

Summary Papers

from the

**U.S.-China Conference on Energy,
Environment and Market Mechanisms**

October 26-28, 1992 at Battelle Seattle Research Center
and
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**U.S.-CHINA CONFERENCE ON ENERGY,
ENVIRONMENT AND MARKET MECHANISMS**

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Foreword

The summary papers in this report were written by Jessica Hamburger, an Associate in the Advanced International Studies Unit at Battelle, Pacific Northwest Laboratory. They draw heavily on original papers presented by the Chinese participants and discussions at workshops held at the Battelle Seattle Research Center in Seattle, Washington, on October 26-28, 1992 and at the University of California in Berkeley, California, on October 29-31, 1992 (see page ix for a list of participants and paper titles).

The workshops provided an opportunity for 12 high-level officials from the China's State Planning Commission (SPC), Ministry of Energy, National Environmental Protection Agency, and other institutions to meet with American analysts to discuss the complementary use of regulations and market mechanisms to raise the level of energy service while minimizing environmental damage, primarily in the context of China's rapid shift toward a market economy. The Chinese participants prepared papers dealing with China's energy profile, energy-related environmental problems, and energy management system reforms, including energy conservation policies, while American participants presented overviews of "what has worked" in the U.S. energy management experience. The U.S. experts supported Chinese efforts to trim the energy bureaucracy and rationalize prices, but warned that U.S. experience has shown that completely free markets are not the answer, and that a strong regulatory framework is also necessary to promote efficiency and environmental protection.

The Chinese participants also visited leading American energy efficiency institutions and experts in the Pacific Northwest and California and discussed the following issues:

- integrated resources planning (IRP) with the Northwest Power Planning Council and the Bonneville Power Administration in Portland, OR;
- building energy standards and metering and computer-assisted energy building design with the Department of Energy's Pacific Northwest Laboratory in Richland, Washington.
- utility incentive programs to promote energy-efficient lighting, insulation, industrial retrofitting, and many other conservation measures with Seattle City Light and Pacific Gas & Electric; and
- technology transfer possibilities with U.S. Wind Power and DOE's Jack Siegel, Deputy Assistant Secretary for Coal Technology.

Members of the Chinese delegation hope to collaborate with the U.S. energy experts on the climate change Country Study, an energy efficiency center in Beijing, technical assistance to improve quality of compact fluorescent lights produced in China, a demonstration project on building efficiency, and a demonstration project on low-cost desulfurization or fluidized bed combustion. Other suggestions included wind resource estimation and development, end-use model energy forecasting, quantification of environmental factors for IRP, and training for energy managers in market economics.

The workshops were sponsored by Battelle, Pacific Northwest Laboratories, Global Studies Program (USA); the U.S. Department of Energy, Office of Policy Analysis (USA); Lawrence Berkeley Laboratory (LBL), Energy Analysis Program (USA); the State Planning Commission, Department of Comprehensive Utilization of Resources and Conservation (PRC); and the State Planning Commission, Energy Research Institute (PRC).

An agenda and list of participants from the Berkeley portion of the conference can be obtained from the Energy Analysis Program at LBL. Copies of the original papers by the Chinese participants and additional information can be obtained from either Battelle or LBL.

William U. Chandler
Director, Advanced International Studies

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Contents

Foreword	iii
Acknowledgments	v
Names, Paper Titles, and Affiliations	ix
Conversions	xi
Summary Papers	
China's Energy Profile	1
Reforming China's Energy Management System	3
Oil Industry Reform	3
Electric Power Industry Reform	3
Coal Industry Reform	4
Suggestions for Further Reforms	5
Promoting Energy Conservation in China	7
Strategies for Promoting Investment	7
Conservation Achievements in the 1980s	7
Toward Integrated Resource Planning	8
Reducing the Environmental Impact of Coal in China	10
Combustion-Related Pollution	10
Mining Waste	11
Appendix A - Battelle Seattle Research Center October 26-28, 1992	A.1
Appendix B - List of Participants	B.1

Names, Paper Titles, and Affiliations

The following original papers by the Chinese conference participants provided the basis for the summary papers in this report:

Han Jiuling, "Air Pollution Control Policy and Measures in China," Air Pollution Division, National Environmental Protection Agency.

Liu Shunxing, "Arrangement, Policies, and Principles of China's State Energy-Saving Capital Construction Investment," Energy Conservation Company of the State Energy Investment Corporation.

Shen Longhai and Zhou Changyi, "Overview of Economic Development, Present Situation and Prospect for Environmental Protection and Energy Conservation in China," Department of Resource Conservation and Comprehensive Utilization, State Planning Commission.

Wang Qingyi, "The Present State and Prospect of China's Energy Conservation Technology," China Energy Research Society.

Wang Xirong, "Reasonable Use of Energy by Replacing Oil with Coal: China Huaneng Group Create High Profit," Huaneng Technology Development Corporation.

Wang Zhongan, "Actual State of China's Energy Industry and Expected Development Policy," Department of Energy, State Planning Commission.

Zhai Ruoyu, "Electric Power Industry and Environmental Protection in China," Department of Safety and Environmental Protection, Ministry of Energy.

Zhang Aling, "Forecast of China's Energy Demand," Institute of Nuclear Energy Technology, Qinghua University.

