfall may be from 1/3 to 60 percent of total dust fall [8]. If the natural dust proves to be harmful to health, much of the health effects of air pollution may be uncontrollable in Beijing, short of lowering population density in the area. If the natural dust proves to be harmless to health, it is still important to identify its magnitude to better understand the relative importance of anthropogenic dust as measured by air quality monitors. As total suspended particulate (TSP) levels in Beijing could be artificially inflated relative to cities where windblown dust is much less of a problem, TSP standards taken from WHO or other countries may not be directly comparable with Beijing.

Demography. From The China Statistical Yearbook, 1988, the population of Beijing Municipality, which includes eight counties and ten districts, was 9.79 million in 1988, of which some portion was rural. Beijing City has a population of 6.07 million spread over 2,734 square kilometers, with an "urban" population of 2.4 million concentrated in 87 square kilometers, or a density of 27,600 people per square kilometer (6 square meters per person).[1] By comparison, the density is slightly larger than Manhattan at 24,561 people per square kilometer. The city has 120 million m^2 of floor space. For the entire municipality, there are 3.59 persons per household for 2.7 million households. The 20-35 age group is the most prevalent, with 32 percent of the population. Employment was 5.59 million, 2 million of this in industry, with average wages of 1459 Rmb, and real wages rising 8 percent since 1985. The net growth rate of the Beijing population (not counting migration) is 11.34 per 100,000, with a birth rate of 17.83 and death rate of 6.49, i.e., about 0.1 percent per year. Household cooking and heating in the city is done primarily with low efficiency individual coal burning stoves.

1/ The Statistical Yearbook has 6.7 square meters per person, compared to 8.5 for urban China.

Economic Activity. There are some 30,505 enterprises, 10,000 of them industrial, operating in Beijing Municipality, for a total value of gross output of 43.7 billion Rmb [1]. Half of the industrial enterprises (5,746) are located in the city, but they produce over 90 percent of the value of output (39.9 million Rmb). Table 1 gives a breakdown of numbers of enterprises by type and output value for Beijing City (plus townships in the Municipality). Significant for their air pollution effects are 25 power plants, 53 smelters (28 of which are non-ferrous), 18 coking plants, 194 chemical plants, 483 metal products (including electroplating) enterprises, and 532 manufacturers of building materials. There are also 42 coal mining enterprises in the metropolitan area.

The precise location of these enterprises is not known to us. However, as part of the government's pollution control efforts, small polluters such as electroplaters were relocated away from the downtown areas in large numbers [23]. This activity began in earnest in 1984. New enterprises are currently discouraged from locating in downtown areas (Dr. Li Chang Sheng, interview, May 1989).

Information on the physical outputs of industrial activities, which could be used to estimate pollution emissions, is presented in Table 2. Coal mining produces 9 million tons of coal, whereas Beijing consumes 21 million tons annually. Electric power, at 10.5 billion KwH annually, is generated almost entirely from coal and as power consumption is 13.5 billion KwH, additional power must be brought in from outside the municipality. Without making any allowance for natural dust fall, the World Bank's Coal Utilization Study of 1985 found that household coal use, industrial boilers, and power stations in Beijing account for 25.8, 68, and 6.2 percent of ground level TSP concentrations, respectively, and 38.7, 58.6, and 2.8 percent of SO_2 concentrations.[2]

Transportation. According to The China Statistical Yearbook, 1988, most of the population of Beijing travels by bicycle (4 million are registered in Beijing). In 1988, there were only 4,090 buses and 12,491 taxis in the entire city, while in 1986 there were about 200,000 vehicles in total. In spite of their small number, these vehicles are highly polluting. Kinzelbach (1983) notes that the Beijing brand jeep and the Shanghai brand car, which together make up about 50 percent of the light vehicles, have a low engine efficiency of about 6 km per liter of gasoline, with emissions far higher than those of comparable Japanese vehicles.

Beijing's Air Pollution Problem

Beijing, like other rapidly growing industrialized cities in the United States and Europe during the 1950s, is a city of high levels of air pollution emitted by poorly controlled sources. Particulates and SO_2 concentrations greatly exceed the Chinese environmental standards which

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2/ Small- and medium-sized coal burning stoves and furnaces in Beijing, while responsible for only 34 percent of SO_2 emissions, contribute as much as 72 percent of ground level SO2 concentrations [27].

themselves are generally weaker than those adopted by most developed countries. Excessive pollution levels are directly attributable to use of outdated, inefficient technology in industrial boilers and urban heating systems and poor quality energy inputs, i.e., unwashed and unscreened coal. A lack of effective management, market incentives and appropriate pricing signals to create more efficient use of resources, underlie the air pollution problem.

Efforts to control air pollution are further constrained by assimilative capacity limitations in other environmental media. For instance, reducing air pollution may increase solid wastes. But the disposal of ash from coal is already a severe problem and may result in surface or groundwater pollution: in Beijing, shortages of potable surface water are commonplace with shortfalls made up by groundwater withdrawals. But the quality of such water is already suspect (Dr. Li, interview, May 1989).

The air pollutants of potential concern in Beijing are reviewed below. Not all of the pollutants are of equal concern in Beijing, although a lack of monitoring data requires caution in making any conclusions.

<u>CO and Ambient Ozone</u>. With few mobile sources in Beijing, CO (outdoors) and ozone should be minor problems, (although incomplete combustion of coal indoors could lead to exceedingly high, indeed, lethal CO levels). Nevertheless, quarterly CO average concentrations in the 4th quarter of 1988 was 3.4 mg/m3 (milligrams per cubic meter), which, because it is not far below the WHO 8-hr. guideline of 10 mg/m^3, may well exceed the WHO standard.

<u>NO_2</u>. As coal dominates the urban fuel mix, NO_2 should not be of major concern. Based on the winter 1988 average quarterly reading of 0.118 mg/m^3 and the U.S. annual average standard of 0.100 mg/m^3 (China does not have a long-term NO_2 standard), it appears that NO_2 is of minor importance. A variety of observers have noted the same.[3] Combining energy inefficiency with unwashed coal makes China's emissions per unit energy input particularly large. Compared to Germany, China's dust emissions for the same coal consumption are seven times as high and the SO_2 emissions are twice as high [8].

<u>Lead</u>. Information on lead levels in the air is not available. With 28 non-ferrous smelters present in Beijing, lead smelting activity, and its associated high levels of airborne lead, may be present.

