Chapter 3

Energy Technology Transfers

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China's present energy shortages appear inconsistent with its vast and varied energy resource base. Some of the shortages can be alleviated by expanding present capabilities, for instance opening more coal mines, but much of the resource base will be unavailable without improved technology. Sophisticated techniques are required to explore for oil and gas offshore or in remote regions. Coal is plentiful, but bottlenecks prevent enough from reaching the market, and the environmental impacts of burning large quantities are severe in some areas. The best potential hydroelectric sites are far from load centers, requiring long-distance, high-voltage transmission systems. Nuclear energy, known to the Chinese through their military programs, requires a quite different approach for power generation. Energy can also be used much more efficiently.

While China may be capable of developing these technologies indigenously, the process can be speeded considerably and made more efficient by the importation of foreign technology. Much already has been imported, and the Chinese have an intense interest in expanding this access.

This chapter reviews the resources available to China and present trends in energy production and consumption. Then the role that technology, both domestic and foreign, might play is evaluated in light of constraints on the Chinese system. Further detail, and the basis of much of this discussion can be found in the background paper "Technology Transfer and China's Energy Industries."

RESOURCES

Reliable data for China's oil and gas reserves are not available, but much can be pieced together. Most exploration has taken place in the northeast corridor, and that is where the giant fields and 75 percent of the reserves are located. Proved and probable reserves in the northeast are estimated at 10 to 15 billion barrels.[1] Cumulative production has been 10 billion barrels, and additional discoveries and advanced technology may add an equivalent amount of oil resources.

Petroleum reserves in the western part of the country are much less certain because exploration has been much less intense. Perhaps 3 to 5 billion barrels will be produced there. Offshore reserves are even more speculative because extensive exploration began relatively recently, and much of the exploration has been disappointing. Offshore reserves of 20 to 30 billion barrels are a commonly accepted projection. Thus the ultimately recoverable petroleum reserves are 50 to 70 billion barrels. China's proved reserves are less than those of the United States though the potential for further discoveries is greater.

Known natural gas reserves are only 4.6 trillion cubic feet, a much lower energy resource than crude oil reserves. However, gas has been a lower priority fuel because it is difficult to transport without an expensive pipeline system, and there is little export market. However, recent offshore drilling in the South China Sea has resulted in a commercially exploitable find in the range of 3 to 7 trillion cubic feet. Basins in western China also show promise of very significant gas resources. These finds may stimulate interest in building the required infrastructure and searching for more gas.

Coal deposits are gigantic, over 7.50 billion tons,[2] and may be double that. Actual recoverable reserves are much lower, but China is in the

[1] See Kim Woodard, Background Paper I, "Technology Transfer and China's Energy Industries," prepared for the Office of Technology Assessment, Apr. 18, 1985.

[2] China Energy Ventures, Inc., unpublished data, April 1985.