Zhou Dadi, "Energy Management System, Pricing and Market Mechanisms in China," Energy Research Institute, State Planning Commission.

Zhou Fengqi, "Integrated Energy-Environmental Planning," Energy Research Institute, State Planning Commission.

Zhou Fengqi, "To Develop the Coal Market Enthusiastically and Open the Price of Coal Progressively," Energy Research Institute, State Planning Commission.

Conversions

Energy^(a)

1 gigajoule (GJ) = 1×10^9 Joules (J)

1 exajoule (EJ) = 1×10^{18} J

- 1 EJ = 34.1 million tons of standard coal equivalent (Mtce)
- = 47.8 million tons of Chinese average raw coal
- = 23.9 million tons of Chinese average crude oil
- = 26.5 billion cubic meters of standard natural gas
- = 25.6 billion cubic meters of Chinese average natural gas
- = 84.4 billion kWh of electricity
- = 59-71 million tons of air-dried firewood
- = 62-83 million tons of air-dried crop residues

1 gigawatt (GW) = 1×10^9 Watts

1 megawatt (MW) = 1×10^6 Watts

Currency^(b)

Up to December 15, 1989

\$1.00 = Y 3.72

Y 1.00 = \$0.27

Up to November 29, 1990

\$1.00 = Y 4.72

Y 1.00 = \$0.21

At March 31, 1992

\$1.00 = Y 5.46

Y 1.00 = \$0.18

(a) Sinton, Jonathan, ed., *China Energy Data Book*, Lawrence Berkeley Laboratory and the Energy Research Institute of the State Planning Commission of China, revised November 1992.

(b) *China, Reform and the Role of the Plan in the 1990s*, The World Bank, Washington, DC, 1992.

China's Energy Profile

China is rich in energy resources. By the end of 1991, China had 166 billion tons (3,480 exajoules (EJ)) of proven coal reserves, 1920 billion kilowatt hours per year (22.8 EJ) of exploitable hydropower resources, 78.7 billion tons (3,300 EJ) of potential petroleum reserves, 999 billion cubic meters (39.0 EJ) of proven natural gas reserves, and 160 gigawatts (GW) of exploitable wind power.^(a)

China is the third largest energy producer in the world. China produced 30.4 EJ in 1990, an increase of 63 percent over 1980 levels. Production increased by an average of 5 percent per year during the 1980s.^(b) China's energy supply is expected to reach 35.2-36.6 EJ in 1995 and 41.0-42.5 EJ in 2000.^(c)

China is also the third largest energy consumer in the world. China consumed 30.42 EJ in 1991. Consumption, like production, increased by 5 percent a year during the 1980s.^(d)

China is one of the few countries that relies primarily on coal for energy. Seventy-six percent of primary energy was supplied by coal in 1991, 17 percent by oil, 5 percent by hydropower and 2 percent by natural gas.^(a) Excessive use of coal has resulted in low efficiency, environmental degradation, and transportation bottlenecks.

China depends primarily on domestic energy sources. China exported 22.6 million tons and imported 10.6 million tons of crude oil and oil products in 1991. China exported 20.1 million tons and imported 1.2 million tons of coal. Net exportation of energy was 1.26 EJ, or 4.1 percent of total domestic energy consumption.^(b) China may soon become a net energy importer to relieve its energy shortage.

Industry consumes over two thirds of China's energy supply. In 1991, 68 percent of energy was consumed by the industrial sector, 20 percent by the residential and commercial sectors, 6 percent by transportation and 5 percent by agriculture.^(c)

Energy Production in 1990^(a)

Type of Energy Source or Product	Percent of Total Energy Supply	Amount Produced (Actual)	Amount Produced (EJ)	World Ranking
Raw Coal	74	1080 million tons	22.5	1
Crude Oil	19	138 million tons	5.77	5
Natural Gas	2	15.3 billion cubic meters	0.616	20
Hydropower	5	126.4 billion kilowatt hours	1.52	(4 in total electricity production)
TOTAL	100	NA	30.4	3

(a) Wang Zhong-an.

(a) Wang Zhong-an.

(b) *Ibid.*

(c) Zhang Aling.

(d) Wang Qingyi.

(a) Wang Qingyi.

(b) *Ibid.*

(c) *Ibid.*

Biomass accounts for 80 percent of rural energy consumption. China's 880 million residents consumed 7.71 EJ of firewood and crop stalks in 1990.^(a) Excessive use of biomass has resulted in severe ecological damage.

The combination of low per capita energy use and high energy intensity results in a low level of energy service. In 1990, commercial energy consumption per capita in China was 2.44-2.52 GJ,^(b) about 40 percent of the world average.

Energy consumption per unit GNP (energy intensity) was twice the average level of other developing countries.^{(a)(b)}

The energy shortage is a bottleneck to economic growth. In 1988, 25 percent of industrial enterprises were operating at low capacity and one third of the agricultural sector suffered from severe power shortages, resulting in a 400 billion yuan loss in output value.^(c)

(a) Wang Qingyi.

(b) Participants gave three different values for per capita commercial energy consumption in 1990. Wang Zhong-an gave 831 kgce, Zhang Aling gave 857 kgce, and Wang Qingyi gave 860 kgce.