<u>Other Toxics</u>. Although information on toxic gases and particles is also unavailable, high levels of toxic pollutants could be present in Beijing air, based on the mix of industries operating in the city and the emissions profile generated by these types of industries in other

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3/ Indeed, NO_2 may present an insignificant health risk according to the scant clinical and epidemiological evidence on its health effects around and above 0.100 mg/m^3.

countries. For instance, carcinogenic compounds are present in gross emissions of chemical plants. In addition, when coal is burned it gives off toxic emissions, such as benzo-pyrene. Kinzelbach (1983) says that this compound is found in concentrations of $0.0069 ug/100m^3$ during the winter heating period. Dianwu Zhao and Bozen Sun (1986) have more data on this.

Acid Rain. Acid rain is a problem for southern China, but not Beijing and other areas in northern China. Although power plants in the North burn large quantities of coal and emit SO_2 untreated into the atmosphere out of tall stacks (a situation ripe for acid rain formation), the presence of alkaline chemicals in north China air effectively neutralizes the acid rain [22].

CO_2. Concern over CO_2 is growing as the relationship between increasing emissions of this gas and global warming is better understood. CO_2 is a product of combustion that enters the global atmosphere without directly causing effects at the regional level. Because this report is focused on very localized air pollution problems, the CO_2 issue is not pursued further, but we are aware that the U.S. EPA is planning a mission to China to study this problem and to assess what role China can play in its amelioration.

Particulates and SO_2. Particulates and SO_2 emissions are of greatest concern in Beijing because they are emitted in large quantities as a result of burning coal to supply the city with its energy needs. In the form of respirable particulates and sulfur compounds, such as sulfates they are linked to both health and non-health environmental effects at the concentrations observed.

The Direct Causes of Air Pollution

The environmental problems associated with high emissions of SO_2 and particulates in Beijing are the result of the following factors:

(i) The use of unwashed, unscreened bituminous coal with high ash content. Only 20 percent of coal consumed is washed, and most of this is used for coking and export. Dirty coal clogs boilers, which raises maintenance and operating costs, may shorten boiler lifetime, and results in high emission levels and large quantities of ash needing disposal.

(ii) The combustion of coal in old and inefficient boilers and stoves (efficiencies of 10-18 percent) for residential/commercial/public heating and cooking, in industrial processes, and to a lesser extent, for electric power. Energy utilization efficiency in China is only 28 percent compared to 40-45 percent in industrialized countries.[4]

4/ That is, to obtain goods of $1 million in value, China needs almost three times the energy input achieved on the average in industrialized countries.

(iii) The severe dust storms in the late winter and early spring.

(iv) The greater energy requirements to heat poorly insulated spaces to target temperatures.

(v) The lack of pollution control equipment on domestic sources of emissions and the low removal rates on industrial dust control devices and about 75 percent of electric utilities.

(vi) The close proximity of population to industrial, and of course, residential/commercial/institutional polluters (e.g., schools, government offices); and

(vii) An institutional and economic system that features limited market incentives to be energy efficient and to control pollution and institutionalized arrangements that encourage wasteful use of resources.

Item (iii) above deserves additional comment. Overall, windblown dust accounts for 60 percent of TSP in summer [26, 3] with coal burning accounting for 40 percent; these figures reverse in winter. Kinzelbach (1983) says that naturaldust fall is 33 percent of the total. Smil (1984) notes that the dust is sand of from 5 to 50 microns in diameter. Particles greater than 10 um would not represent a health threat, although they may contribute to materials, visibility, and soiling damages. A study on background dust in Beijing is on-going at Qinghua University, according to the World Bank's Coal Utilization Study.

Institutional Arrangements

Of critical importance for understanding the causes of air pollution and for designing effective control strategies, is China's environmental protection law, its banking system, and its mix of centralized planning and markets.

Environmental Legislation. The Environmental Protection Law, passed in 1979 marked the beginning of formal environmental policy in China. According to Ross and Silk's (1987) reprint of the translated law, its key provisions include:

(i) The charge to integrate environmental protection and improvement in national economic development plans (article 5);

(ii) The requirement for new projects to have an environmental impact report approved before construction begins and that the means of controlling pollution be placed into effect simultaneously with this construction (article 6). (This was extended in 1983 to expansion and renovation projects);

(iii) The polluter pays principle (article 6);

(iv) Discharge of harmful materials to be carried out in accordance with state standards (article 6);

(v) The right of citizens to supervise, inform against, and accuse anyone of causing environmental damage without retaliation (article 8);

(vi) The prohibition of locating new polluting projects near living quarters and protected areas and the option of relocating them (article 17);

(vii) Emphasis on recycling (article 18), motivated by price or tax adjustments to goods made from recycled materials, with profits kept by the enterprise for pollution control uses (article 31);

(viii) Statement of goal to use low-polluting energy sources and develop district heating systems (article 19);

(ix) The assessment of fees on pollution exceeding state standards based on the amount and concentration of pollutants. (This was changed in 1984 to permit assessments on all emissions);

(x) In response to violations of standards, assessment of fines to compensate for losses or actions to shutdown plants; leaders unit can be held personally responsible (article 32); and

(xi) The creation of an environmental protection bureaucracy at the national level to draft regulations, policies, and standards, to supervise their enforcement, monitor pollution, promote R&D and aid in technology transfer (article 26); the requirement that similar environmental protection bureaus be set up at the provincial and local level with principal responsibility for implementing the laws (article 27); and that environmental protection organizations be set up within all but the small enterprises.

To better integrate environmental protection, and coordinate environmental activities across agencies, the Environmental Protection Commission was established in 1984. The present Environmental Protection Agency is its secretariat. Ross and Silk (1987) provide the environmental control administrative structure and the scheme for organizing environmental legislation.

The most clearly defined outcome of this law is the development of standards for environmental quality and of emissions standards for air and other types of pollutants from a variety of industries. The emissions standards are generally uniform for a given pollutant across industries. One interesting and potentially important deviation from uniformity, is differential SO_2 removal requirements for new power plants depending on whether they burn high or low sulfur coal [23]. One other notable feature of the emission standards is that they are tighter for lower stacks, providing some incentive for building taller stacks, which will reduce local emissions but may contribute to acid rain and other long-range pollutant transport problems.

Another consequence of the law is implementation of an emission fee system and collection of fines to compensate for environmental damage. From the China Statistical Yearbook, 1988, by 1988, 2,528 units in Beijing, or 8 percent of all enterprises, were charged a fee, with fines of 35.8 million yuan levied (0.08 percent of output value) and 30.5 million yuan paid. The proportion of fees related to air pollution is unknown.

The main result of the fee system appears to be to give the local EPBs a source of revenue to allocate to environmental matters and to raise pollution investment capital. Eighty percent of collections are placed in banks for borrowing by enterprises making pollution control investments. The investment funds cover only about 20-25 percent of pollution investment needs; nevertheless, this investment pool represents an important source of earmarked pollution control funding. Ross (1988) notes that charges give regulators flexibility to deal with polluters. While they refuse to pay, the fines are adding up and may be increased because of non-compliance.