(a) Zhang Aling.

(b) This figure for energy intensity may be highly exaggerated because China's GNP appears low when converted to dollars according to the official exchange rate, but is much higher when purchasing power is taken into consideration.

(c) Zhang Aling.

Reforming China's Energy Management System

During the past 14 years of economic reform, China has introduced markets, made major price adjustments, decentralized enterprise decision making, and allowed the growth of a large non-state sector. But while China's economy as a whole is booming as a result of these reforms, the energy sector is still plagued by the problems associated with traditional central planning. Conference participants summarized the reforms that have already been adopted in the energy sector, and made recommendations for the future.

In the 1980s, energy and electric power production increased dramatically, but the energy industry suffered huge financial losses. According to Zhou Dadi, Associate Director of the State Planning Commission's Energy Research Institute, the total production volume of primary energy in China increased from 18.67 EJ in 1980 to 30.45 EJ in 1991. Electric power generation also grew quickly, especially in the late 1980s, increasing from 300 billion kWh (1.08 EJ) in 1980 to 677 billion kWh (2.44 EJ) in 1991. Power generation capacity increased from 65 GW in 1980 to 151 GW in 1991. Meanwhile, public coal mines fell into deficit at the beginning of the 1980s. The number of mines in deficit increased rapidly over the decade, as did the total volume of the deficit. According to the public coal mines themselves, the deficit exceeded 10 billion yuan in 1991, although this figure has not been verified. The crude oil production sector began operating at a loss in 1990, and the capital profit rate of the electric power grids declined steadily from over 10 percent to around 3 percent. The cumulative debt owed by public coal mines and utilities amounts to 100 billion yuan, and there is no way to pay off the debts within the existing management system.

Oil Industry Reform

Zhou described the reform of the different management systems for oil, power, and coal. The oil industry has the least amount of competition of the three because of the way it was reformed. The Ministry of Oil Industry was

replaced by the China National Oil and Natural Gas Corporation. This corporation is responsible for all of the exploration and production of crude oil and natural gas for the whole country, and carries out many of the government functions of the previous ministry. More than 95 percent of inland oil and natural gas fields are controlled by this corporation, while all offshore oil and natural gas exploration and production is under the control of the China National Offshore Oil and Natural Gas Corporation. The latter corporation negotiates with foreign investors in offshore oil and gas ventures like a government agency. China National Petrochemical Corporation (known as Sinopec) operates almost all the oil refineries and most of the petrochemical plants in China.

Because of the monopoly, there is no way for outside investors to enter the industry. Crude oil is sold at three levels in China: the low plan price, the high plan price, and the international price. The central government sets the high and low plan prices and determines how much oil will be sold at each level. If production exceeds the quota, oil can be sold at the international market price.^(a)

Electric Power Industry Reform

Reform of the electric power industry was quite different from that of the oil industry. When the Ministry of Water Resources and Power Industry was abolished, no national corporation was established to take its place. Instead, five large power companies were set up, each covering several provinces. In addition, several provincial

(a) Major changes in the structure of oil pricing occurred at the beginning of 1993. The low plan price for oil tripled, from around \$5 a barrel to \$16.30 a barrel. This price hike brought about two thirds of China's oil closer to the international price, which was around \$21 a barrel. In addition to raising the low plan price, administrators also decided that much of the oil formerly assigned to the low price category will now be sold at the high plan price. The high plan price is actually higher than the international price now because of transportation bottlenecks. (Carl Goldstein, "China's Oil Shock," *Far Eastern Economic Review*, Nov. 12, 1992.)

power companies, independent of the five large ones, were established. The power companies are all under the guidance of the Ministry of Energy, but they are financially independent enterprises. They are responsible for power grid development within their territories.

Funding and ownership are more varied in the power industry than in the oil industry because the government introduced a multiple investment policy for power plants. Under this policy, local governments and power consumers can own and operate power plants. The proportion of investment from non-state sources has grown quickly since this policy was adopted, and has spurred construction of more than 10 GW of new generating capacity annually in the past few years.

The largest of the new power companies is the China Huaneng Group (CHG), which was established with state funds garnered from exporting oil in the early 1980s. CHG built one third of the new power plant capacity added during the Seventh Five Year Plan (1986-90), according to **Wang Xirong, President of Huaneng Technology Development Corporation**. The plants were built by Huaneng International Power Development Corporation and Huaneng Power Generation Corporation, two of CHG's 11 subsidiary corporations. Coal used by Huaneng power stations is supplied by Huaneng Coal Corporation, which owns the two largest coal fields in China. Steel, timber, and cement for power plant construction are provided by Huaneng Raw Material Corporation.

CHG subsidiaries also promote comprehensive utilization, efficiency, and environmental protection. China Comprehensive Utilization Development Corporation, for example, operates eel farms using warm water from power plants and uses coal ash to make reinforced bricks. China Huaneng Technology Development Corporation has invested about 400 million yuan in research and development of cleaner and more efficient technologies, such as liquified coal pumps, oil coal pumps, high efficiency burners, oil-saving burners, and high-energy automotive ignitions systems.

Showing an entrepreneurial spirit that would have been unthinkable a decade ago, CHG even has its own bank, Huaneng Financial Corporation, with total capital of 2.9 billion yuan. CHG has also established Huaneng International Trade Corporation and Huaneng Real Estate Development Corporation in order to increase profits by diversifying its investment portfolio.

Price Reform. Electricity prices are regulated for state-operated power plants, and deregulated for plants operated by investors, which may be local governments, users, or semi-private corporations, such as CHG. The state plants still sell electricity at relatively low plan prices, although the prices have been raised somewhat due mostly to the rising cost of fuel. Non-state plants set prices by calculating interest and profit from the capital investment and operation costs. The price paid by the consumer is often much higher than the price set by the generator, however, because governments at the provincial, municipal, and county level may impose fees to raise funds for electricity development. In addition, all plants are allowed to sell electricity at a higher price if they exceed their quotas.

The multi-tier system has had the positive result of raising the average price of energy products, thus providing an incentive for energy efficiency as well as generating funds for energy development. The downside of the multi-tier system is that different prices exist for the same commodity at the same place and time, even when there is no difference in quality or quantity. Price differences are not used in a coordinated way to achieve efficiency, environmental protection, or equitable allocation. Instead, they come about haphazardly as government agencies react to fiscal emergencies, such as deficits in energy enterprise or government budgets.

Coal Industry Reform

The degree of monopoly in the coal industry falls somewhere between the oil and power industries. Coal mines may be owned by the central government, local government, or township. Around 45 percent of China's coal is currently produced by state-owned mines, known as

Centrally Allocated Public Coal Mines (CAPCM). Around 70 percent of CAPCM are owned and operated by the China National Coal Corporation. The rest are run by the Northeast Coal Company and the new Fine Coal Company, which was recently established to exploit coal in northwest China. CAPCM are run according to the tradition central planning system.

Local public coal mines produce 20 percent of total coal output. They are owned and operated by provincial, municipal or county governments. Beijing has a China National Local Mines Development Corporation to provide policy guidance, but the central government does not have much control over these mines. The market plays a limited role in local mines--prices are somewhat flexible and output is determined by demand.

Township coal mines produce the rest of China's coal, about 35 percent. They are owned and operated by towns, villages, or individuals. Township mines were responsible for 60 percent of the growth in coal output in the 1980s. Their production and sales are mainly dependent on market forces: although they are barred from long distance transport by the railway transport plan, they often find a way to sell their product in remote markets if demand exists. If demand decreases, they do not receive any government subsidies and they may go out of business.

Suggestions for Further Reforms

The energy sector's limited use of market mechanisms has made it the exception to the rule in China's reformed "socialist market economy." Price control in the energy industry has exacerbated shortages: low prices prevent energy producers from breaking even, let alone making a profit to finance increased production. Until recently the government has been willing to subsidize huge losses because price control of the energy sector has provided a measure of economic and social stability. Now Deng Xiaoping has initiated a new wave of reform, encouraging rationalization of prices, and streamlining or elimination of state-owned enterprises that fail to make a profit.

Reforms will also attempt to reduce China's excessive use of coal by promoting conservation and fuel-switching.

Participants discussed the possibility of implementing following reforms:

1. **Redefine the government's role in the energy industry.** Under the current system, national corporations still retain certain government functions, such as imposing environmental regulations on themselves. These government functions, which may conflict with profit maximization, should be taken away from national corporations and given to separate regulatory agencies. Enterprises can then focus on maximizing profits and government can focus on regulation.

The government will also have to change its social welfare program. If subsidies to unprofitable energy enterprises are cut, more resources will have to be allocated for providing unemployment insurance and job training for the millions of workers, especially coal miners, who will lose their jobs as the price of higher efficiency.

2. **Create independent energy enterprises.** The creation of national energy corporations has not been sufficient to improve efficiency and increase competition. The government should break up monopoly energy corporations and encourage the creation of enterprises that are owned and operated by local governments, enterprises, and individuals in order to promote competition.
3. **Reform the energy price system.** Current energy prices are not only below production costs, but also too complicated and irrational. Often many different prices exist for the same product in the same place because they were negotiated at different times on an enterprise-by-enterprise basis. Supply and demand should be the basic determinant of prices, and modification of market prices through regulation should be used in a rational way to

encourage conservation and reduce peak load. Chinese participants noted that coal prices may be deregulated as soon as 1995.

4. **Integrate China's energy industry into the international market.** Current policies to promote energy self-sufficiency by limiting oil and gas imports also promote excessive use of coal. Allowing foreign imports and firms to compete in the domestic market will decrease the share of coal in China's total energy consumption and will put pressure on Chinese energy producers to improve their efficiency. China can also make use of foreign capital, equipment and manufacturing techniques to improve efficiency and expand the use of renewable resources.
5. **Adopt integrated resource planning (IRP).** The central government should encourage utilities and local governments to work together to assess the economic and environmental costs and benefits of various supply and demand side energy options. Adoption of IRP will encourage energy

conservation because demand side measures are often much less expensive than the marginal cost of supply. It will shift the fuel mix away from coal because coal's true cost is much higher when the environmental degradation it causes is figured into the equation.

6. **Improve the energy transport system.** China's largest coal reserves are in the west and north, while the greatest energy demand is in the east and southeast. Transportation problems can be reduced by washing the coal before it is transported, siting power plants closer to mines, and expanding railway capacity.
7. **Increase energy investment.** The central government should expand the energy industry's share of total investment in fixed assets.