Although, even a revenue raising fee system potentially has some incentive effects, the charges are not considered high enough to induce enterprises to cut back pollution [6]. Dr. Li reports that a standard practice is for an enterprise to pay the fee in the beginning of the year (based on last year's emissions) and then ignore the system the rest of the year. Even the amount of the fine is negotiable and, according to the World Bank's Coal Utilization Study, firms that can't "afford" the fee don't pay.

The fee system may even have perverse effects by allocating investment funds to relatively minor sources of pollution. The coal industry is highly taxed and coal prices are kept low. Therefore, it is a low-profit industry incapable of making pollution control investments. Meanwhile, low tax, high priced, and high profit industries, such as the oil industry, have spent much on pollution (primarily water pollution) control and have been praised for their efforts.

The Compensation Provision. In Beijing, compensation was collected of 440,000 yuan, with penalties assessed of 10,000 yuan [1]. Such collections, which are very small amounts, are usually made when some economic asset, such as an agricultural crop or fish, is damaged. Compensation payments are not generally assessed for damages to health.

III. GOVERNMENT ACTIVITIES AND RECOMMENDATIONS FOR ENERGY CONSERVATION/POLLUTION CONTROL MEASURES

China has made strides in improving energy efficiency. According to Mark Levine, Lawrence Berkeley Laboratory (LBL), between 1981 and 1988 energy use grew only half as fast as GDP while over the recent five-year period some 6 billion Rmb were invested in energy management activities alone. While some of the reduction in energy per unit output was due to a change in the industrial mix, LBL finds that 70-80 percent was the result of energy conservation.

LBL is preparing a project to design schemes for Government energy pricing so as to allow energy prices to rise while subsidizing households through tax rebates to offset the increase in the cost of living.

From Ning, et al. (1986), the strategies already adopted to improve energy efficiency and the environment include: industry relocation, allocation of low sulfur coal to urban areas, more natural gas made available for household use, increased coal gasification, increased central heating, etc. However, we do not know how extensively these strategies have been implemented.

Environmental protection started to be implemented in Beijing in 1984, when 12 major projects, including factory relocation, were approved [23]. This resulted in "compulsory abatement, shutdown, or relocation of many establishments, particularly small shops involved in dirty technologies such as electroplating...." The criteria for choosing factories for relocation is unclear, however.

Beijing government funding for pollution control is rising. The city spent over 6 percent of its technological renovation funds on pollution control and environmental protection in 1984, up from less than 3 percent in 1983. In 1987, spending for pollution control was 217 million Rmb, of which 43.5 million was for waste gas control projects. A total of 427 waste gas control projects were either started or completed in 1987. The funds for these pollution treatment projects were obtained from the capital fund (12 Rmb), state subsidies (23 Rmb), and loans (107 Rmb) [1].

<u>Air Pollution Control Plans of the Chinese Government</u>

The "Regulations on Controlling Coal Burning Pollution," State Council's Environmental Protection Committee, October 9, 1984, provides insights into the government's overall cleanup strategy for reducing emissions from coal. This extensive list is neither prioritized nor developed with concrete implementation proposals or specific goals. It involves the following measures:

- screen coal and processing fine coal into molded coal
- use more honeycomb briquettes
- do more coal washing and sulfur recovery
- see that coal supply meets demand
- supply coal with < 1 percent sulfur content to households
- reduce coal storage dust
- expand district (with cogeneration) and central heating
- use larger boilers
- supply more natural and coal gas to cities
- iron and steel complexes supply coke oven gas to cities
- improve coking practices
- improve in-place and new boiler technology
- use TSP control devices on all power plants and large industrial boilers and kilns
- treat ash residues

Dr. Li suggests following a two-step process to reducing emissions from coal burning. The first step is to reduce heating emissions by: (i) increasing central heating for residences, (ii) using district heating with cogeneration, (iii) improving coal quality and combustion. The second step is to (i) increase coal washing, (ii) stop burning raw coal, replacing it with briquettes, gas, and central heating.

Finally, according to Ross (1988), the 7th Five Year Plan provides two environmental goals: a 30 percent reduction in dust levels, and a 150 percent increase in houses served by central heating.

Recommendations of Other Parties

Coal Utilization Mission. The coal utilization mission of the World Bank has provided some new insights into the underlying causes of high coal burning emissions and makes suggestions for measures to be taken to improve the situation. Below, we list those not made by other analyses:

- The negotiated coal market is expanding; this should be encouraged in the context of a price reform policy.

- Bottlenecks in coal transport and processing are severe, and should be dealt with in conjunction with the apparent excess capacity in coal washing.

- With increased incomes, demands for energy and for cleaner fuels will increase.

- Prices for higher quality fuels could be raised to provide incentives for their supply.

- Gas prices should be raised.

- Targets set for coal gas production and district generation seem unrealistic under current institutional arrangements, price structure of fuels, and capital costs.

- Homes should be insulated to reduce inefficient use of energy.

Smil (1984): Smil favors using coal gas to heat cities because of its good reasource base, its efficient and well established technology available at moderate cost, and its use in many cities worldwide. Capital needs to implement such a program would be high; however Smil feels that China should also pursue increased combustion efficiency and installation of control devices.

Ning et al. (1986): Coal preparation to reduce ash by 50 percent and sulfur by 30 percent, more dust collectors, and more use of sulfur fixing binders in coal briquettes to reduce ash and sulfur emissions by 50 percent. Given large projected increases in coal use, these measures could reduce emissions of TSP and SO_2 by 80 percent and 20 percent, respectively.

<u>Wang Hanchen and Zhau Dianwu</u>: The authors suggest increasing the smokeless combustion of coal briquettes supplied to households. When burned in efficient household stoves, coal use could be reduced by 30 percent, and CO could be decreased by 75 percent.

From our review, the following pollution control strategies should be further examined as to their potential effects on improving the ambient air quality and the feasibility relative to underlying institutional and environmental policies:

- Increase the supply of washed coal to the cities. This could be implemented by allowing prices for clean coal to rise, allowing enterprises that make and distribute such coal to keep the extra profits, and designing measures to offset the rise in urban fuel prices.

- Raise the allowable temperature in centrally heated apartments, but add thermostats. Warmer apartments will discourage inefficient and unhealthy burning of coal in supplementary stoves (although emissions from central boilers will rise). Thermostats will give consumers some control over heating costs, especially if heating rates are calculated proportionally to square footage and quantity of fuel used rather than as a fixed fee (which is what is often done now).

- Disseminate information about life-cycle costing of investments and make it easier to obtain capital for projects. This may help reduce the current bias against projects with high initial capital outlays with low subsequent operating and maintenance costs. This practice may eventually lead to the construction of insulated apartments and the purchase of more efficient, less polluting fuel burning equipment.

- Raise emission charges and tighten up enforcement to stimulate more pollution control.

- Institute incentives for energy conservation, while allowing the population to benefit from the comforts of winter heating.

- Encourage more production of sulfur absorbant briquettes and their burning in energy efficient household stoves. Information on the availability of such stoves and their cost is a major research need.

<u>Air Quality and Monitoring</u>

Since July 1981, five cities in China, Beijing among them, have participated in WHO's Global Air Monitoring Project (GEMS) to monitor total suspended particulates using a high volume sampler and SO_2 using the pararosaniline method. This information is reported annually in decile format, by monitor. In addition, cities in China have installed monitoring devices on their own initiative, although we do not know how many. For Beijing, sketchy information is available on NO_2 and CO concentrations.

Beijing has four monitors in the GEMS network. The monitors are operated, on average, approximately 120 days per year (i.e., ten days per month), although data for many more or many fewer days may be collected in any given year. Only after understanding why the variability of days sampled is so great can we be confident that the monitored data are unbiased.

The four monitors are located in different types of areas. One is two miles from a steel plant, another is in the business district, a third is in a suburban park, and the fourth is in a residential area in center-city. The location of monitors in different areas is well thought out. However, four monitors all far too few to adequately characterize exposures to localized pollutants, such as TSP.

The following discussion of ambient particulate and SO_2 concentrations will focus on the latest data from each monitor and averaged over all monitors. Pollution levels are compared to standards in China and the U.S. and to WHO guidelines.

Table 3 provides data on air quality standards for each monitor: daily average concentrations, the daily maximum concentration, and the percent of the monitored days exceeding China's most lenient air quality standard (Class III; see below). The first set of data is for the first third of 1988 (basically the winter months and early spring) and the second set is for all of 1987.

China's air pollution standards cover three classes. Class I, the no effects level, is applied by the federal government to tourist, historical, and conservation areas. Class II, a threshold level for sensitive plants and influence on chronic disease, applies to urban residential and rural areas. Class III, the level necessary to protect people from acute effects and to protect plants and animals, applies to industrial districts and heavy traffic areas, such as Beijing. Localities have the responsibility to designate Class II and III areas. SO_2 standards are for a daily and an annual average while only a daily standard is used for TSP.

The class I and II standards are in the range of the WHO guidelines. WHO's 98th percentile standard ranges from 0.15 to 0.23 mg/m^3 for TSP while China's standards are 0.15 and 0.30 for classes I and II, respectively. Yet, the Class III standard of 0.50 is more than double the WHO guidelines. The same relative order of magnitudes apply to SO_2 standards.

In contrast, the daily TSP standard for the U.S. is at the WHO lower range, while the annual standard falls in the middle, at 0.075 mg/m^3. The no-effects level of TSP for the U.S. is 0.08 mg/m^3 (actually, the U.S. now controls only fine particulates (PM10)). But, for SO_2, the U.S. standards are much weaker than WHO's (0.365 mg/m^3 for the U.S. versus 0.10-0.15 for WHO), and the U.S. daily standard exceeds even China's Class III.

According to available data, it appears that China's standards are rarely enforced. For 1987, both the annual average and the median TSP concentrations exceed the WHO guidelines, while, with the exception of the suburban monitor, readings over 0.500 mg/m^3 occur over ten percent of the monitored days. Often, maximum daily readings can double the Class III standard (at 1.049 mg/m^3). Still, these daily readings are far below those associated with acute mortality. Black smoke readings in Donora were 1.7 mg/m^3 (analogous TSP readings would be much larger).

The small differences between mean and median readings from Beijing's monitors are highly unusual. In the U.S., air pollution data usually take a log-normal distribution, with a few outliers pushing the mean far above the median. That this does not happen in Beijing implies that there is a constant source of TSP, perhaps the windblown dust.

Annual average SO_2 levels were under the U.S. standard for 1987, and median levels were far lower than even the WHO guidelines. Yet, SO_2 concentrations did spike occasionally, with one monitor (in the business district) registering violations of the Class III standard over ten percent of the monitored days. Peak daily readings can exceed the WHO 98th percentile standard (of 0.15) by four or five times (0.723 mg/m^3 in 1988) and the China Class III standard (of 0.25) by three times. As noted above, as high as this reading is compared to the standard, SO_2 readings in Donora were much higher at 1.82 mg/m^3.

WHO (1985) provides some information on CO concentrations: 3.5 mg/m^3 in summer, 5.5 in winter, and an average of 9 in high traffic areas. While the averaging time is unstated, this seems quite low relative to WHO guidelines (e.g., 30 mg/m^3 for a one-hour standard, 10 for an eight-hour standard).

Sources and Emissions of Pollutants from Coal Combustion

The entire coal fuel cycle is a source of pollution: mining, preparation (i.e., washing), storage, distribution, burning, and ash disposal. Because of the proximity of the population to sources of coal combustion and the attendant concern over health effects, we focus on the emissions from burning coal. However, there are 9 million tons of coal actually mined in Beijing Municipality [1], which means that Beijing is subjected to additional emissions associated with this and other stages in the fuel cycle.

In Beijing, according to the World Bank reports, the largest consumers of coal are industry (30 percent), followed by coking (27 percent), residential (23 percent), and electric power (14 percent), plus 6 percent for "other". This consumption takes place in 19,500 boilers (two-thirds for heating), 35,000 restaurant stoves, 13,000 small boilers for drinking, 2,000 kilns and furnaces for industry, and 1.5 million household stoves. SO_2 emissions from the major consuming sources are 526,000 tons annually, 38 percent industry, 23 percent coking, 14 percent residential, and 24 percent electric power, plus 1 percent for "other". TSP emissions are not broken down for these sources in this way. However, about 60 percent are related to industrial boilers and kilns (which may not include coking), 29 percent are associated with heating boilers (which would include residential central and district heating), while the rest (about 12 percent) are split between commercial and residential stoves. These sources amount to 115,600 tons annually. In winter, the residential share of TSP emissions increases to 34 percent.

Aside from factors associated with the volume of coal needed to produce the desired energy output, the volume of emissions is influenced by: the quality of the coal being burned, the technology for burning it and capturing emissions, the management of the burning operation, which itself depends on the structure of incentives and institutional factors which include economic structure, pricing and regulatory policies, etc. In addition, the location of emission sources (which affects exposure of people to the pollutants, and thus, the health effects), is determined to a large extent by institutional factors. Not all of these factors are significant in determining the contribution of a particular coal-using sector to Beijing's pollution problems, however. Below, we identify those that appear to be key problems across sectors and for each sector separately.