Promoting Energy Conservation in China

China's rampant economic growth has created a serious energy shortage. Conference participants agreed that only through a combination of conservation and increased production can China begin to reduce the gap between energy supply and demand. Current energy policy officially gives equal weight to conservation and production, but in reality the bulk of government funds is allocated to increasing energy supply, which is more costly in both economic and environmental terms. Participants discussed the state energy conservation investment policies of the 1980s and the potential for increased use of market mechanisms in the 1990s and beyond.

Strategies for Promoting Investment

Chinese enterprises have little incentive to conserve energy because energy prices are low. To compensate for the absence of correct market signals, the Chinese government created an energy efficiency investment program in 1981. The program, which provides low-interest loans, tax exemptions, and equipment for efficiency improvement projects, is administered by the Energy Conservation Company of the State Energy Investment Corporation, according to **Liu Shunxing, an engineer in the Energy Conservation Company.**

The program invested 7.28 billion yuan from 1981 to 1989, and 4 billion yuan from 1989 to 1991, attracting funds from local governments of 4.85 and 5.14 billion yuan respectively. As a result, annual energy conservation capacity totaled 0.586 EJ. Funds went to construction of 7350 MW of cogeneration capacity (5500 MW have been installed so far); creation of 54 million square meters of district heating; recovery of 16 million cubic meters per day of waste gas, supplying 7 million households; 60 million tons per year of coal washing capacity and 13 million tons per year of coal briquettes; rehabilitation of 210 fertilizer and 85 cement factories; and implementation of pilot projects using advanced technologies. According to Wang Qingyi, some

efficiency loans are being repaid through electricity bill savings.

Before 1985, the central government provided full funding for all kinds of projects. Since 1985, the state has reduced its investment share to 40 percent for more conventional projects, such as cogeneration and district heating, reserving full funding for pilot projects using advanced technologies. Pilot projects funded by the Energy Conservation Company include the circulating fluidized bed boiler, coal gasification technology, low temperature nuclear district heating (200 MW), coal gas for heat and power generation, and coal powder injecting technology in electric furnace steel smelting.

In the future, the Energy Conservation Company plans to promote more scientific and technical exchanges with other countries and import more advanced technology and equipment. Liu said the Energy Conservation Company is well positioned to facilitate international cooperation because of its wide area of investment, abundant funds, and close relationships with ministries, local governments, research institutions and universities. The Energy Conservation Company also plans to pay more attention to environmental protection and comprehensive utilization of resources, and will provide public information and consulting services.

Conservation Achievements in the 1980s

Increased investment led to significant gains in energy efficiency in the 1980s. As **Shen Longhai, director of the State Planning Commission's (SPC) Department of Comprehensive Utilization and Resource Conservation** explained, energy conservation was formally introduced into China's national economic plan in 1981. Laws and regulations were passed, and the SPC undertook a study of energy consumption and the potential for conservation by enterprises. Based on the results of the SPC study, the

universities conducted over 30 case studies of energy-intensive processes and equipment. Guidelines for the management of energy conservation projects were developed. Energy-efficient design specifications were established for 25 items, and efficiency standards were set for 600 items.

China made the following gains in energy efficiency in the 1980s, according to Shen:

- Energy consumption per 10,000 yuan of GNP fell from 392 gigajoules (GJ) in 1980 to 273 GJ in 1990. Energy intensity decreased by 30 percent over the decade, an annual average rate of 3.5 percent. The accumulated energy savings was 7.91 EJ.
- The income elasticity of energy demand was 0.56 during the 1980s. Almost half of the incremental growth in the national economy was made possible by energy conservation. Elasticity was reduced by two thirds compared to the previous 25 years.
- Energy efficiency improvements were achieved in two thirds of industrial products examined in a government survey. Examples include coal-fired power generation, steel, cement, aluminum, fertilizer, and crude oil processing.

Wang Qingyi, Vice-President of the Chinese Energy Research Society, provided a sector-by-sector analysis of the conservation measures implemented in the 1980s and the targets for the 1990s. China's conservation measures focused on industry, which consumed 19.81 EJ in 1990. Measures were aimed specifically at the chemical, iron and steel, and building materials industries, each of which accounts for about 15 percent of total industrial energy use, and on widely used equipment such as industrial boilers, fans, and pumps.

The main measures adopted were equipment retrofits; elimination of inefficient equipment; restrictions on wasteful and environmentally harmful production methods; adoption of efficiency standards; utilization of new energy conservation materials and equipment, such as

computers to monitor consumption; waste recovery and utilization; and cogeneration. In fertilizer production, for example, significant energy savings were achieved by installing new equipment, using a new method to synthesize ammonia, and using electronic process controls.

Large savings were also achieved in the steel industry through the adoption of various energy efficient technologies and cogeneration. Boilers were made cleaner and more efficient through design changes; use of cogeneration, briquettes, and control mechanisms; and adoption of fluidized bed and dust removal technology. Large efficiency gains can be made simply by replacing equipment designed and/or made in the 1950s, 1960s and 1970s with more recent designs. In many cases, the more advanced designs already exist in China, but need to be popularized.