Coal Preparation. With the exception of much of the coal used for coking, virtually none of the coal burned in Beijing is washed (only 10 to 20 percent of non-coked coal in all of China).[5] Burning unwashed coal raises ash and sulfur content. Indeed, Kinzelbach (1983) notes that the pyritic waste from the coal that is washed -- the lowest quality coal available-- is sold to private households. Lack of coal sizing and screening creates operating problems for industrial use and heating boilers not designed for pulverized coal. Overall, the poor quality of coal also leads to lower burning efficiencies and greater downtime for maintenance. Boiler lifetimes may also be shortened.

Electric Power: The largest of the coal fired electric power plants have electrostatic precipitators to capture particles (about 25 percent of plants in China). However, World Bank's Coal Utilization Study notes that they may be operating below their specifications of 98 percent removal. The other plants have less complete particle removal. No plants remove SO_2.

Beyond the expense of pollution control equipment, institutional factors are partly responsible for the low level of pollution removal and high rate of emissions per BTU delivered. Most of the plants are small and scattered. Incentives are strong for building small power plants - primarily because local authorities can avoid the lengthy and uncertain process of gaining approval from the central government to build and operate such plants. In addition, because the small power station can charge a negotiated price for its power, it can return profits to the local

5/ Most, if not all, coal burned by households in Beijing is processed to some degree.

government. It can also be built fast. Unfortunately, small plants are poor environmental buys because they use venturi cyclone filters, which have much lower removal efficiencies than electrostatic precipitators. In addition, smaller plants are less efficient generators of electricity. Thus, their unit costs are higher and their emissions per unit of electricity delivered are higher than those for larger plants.

Industry. Although some 90 percent of industrial boilers have some kind of TSP pollution control equipment, they are still emitting large quantities of particulates. The plants are characterized as old and too small, leading to low efficiencies in burning. Compounded by use of outdated production processes, resource unavailabilities, and lack of cost accountability, energy intensity is twice as high as in the developed countries. The lack of capital markets, and the need for central government approval of large investments, are acting as incentives against projects with high initial investment costs. As a result, economies of scale are lost and pollution control equipment per unit of output becomes prohibitively expensive.

Coking. We have no information on factors affecting the coking industry.

Commercial/Public Coal Use. People spend much of their day in public buildings (day care centers, schools or the workplace, which, in Beijing, is often government buildings) or in commercial establishments. Newer public and commercial buildings are heated by central or district boilers, but older buildings are usually heated by coal stoves, which create high levels of indoor pollution. A relatively dirty form of processed coal, called "ball" coal, is sometimes burned.

Residential Coal use. From World Bank's Coal Utilization Study, half the homes in Beijing are heated by small, inefficient coal stoves located in the living area while half are heated by hot water, which is heated by central boilers burning coal or by district heating facilities (which also burn coal supplemented by industrial waste gas or other means of cogeneration). Because the temperature in the latter homes is often lower than desired, many people supplement central or district heating with heat from coal stoves. With almost 90 percent of the population having access to canned or piped gas (LPG, primarily) and a stove to burn it [1], most cooking can be done with gas. However, based on a 20 percent increase in the purchase of canned gas in winter, it is speculated that the gas is being used by some households to supplement inadequate central and district heating. In addition, in winter, some cooking may be done on the coal stove.

From a health perspective, pollution problems are potentially most severe when coal is burned in stoves located in the living area. Raw coal is not generally purchased for home heating in Beijing. Rather, two types of briquettes are available, one is easy to light, provides high heat output, and leaves little ash, but burns fast; the other is larger and more cumbersome to store but burns more slowly. Also, some briquettes have additives that reduce the formation of SO_2 in burning. Particulate and SO_2 emissions (as well as other compounds) are emitted outside the home from the venting of exhaust gases out of a low stack and indoors when the stove is opened or through leaks. Incomplete combustion also can generate large, if not lethal, amounts of CO. Particularly high levels of all types of emissions may be generated if the coal stove is used for cooking. WHO (1985) found levels of CO and respirable particulates (RP) far higher for apartments without central heating than with central heating.

Households living in apartments with central heating are spared indoor heating emissions if they do not supplement their heat and the central units vent their gases from relatively tall stacks (although efficiencies are reported to be very low). Units generally have no controls for heat and apartments are quite cold in winter. Cold spells before the heat is turned on November 15 or after it is shut off March 15, can also result in poor living conditions. It appears to be a governmental policy to keep indoor temperatures at levels lower than those accustomed to in the developed countries. As a result, people supplement the central heat. Such heat supplements may occur through burning gas or coal.[6] Either of these uses increase energy demands and raise indoor and outdoor emissions. Such heat demands could be satisfied per BTU by burning more coal centrally. If households did not supplement their heat, sickness would probably be more prevalent and productivity even lower than currently observed.

Those living in apartments heated by district heating, 16 percent of floor area in Beijing, are in a similar situation to those with central heating [10]. Emissions per BTU are lower with district heating, however, if the district heating system uses cogeneration and, if owing to the larger size of the heating unit, more advanced pollution control techniques are used.

Energy costs, whether to purchase home heating or cooking fuel directly or to pay a fee for central or district heating services, are very low, in part, because of government subsidization. The subsidies may encourage excess energy use. The government controls access to gas stoves and cans for gas.

Insulation is non-existent in China and windows and doors fit poorly (World Bank's Coal Utilization Study). Incentives are not in place to have the energy cost savings from insulation be factored into the initial decision on whether to insulate. Levine and Adamson (1988) note that apartment buildings in Beijing can be designed to obtain temperatures of at least 14 degrees C for all but 100 hours per year without a heating system. This is a significant improvement over current conditions in unheated buildings. More important, for a heated building in Beijing, energy consumption can be reduced from 78 kWh/m2 to 11 kWh/m2 with installation of double glazing and moderate wall and roof insulation plus a 50 percent reduction in air exchanges per hour (from 1.1 to 0.5).

6/ The use of electric blankets has been observed (World Bank's Coal Utilization Study).

A collaborative study by the Lawrence Berkeley Laboratory and Qinghua University is in progress to survey urban use of fuels in the home. Currently, data collection protocols are being designed. Results from this study are not expected for two years.

Emission Inventory. In order to formulate cost-effective air-pollution control options, an emission inventory is needed. This should contain:

(i) At least a rudimentary inventory of major point sources located on a grid;

(ii) Associated stack heights, exit velocity, and temperature of exhaust gases;

(iii) A rough estimate of coal use per day by type of residence (heating by stove, central, district);

(iv) An estimate of number of residences by type by grid;

(v) Household size by residence type;

(vi) Meteorological variables;

(vii) Background dust estimates

When the above information is used in a simple dispersion model, one can then forecast concentrations by grid and attribute concentrations to particular sources and residence types. Such an inventory and associated dispersion model appear to be in use in Beijing.