Toward Integrated Resource Planning

China's considerable achievements in energy conservation in the 1980s can serve as the basis for more ambitious efforts to adopt integrated resource planning (IRP) in the 1990s. U.S. participants emphasized that while "getting the prices right" is the first step toward achieving an energy efficient economy, the next step is designing policies to deal with areas in which the market does not work, for example, in incorporating environmental externalities. **Debbie Bleviss, of the International Institute for Energy Conservation**, described how IRP works, using Thailand as an example.

Zhou Fengqi, Director of the Energy Research Institute, has laid the groundwork for demand side management by comparing the end results of applying demand side measures for reducing coal use, i.e., efficiency, to supply side measures, i.e., replacement of coal with other fuels.

Zhou uses an Energy Supply Cost-Benefit Model to analyze a base case scenario of continued high coal use and two alternative scenarios. Both alternative scenarios meet the same economic targets while reducing environmental degradation

by reducing coal use as compared with the Base Scenario. The Conservation Scenario reduces coal use through shifting investment from energy development to conservation. The Replacement Scenario shifts the mix of energy sources away from coal toward oil, natural gas, hydropower and nuclear energy.

The model calculates the total cost of each scenario, which includes the cost of investment, operation, conservation, SO₂ pollution reduction, and energy shortage. The Conservation Scenario, which reduces total energy use by 10 percent, has not only the lowest total cost, but also the highest net income, and the lowest SO₂ and CO₂ emissions.

To be more exact, the total cost of the Conservation Scenario is about 2.3% lower than that of the Base Scenario, and 9.8% lower than that of the Replacement Scenario. Similarly, the net

income of the Conservation Scenario will be 35% higher than that of the Base Scenario and 37% higher than that of the Replacement Scenario. In addition, the Conservation Scenario will have the best environmental results: SO₂ and CO₂ emissions will be 17% less and 13% less, respectively, than in the Base Scenario. Replacement appears to be as effective as conservation in reducing SO₂ emissions, but will only reduce CO₂ emissions by 2% compared to the base case.

Zhou's energy and environmental analysis at the national level establishes a basis for IRP by utilities at the regional level. Future efforts will require more detailed analysis by end-use sector in order to identify measures which will provide the greatest energy savings and environmental benefits for the least cost.

Reducing the Environmental Impact of Coal in China

China has large coal reserves and a desire to be as self-sufficient as possible in energy consumption while maintaining a rapid economic growth rate. Therefore, China will probably continue to rely on coal for three quarters of its energy supply well into the next century. Conference participants agreed that while China will not renounce coal as its main energy source in the foreseeable future, preserving local, regional, and global environmental quality depend on reducing China's use of coal to the greatest extent possible. Among myriad environmental problems caused by coal use, global warming was of most concern to the U.S. participants, while the Chinese considered ambient air pollution to be the greatest threat. Two main strategies for reducing the environmental impact of coal use were discussed: 1) use of pollution prevention and reduction technologies, and 2) reduction of the growth rate of coal use through conservation and fuel switching. The first strategy is addressed below.

Combustion-Related Pollution

Han Jiuling, Deputy Chief of the Air Pollution Division of China's National Environmental Protection Agency, described the damage to air, water and land caused by coal combustion. Ms. Han stated that coal combustion is responsible for 75 percent of particulate emissions in China, a total of 23 million tons per year, and 90 percent of SO₂ emissions, a total of 15 million tons per year. Serious acid deposition problems have developed in southwest and south China because of the high sulfur content of the coal used there and the nearly complete absence of measures to reduce SO₂ emissions. To combat this problem, the Chinese government has begun to implement air pollution mitigation programs for primary and secondary uses of coal.

Primary Production. Unlike the U.S., which converts most of its coal into electricity, China uses a large proportion of coal directly for heating and cooking. The principal measures that China has adopted for reducing uncontrolled emissions

from coal-fired furnaces and kitchen ranges are, according to Ms. Han, promotion of urban central heating, coal gasification, and the popularization of coal briquettes.

- The replacement of household-based heating with central heating had, as of the end of 1989, reduced coal use by 1.5 million tons, reduced dust emissions by 73,000 tons, and reduced SO₂ emissions by 23,000 tons.
- Replacement of coal by gaseous fuels for kitchen ranges saves 3.5 million tons of coal, reduces SO₂ emissions by 59,000 tons, and reduces municipal waste by 1.05 million tons per year.
- Compared to raw coal combustion, briquette combustion reduces CO₂ emissions by 70 to 80 percent, reduces particulate and benzopyrene emissions by 90 percent, and reduces SO₂ emissions by 40 percent when lime or calcium carbide wastes are included in briquette binding material.

Shen Longhai, Director of the State Planning Commission's Department of Comprehensive Utilization and Resource Conservation added that China's announced target for the year 2000 is for SO₂ emissions to be capped at 20 million tons. The targeted treatment rate is 82 percent for industrial waste gas and 60 percent for urban gas fuel combustion, and a goal of 470 million square meters has been set for district heating space.

Secondary Production. Power plants are another focus of emissions reduction efforts. **Zhai Ruoyu, Deputy Director of the Department of Safety and Environmental Protection in China's Ministry of Energy** described the mitigation technologies used in China and plans to expand their use. The main technologies are electrostatic precipitators for reduction of dust emissions, sulfur scrubbers and other SO₂ reduction techniques, effluent treatment, and fly ash utilization.