Since 1980, INET of Tsinghua University has been operating a National Energy Demand Model that also contains a macroeconomic sub-model [21]. Among its other uses, this model can be used to assess the economic results of investments in energy conservation technologies. Such a model could be helpful in identifying cost-effective approaches to pollution control. From data generated by this model it was found that approximately 70 percent of the energy consumed by the chemical industry in China is being used for producing ammonia, ethylene, caustic soda, and calcium carbide, although these account for only 10 percent of the industry's output value. Reducing energy use by improving the industrial processes in the production of these chemicals is a promising energy conservation and pollution reduction opportunity.

Pollution Control Costs

We have no information on control costs in China of various technological options and only anecdotal information on the degree of controls on industrial and electric power sources of emissions. Even if cost information were available it will not necessarily reflect marginal social cost. Much of the cost information is to be developed by energy sector-specific studies.

According to James (1989), enterprises are required to spend 5-7 percent of investment funds on pollution control, a target that is not always met. But they are not permitted to raise prices more than 0.5 percent of cost. Firms that are already profitable or invest in more efficient processes can survive financially making such investments, even if financing comes from an investment pool created out of collections of fees on emissions. As the most profitable firms are not necessarily also the most polluting or the most efficient, the consequences of permitting firms to raise prices beyond 0.5 percent of cost and of establishing rules for allocating funds from the pollution control pool based on economic criteria of efficiency should be studied.

IV. HEALTH EFFECTS OF AIR POLLUTION

Health effects of air pollution depend on the concentrations and potencies of pollutants present in the air, and the size and other health and life-style characteristics of the population exposed.

Exposures

A personal monitor study was mounted in Beijing to estimate exposures to the use of coal indoors. WHO (1985) provides some information on exposures to CO and respirable particulates in Beijing. This source reports on a personal monitor study as well as summarizing exposure research in China. For the personal monitor study, indoor, outdoor and personal exposures were monitored for 20 subjects (non-smoking volunteers from the Institute of Health) over a one week period in summer and winter of 1984/5.

With ambient CO of 10.3 mg/m^3 in winter for these subjects, indoor levels reached an average of 23, with over 115 reached in one case. Carboxyhemoglobin levels in the blood (COHb), which is a good indicator of potential health effects, jumped to 1.9 percent in the winter from 0.2 percent in summer. CO levels in winter using personal monitors averaged 15.9, with a high of 41. Respirable particulates, on the other hand, were not elevated much higher indoors than outdoors.

Ambient RP averaged 0.595 mg/m^3 in winter, 0.230 in the work place, 1.067 in public indoor areas, and 0.24 in traffic. Personal exposures to RP averaged 0.191 in winter (a high of 0.378), compared to indoor exposures averaging 0.364. Summer levels were much lower (0.192 outdoors). For RP, the same relationship between outdoor, indoor, and personal levels held. Exposure patterns across housing types are not given.

Time-weighted exposure calculations were found to yield results similar to personal monitoring.

The activity analysis found that the subjects spent an average of 65.4 percent of their time at home and 25.7 percent at work in winter, with slightly higher levels at home in the summer. Time spent indoors averaged 94 percent, irrespective of season.

A summary of indoor air pollution studies in China by WHO (1985) states that long heating seasons and coal burning cause the major pollution problems, with TSP, SO_2, and CO being major pollutants, but not NO_x. Smoking has been found to be a major cause of indoor CO (pushing personal exposures to 17 mg/m_n^3). The results of this study for China were compared to results from similar studies in other cities (Zagreb, Toronto, and Bombay). Beijing's RP and CO indoor concentrations were far higher than those of the other countries, irrespective of season.

Health Effects

Clinical and epidemiological research outside of China clearly implicates the pollutants of most concern in Beijing -- TSP, SO_2, and perhaps CO, lead, and other toxic air pollutants -- in damaging human health. This research is summarized below.

Current thinking is that acid aerosols, such as sulfates and nitrates, particles around 0.25 um in size, are the best proxy for the agents that damage the lung [13]. The ultimate damaging agent may be hydrogen ions. In contrast, the largest particles, those > 10 um in diameter, are thought to carry little health risk, although they may be largely responsible for soiling and visibility damages. Therefore, the TSP measure, which includes all particles up to 100 um in size, is a poor proxy for the concentration of damaging agents, particularly so for Beijing, where natural dust fall is so high.

Whatever the damaging agent, their proxy measures have been linked to premature mortality in epidemiological studies (around 3 deaths per 100,000 per 1 um/m^3 TSP) in the U.S. and elsewhere and to morbidity, in terms of restricted activity days and elevated rates of hospital admissions for exacerbations of chronic respiratory disease [4].

SO_2 has also been linked to mortality in epidemiological studies. (Joyce, et al. 1989 shows a link to infant mortality) and morbidity effects in the lab and in the field. In many studies exposure to particulates and SO_2 is highly correlated, making it difficult to separate out the effects of each pollutant.

CO in relatively low concentrations has been linked to angina and neurobehavioral effects that are reversible. At high doses, such as those occurring with poor ventilation of a room heated by a coal stove, death through asphyxiation can result.

Lead represents a critical risk to children, resulting in both obvious neurological effects and subtle effects, such as learning disabilities.

Considering health studies in China, Kinzelbach (1983) cites findings that lung cancer mortality in cities in China is between 17 and 31 cases per 100,000 (versus 47 in the U.S.). Dr. Li says that lung cancer rates increased 145 percent in Beijing from 1949 to 1979, with incidence

7.3 times higher in the cities than the countryside. Kinzelbach also cites the high rates of chronic bronchitis and chronic respiratory infections in the cities as opposed to the rural areas as evidence for the effects of air pollution. Dr. Li notes that the incidence of respiratory disease is 6.79/10,000 in cities and 2.8 in rural areas, which is a very low rate and should be thoroughly investigated.

Mumford et al. (1987) shows that rural women who cook and heat their homes with "smoky" coal have elevated rates of lung cancer relative to other rural women. The age-adjusted mortality rate from lung cancer in the three high mortality counties where smoky coal is burned was 125.6/100,000 over the 1973-79 period compared to 3.1/100,000 where such coal is not generally burned and 6.3/100,000 in the United States. As virtually no Chinese women smoke, the difference between the U.S. rate and that of the low mortality China county rate may reflect the effects of smoking. This study also characterized indoor air from smoky coal. The smoky coal contained only 0.2 percent sulfur, 23.5 percent ash, and was a medium volatile bituminous coal. Concentrations of PM10 were around $20mg/m^3$ and 50 percent of the particles were less than one micron. The coal also contained high levels of organic carcinogenic compounds, such as benzopyrene, which were at concentrations comparable to occupational exposure to coke oven emissions.

There are several estimates of aggregate health effects and economic damages from air pollution. These have limited value for analyzing policy effects because they seek to assess total, rather than marginal, damages. James (1989) cites a study by the China EPA on air pollution damages from coal use. Smil (1984) cites a study by Qin Ling (1980) that air pollution in Beijing, Shanghai, Wuhan, and Guangzhou results in 3.5 million work loss days per year and 6,000 premature deaths.

V. ISSUES AND RELATED RECOMMENDATIONS FOR STUDY IN BEIJING

Based on the above information, we draw some general conclusions concerning the air pollution situation in Beijing and make some recommendations for future study as follows:

(a) The air pollution problem in Beijing is severe, with particulates and SO_2 pollution from coal combustion being the major, known cause.

(b) Relative to the level of industrialization of the area, pollution controls are scant, and the population lives in close proximity to a variety of industries. It is likely that other, as yet unmeasured, air pollutants are contributing to health problems of such urban populations. Based on typical emission profiles of U.S. industries corresponding to the types of industry found in Beijing, these pollutants may include lead, benzopyrene, and other toxic, carcinogenic air pollutants.

(c) There is agreement that electric utilities are not the major cause of the particulate/SO_2 problem in Beijing; rather industrial and residential (and perhaps public and commercial) coal burning are thought to be primarily responsible, with some uncertainty about the proportion of responsibilities between these sources. It is important to resolve this uncertainty because control strategies for reducing pollution would be very different according to whether the focus is on industrial or residential sources.

(d) The health effects of air pollution in Beijing are not well quantified, with several studies, for instance, concluding only that respiratory disease and cancer prevalence in Beijing are higher than in less polluted areas and others estimating economic losses based on little data. However, a large clinical and epidemiological literature on the effects of air pollution on human health in other areas can be drawn upon to infer the effects of control strategies on human health, assuming we have a good understanding of the sources, types and quantities of emission and concentration.

(e) The national and local governments are aware of the environmental problems in Beijing. They have proposed a wide ranging plan to address the air pollution problem that includes measures for direct pollution control and increased efficiency in the use of energy and the production of output. However, the plan lacks specifics and, with very scarce resources for implementation of pollution controls, needs prioritization. This ranking of strategies requires information on control and enforcement costs, and on the potential air quality and health improvements realized through control.

(f) The Environmental Protection Law provides a framework for applying both command and control and economic incentive measures to Beijing's air pollution problems caused by industrial sources. At present, the government bodies charged with carrying out the law in Beijing, both the National Environmental Protection Agency (NEPA) and Beijing's EPB, have made strides in reducing pollution primarily by relocating polluting enterprises from the city and in influencing the location decisions of new enterprises. They have been limited in their effectiveness on other fronts, however, because of the large numbers of sources needing control, the need for cooperation among other, more powerful government agencies with their own priorities, a small staff and budget, and a tradition of negotiated pollution reductions rather than enforced reductions to meet predetermined emissions standards. The emission fee system appears to be primarily a financing tool for pollution control. But it has potential to act as an an incentive to directly reduce pollution.

(g) Institutional factors, including the size and structure of energy markets, government subsidization of energy prices, and the banking system, are potential primary causes of air pollution as expressed by, e.g., the lack of incentive to provide washed coal to the cities, the perverse incentive to move away from economies of scale in production, and the emphasis on the short-term view in the evaluation of investment. Regarding the last, the initial costs of projects both in residential construction and in pollution control are almost exlusively considered without any regard for operating and maintenance expenditures.

(h) The problem of air pollution caused by residential, commercial, and public coal combustion is less tractable than that of industrial pollution because sources are small, numerous, and widely dispersed. To make informed choices on the most cost-effective control strategies, more information is needed on (1) the proportion of sources using a coal stove as a source of heat, (2) costs and efficiencies of coal, gas, and electric heaters and electric blankets, (3) costs and emissions consequences of providing low ash/low sulfur briquette to sources heating with coal, and (4) economic feasibility of improving building insulation.

There is a need to identify for Beijing a set of cost-effective measures to reduce air pollution, in the sense that they reduce pollution concentrations or health effects in the city at least cost (net of energy conservation savings). The measures would be consistent with the economic constraints imposed by Beijing's local economy, the institutional constraints imposed by China's planned economy and the Environmental Protection Law, and the environmental constraints of other media.

Therefore, a future study in Beijing should concentrate on developing and implementing a method for assigning priorities among the most promising control options and evaluating the sensitivity of the result to macroeconomic policies. In the cost-benefit framework, this would involve evaluating the costs of various strategies to control pollutants primarily generated by coal combustion. A variety of policy and enforcement options would be evaluated including those that appear from the foregoing analysis to be most promising and any others that have been emphasized by the Chinese government or analysts. We identify the most promising options as those that can promote both economic development and environmental improvement. The full set of options include:

(i) Increased coal washing and use of such coal in urban areas;

(ii) Energy sector reform: including prices, wages, and management incentives;

(iii) Pollution control sector reform: mandate installation of pollution control devices, increase fees and make changes to the fee system, sharpen incentives to relocate dirtiest units outside urban areas;

(iv) Financial sector reform: enhance opportunities for borrowing for capital improvements in construction and pollution control;

(v) Give municipalities tax and other incentives to expand use of district heating with cogeneration;

(vi) Expand the supply of coal gas to urban areas;

(vii) Expand use of briquettes with attractive environmental characteristics by providing more information and price incentives to consumers;

(viii) Promote use of insulation in buildings, both new and retrofitted.

To support this analysis, a number of specific sub-projects would need to be initiated and the results of on-going projects at the World Bank and elsewhere would need to be drawn upon. The on-going projects include the coal utilization study and the coal transport study being conducted by the World Bank as well as the residential fuel use study, the energy price reform study, and a retrospective study on energy conservation progress in China being conducted jointly by Lawrence Berkeley Laboratories and the Chinese government and academic institutions, and the results of future USEPA missions to China to examine options for reducing China's contribution to global warming. In addition, energy demand models in use in China could be harnessed for this analysis. Seven new potential study projects are described below:

(1) To identify the extent of health improvement as a result of specific policies, a pollution effects model (see Krupnick and Kopp, 1988) could be built for Beijing. This model would use Beijing's emissions inventory, data on population by location in the city, and dose-response functions (taken from Western sources as needed) as well as a simple air dispersion model for particulates and SO_2. The emissions inventory could use data on the type of enterprise, its location, and its production level along with USEPA emission factors (to the extent that such factors are not available specifically for China) to buílld an emissions inventory for all types of pollutants, concentrating on particulates. The inventory would describe residential/commercial/public emissions as well. The inventory would also need to identify background dust levels. An on-going study in China could be used on for this information. If the emissions inventory reveals that large amounts of toxic pollutants are probably being released by industry, special monitoring programs could be initiated.