The number of highly efficient electrostatic precipitators in use has grown from 18 units in 1979 to 236 units in 1991. Particulate emissions have been reduced from 136 kg per MW in 1979 to 43 kg per MW in 1991. The goal for the Eighth Five Year Plan (FYP, 1991-1995) period is to achieve an average of 95 percent particulate emissions reduction and for annual dust emissions from Ministry of Energy power stations to be less than 4.6 million tons.

Most Chinese power plants lack desulfurization equipment because it is too expensive. Some plant operators have built high stacks to lower the ground density of SO₂, but of course this only spreads the problem of acid rain over a larger area. The effects of unmitigated sulfur emissions are felt as far away as Japan. Zhai said that Mitsubishi Heavy Industry of Japan will conduct a wet system desulfurization demonstration project at the Luohang power station in Chongqing. China will compare the cost and results of this project with demonstrations of other desulfurization technologies during the Eighth Five Year Plan period (1991-1995). Options under consideration include demonstration of a rotary spray technique, importation of an in-furnace injection technique, importation of utility-sized CFBC boilers, domestic production of wet system technology imported through the Luohang project, and a pilot project in integrated desulfurization and compound fertilizer production processes.

China also plans to expand its coal washing operations in order to reduce ash and sulfur content and reduce the total quantity of coal that must be transported by rail. In 1989, about 120 million tons of coal produced in state-owned mines were washed. China hopes to increase the amount of coal that is washed prior to shipment, but sufficient water supply is not always available at the minehead.

Technical and economic constraints are currently impeding progress in the adoption of desulfurization technology. Zhai said China is looking for a low-cost sulfur scrubber which would not remove as much sulfur as the most advanced model, but would be affordable for China. An American

participant suggested that it would be more cost-effective in the long run to switch to fluidized-bed combustion, a technology which is more expensive, but pays for itself through the avoided cost of damage caused by sulfur emissions.

China has improved its treatment of de-ashing water, the main effluent from power plants. By the end of 1990, waste water treatment facilities had been installed at 246 thermal power plants of 50 MW or more.

- Dense phase ash treatment reduces the water to ash ratio from 1:15-20 to 1:2-4. Sixty to eighty percent of waste water is reclaimed for reuse after sediment is separated out in settling ponds. Forty plants have adopted this system.
- Separation of fly ash and bottom ash reduces water use by 40 percent. By 1990, this technique had been adopted for 320 boilers throughout the country.
- Closed loop circulation for de-ashing water had been installed at 44 thermal plants by the end of 1990.

Fly ash utilization reached record levels in 1990. More than 20 thermal power plants in China used 100 percent of their fly ash for other industrial processes, such as cement production. More than 1,000 hectares of ash dumps have been reclaimed.

Mining Waste

Mining of coal, as well as its combustion, poses a great threat to the environment, as **Zhou Fengqi, Director of the Energy Research Institute of China's State Planning Commission**, explained. Mining causes subsidence (the sinking of land located above coal mines), produces large quantities of harmful liquid and solid waste, and releases methane, a greenhouse gas.

- Subsidence damages overlying buildings and railroads, and reduces agricultural output by destroying land and irrigation projects. One billion cubic meters of land have been destroyed by subsidence.

- Only 56 percent of enterprises with coal washing plants have a closed system that treats and reuses waste water. The remainder discharge untreated water to the environment, a total of 45 million tons in 1989. In addition, 1.5 billion tons of mostly unused ground water were also discharged from coal mines.
- Two billion tons of gangues, the worthless rock or vein matter in which coal is found, have accumulated as a result of coal mining, with 100 million more tons added every year. Sometimes these materials spontaneously combust, producing fumes which are harmful to human health and the environment.
- Several cubic meters of methane are released for every ton of coal produced. Only a small portion of coalbed methane is used as fuel, the rest being released to the atmosphere and contributing to the greenhouse effect.

Dina Kruger, Project Manager of the U.S. EPA's Global Change Division, discussed her efforts to promote the use of coalbed methane in China, a process which provides clean fuel while reducing the threat of global warming. EPA has succeeded in obtaining funding for coalbed methane recovery projects from World Bank's Global Environment Facility. Aside from coal bed methane recovery, specific measures for reducing mining waste were not discussed at the conference.

Shen presented an overview of China's progress in environmental protection which included

waste treatment. He stated that environmental quality has remained stable as China's economy has grown at a rate of 9.6 percent a year. Technological innovations and adjustments in industrial structure and production allocation allowed the quantity of discharged waste to remain constant while industrial production increased. Discharge minimization has also been achieved through waste material recovery. Around 756 million tons of industrial waste was recovered from 1981 to 1990. The total value of waste recovery reached 26 billion yuan in 1990.

Shen noted that China hopes to cap discharge of industrial waste water at 32 billion tons by the year 2000. The targeted treatment rate for that year is 84 percent for industrial waste water, 70 percent for installed waste water equipment and 20-30 percent for urban waste water. China also hopes to achieve a comprehensive utilization rate of 37 percent for industrial solid waste, a total of 320 million tons.