(2) The link between reductions in ambient concentrations and health may be less important than the link between indoor air pollution from coal combustion and health. The latter linkage should be investigated in a study of indoor air pollution that would follow

a similar approach to WHO (1985), who studied the effect of heating practices and housing quality on indoor, outdoor, and personal monitored levels of CO and respirable particulates. The finding in WHO (1985), that pollution levels in public buildings are twice as high as ambient levels requires further research.

(3) A study of residential, commercial, and public fuel use should be conducted to improve information about baseline energy use and to obtain better insight into the effect of emissions reduction/ energy conservation policies. Guidelines on the heating targets for central and district heating units and estimates of actual temperature levels should also be sought, to identify low-cost options for reducing emissions and increasing heating efficiencies identified and to measure their cost-effectiveness in reducing emissions. This effort could be designed to complement the LBL study of residential fuel use which is expected to yield some results in two years.

(4) A study should be conducted on the costs, emissions, concentrations, and health benefits of requiring the installation of specific pollution control devices on point sources in Beijing. It is important to investigate the potential economic impact for a specific industry of extending article 31 of the Environmental Protection Law. Article 31 states that profits arising from the favorable tax or price treatment applied to recycled goods, may be kept by the unit producing such goods for investment in pollution control. The objective would be to permit profits in some major polluting industries to be retained if pollution reductions were obtained by production process change or implementation of energy conservation activities.

(5) There is uncertainty over the actual workings of the fee system. One should examine how the system has worked in practice to date through the implementation of several case studies. The system of relocating polluting firms has been touted as an effective instrument of pollution control and should be reviewed and the implementation of this policy in Beijing to date should be reviewed and, in particular, the rules used to decide on which units are relocated, the reductions in emissions obtained, and the costs to the local economy of such relocations, if any.

(6) It is particularly important to analyze the current banking system, the availability of capital for plant expansion, new plants, and residential construction, and for pollution control, and how credit policies and the organization of the banking system affects managers' decisions regarding the adoption of technologies/processes that could be environmentally less damaging.

(7) The cost-effectiveness (cost-benefit) of district heating and coal gasification as applied to residential heating in Beijing should be further investigated, along with the effects of building insulation on energy consumption.

Table 1
Industrial Enterprises in City of Beijing and Townships in Beijing Municipality, 1987

Type	Number	Output Value (Billion Rmb)
Light industry	3192	16.5
Heavy industry	2554	23.4
Total	5746	39.9
Category (selected)		
Electric Power	25	.9
Coking	18	.5
Chemicals	194	5.8
Smelting-Ferrous	25	3.3
Non-ferrous	28	.8
Coal Mining	42	.2
Petroleum	7	.1
Building Materials	532	1.8
Textiles	279	2.8
Plastics	197	.7
Metal Products	483	1.1
Machine Building	726	4.4

Source: China Statistical Yearbook, 1988

Table 2
Output of Selected Polluting Products in Beijing 1986/7

Type (units)	Output
Electric Power (billion kwh)	10.5
Hydro	.2
Coal	10.3
Coal Mining (million tons)	9
Iron & Steel	
Pig Iron (million tons)	3.3
Rolled Steel " "	2.8
Steel " "	3.4
Coke " "	3.3
Cement " "	3.2
Vehicles (000's)	74
Trucks " "	31

Source: China Statistical Yearbook, 1988

Table 3
Air Pollution Standards and Monitored Concentrations (mg/m^3) in Beijing, 1987 and 1988

Standards	TSP Daily	TSP Annual	SO_2 Daily	SO_2 Annual Average
Class				
China I	.15		.05	.02
II	.30		.15	.06
III	.50		.25	.10
US std	.150	.075	.365	.08
	98th	Annual	98th	Annual
WHO Guidelines	.15-.23	.06-.09	.10-.15	.04-.06
(Black Smoke	.10-.15	.04-.06)		

Monitored Daily Data

1988

		TSP			SO_2	
		Station	#Obs	Conc.	#Obs	Conc.
Measure						
Average		1	37	.473	42	.123
Maximum				.930		.332
Percent	> Class III			>30		>5
Average		2	40	.504	42	.249
Maximum	> Class III			.853		.556
Percent				>50		>40
Average		3	44	.321	42	.074
Maximum	> Class III			.610		.246
Percent				>10		>0
Average		4	45	.493	41	.219
Maximum	> Class III			.965		.723
Percent				>30		>30
Benchmarks						
Donora		(Black Smoke)		1.7		1.82
Adverse Effects				.08		

1987

		TSP			SO_2	
		Station	#Obs.	Cons.	#Obs.	Conc.
Average		1	112	.362	113	.041
Maximum	> Class III			1.049		.272
Percent				>10		>1
Median				.328		.014
Average		2	117	.376	124	.076
Maximum	> Class III			.854		.562
Percent				>10		>10
Median				.334		.026
Average		3	124	.226	126	.021
Maximum	> Class III			.538		.211
Percent				<1		0
Median				.210		.006
Average		4	124	.336	111	.069
Maximum	> Class III			.879		.611
Percent				>10		>5
Median				.275		.022

Notes:

Station	Category
1	2 Km. from steel plant
2	Business district
3	Suburban Park
4	Center-city residential

a. From GEMS.

TABLE 4

EMISSIONS AND SHARE OF AMBIENT CONCENTRATIONS OF SECTORS IN BEIJING IN 1985

SECTOR	PARTICULATES				SO_2		
	Annual (1,000t)	Emissions (%)[a]	Winter (%)[a]	(%)[a] Winter Concentrations	Annual (1,000t)	Emissions (%)[a]	Concentrations (%)[a]
Industry	68	59		24 (population tables)	203	39	59
Heating-Boilers	34	29		35	?		
Commercial Stoves	7.6	7		?[b]			
Household Stoves	6	5	34	40	73	14	38
Subtotal	115.6	100.0		100.0	?		
Power Plants	?				126	24	3
Coking	?				124	24	
Subtotal	?				526	100.0	100.0
TOTAL	?				?		

a/ Percent of total tons known.
b/ Figures omit commercial stoves, though percentages sum to 100%.

Source: World Bank Coal Utilization Study (Draft), June 1989.

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