Both pollution prevention and energy efficiency improvements are essential if China is to maintain economic growth without destroying its environment, but the latter affects short term growth while the former determines long term sustainability. Discussion of pollution issues therefore remained secondary to efficiency issues at the conference because of the immediate impact of energy efficiency on the economy.

Appendix A

**Battelle Seattle Research Center
October 26-28, 1992**

Appendix A

Battelle Seattle Research Center October 26-28, 1992

Agenda

Monday, October 26

4:00 PM Reception

4:45 PM Welcome

Workshop Purpose and Goals (Co-Chairs)

William Chandler
Zhou Dadi
Mark Levine

5:00 PM Roundtable: Introductory Comments by Participants

6:45 PM Dinner

8:00 PM **OVERVIEW**

Presentation:

- *Energy and Change in China*

Shen Longhai, Director, Department of Comprehensive Utilization and Conservation of Resources, State Planning Commission of China

- *Energy and Change in the United States*

I.L. (Jack) White, Senior Director, Energy Programs Office, Battelle Memorial Institute, Pacific Northwest Laboratory

Tuesday, October 27

7:00 AM Breakfast

8:00 AM **ENERGY DEVELOPMENT IN A MARKET CONTEXT**

Tuesday, October 27 (contd)

Presentations:

- *Fossil Energy Market Mechanisms and Pricing Policy for China*

Zhou Dadi, Associate Director, Energy Research Institute, State Planning Commission of China

- *Energy Demand Outlook for China*

Zhang Aling, Professor, Institute of Nuclear Energy Technology, Qinghua University

- *Fossil Fuel Exploitation Policy for China*

Wang Zhongan, Senior Engineer, Department of Energy Industry, State Planning Commission

9:00 AM Respondents:

- *U.S. Energy Management: Markets vs. Regulation*

Thomas Foley, Manager, Battelle Portland Operations

- *Fossil Energy Technology: Government and Private Sector Relationships*

Jack Siegel, Deputy Assistant Secretary for Coal Technology, U.S. Department of Energy

- *Managing the Transition from Planning to Markets*

Zbigniew Bochniarz, Professor of Economics, University of Minnesota

10:00 AM Break

10:30 AM Discussion

12:00 PM Lunch

2:00 PM **ENERGY EFFICIENCY PRACTICE AND PROSPECTS**

Presentations:

- *Economic Development and Energy Efficiency in China*

Zhou Changyi, Division Chief, Department of Comprehensive Utilization and Conservation of Resources, State Planning Commission of China

Tuesday, October 27 (contd)

- *Financing Energy Efficiency in China*

Liu Shunxing, Engineer, Division of Energy Conservation, Energy Conservation Company of the State Energy Investment Corporation of China

- *Technical Alternatives for Energy Efficiency in China*

Wang Qingyi, Senior Engineer, Information Institute of the Academy of Coal Science and Technology

3:15 PM Break

3:45 PM Respondents:

- *What Works in the United States and in Transition Economies*

Marc Ledbetter, Deputy Director, American Council for an Energy-Efficient Economy

- *A U.S. State Perspective*

Phil Carver, Senior Policy Analyst, Oregon State Department of Energy

4:15 PM Discussion

5:15 PM Break

6:00 PM Dinner

7:30 PM **ELECTRIC POWER: ORGANIZATION, PRICING, AND EXPANSION**

Presentations:

- *Power Generation in China: Technology and Management*

Wang Xirong, President, China Huaneng Technology Development Corporation

- *Electric Power: Pricing, Demand, and Growth*

Wang Zhongan, Engineer, Department of Energy Industry, State Planning Commission of China

Tuesday, October 27 (contd)

8:00 PM **Respondents:**

- *Regulatory Frameworks*

Dick Watson, Director, Power Planning Division, Northwest Power Planning Council

- *Integrated Resources Planning*

Deborah Blewiss, Director, International Institute for Energy Conservation

8:30 PM **Discussion**

9:00 PM **Break**

Wednesday, October 28

7:00 AM **Breakfast**

8:00 AM **ENVIRONMENTAL MANAGEMENT**

Presentations:

- *Environmental Issues Associated With Development of the Energy Industry in China*

Zhou Fengqi, Director, Energy Research Institute, State Planning Commission of China

- *Environmental Issues Associated with Development of the Electric Power Industry in China*

Zhai Ruoyu, Deputy Director, Department of Safety and Environmental Protection, Ministry of Energy of China

- *Air Pollution Control Policy in China*

Han Jiuling, Deputy Chief, Department of Air Pollution Control, National Environmental Protection Agency of China

9:00 AM **Respondents:**

- *Regulation and Market Mechanisms for Environmental Protection: The U.S. Experience*

T.J. Glauthier, Director, Energy and Climate Program, World Wildlife Fund

Wednesday, October 28 (contd)

- *Cooperation for Environment and Development*

Dina Kruger, U.S. Environmental Protection Agency

Michael Adler, U.S. Environmental Protection Agency

9:45 AM Discussion

10:30 AM Break

11:00 AM **SUMMARY: U.S.-CHINA COOPERATION IN ENERGY AND ENVIRONMENT**

12:00 PM Close

12:30 PM Lunch

Appendix B

List of Participants

Appendix B

List of Participants

Sponsors

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