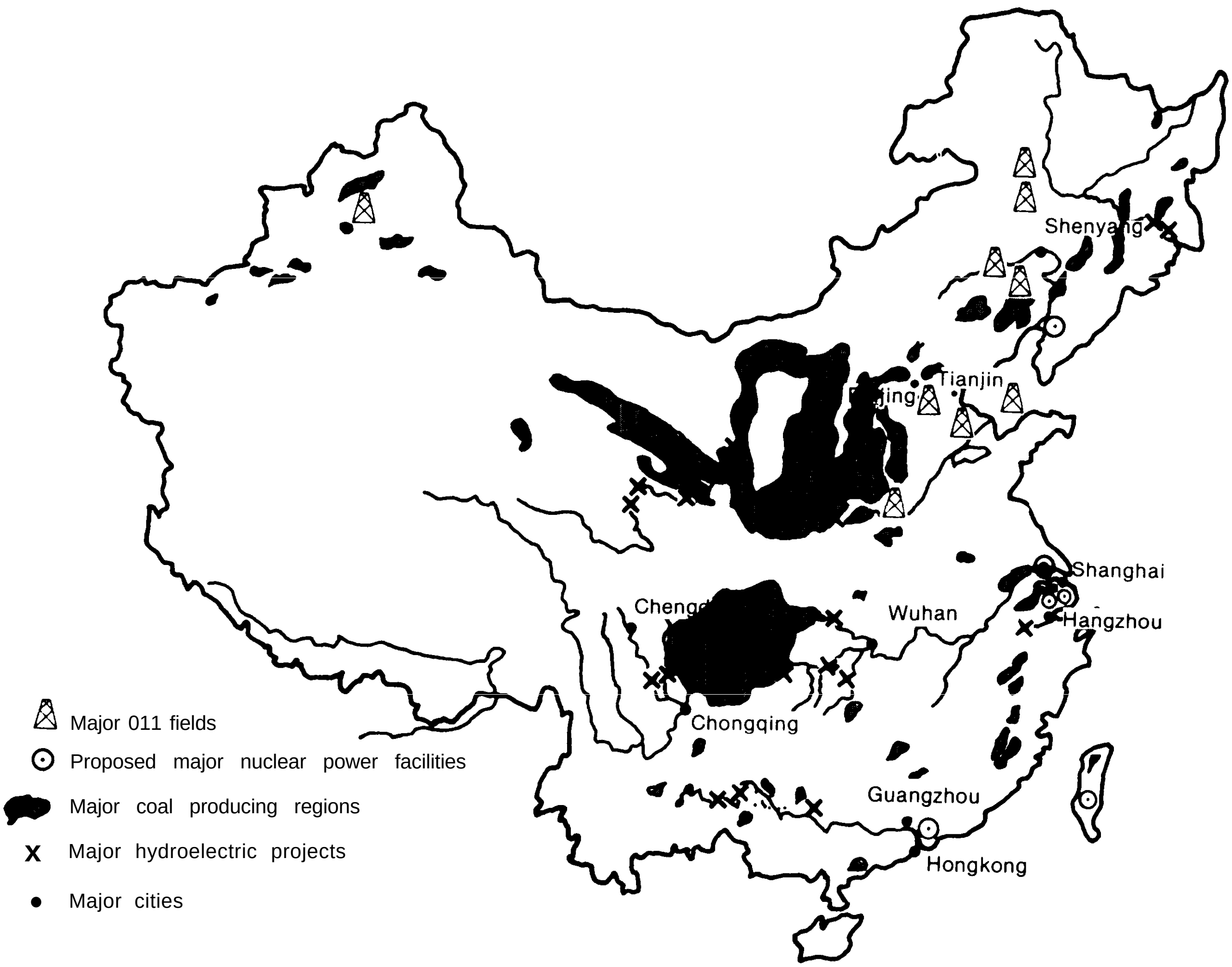
same class with the United States or the U. S. S. R., which have the largest in the world, At the present rate of exploitation, this coal would last hundreds of years. Most of it is reasonably good quality bituminous grade. Pockets of coal occur practically everywhere in the country, but the major seams are in the central and north central regions, far from the major industrial regions near the coast.

Hydropower resources are also huge, potentially as much as **380,000** megawatts (MW).[3] Only **22,000** MW have been exploited. About **60** percent of the potential is in the Southwest, a great distance from population centers.

Figure 1 shows the location of the major energy resources.

[3] Ibid.

Figure 1 .—China's Energy Resources



SOURCE Office of Technology Assessment

TRENDS IN ENERGY PRODUCTION AND USE

Petroleum

Crude oil production rose rapidly in the 1970s to over 2 million barrels per day in 1979 (the United States produces 8.6 million). By 1980, however, production flattened out due to the maturing of the biggest fields and a rapid decline in one unusual formation. Output in most fields has now stabilized or is increasing slightly, but at the expense of ever-increasing water injection to maintain pressure. Production data are shown in table 1. The fields that are mature now are expected to decline in a few years.

This situation has developed largely because of a lack of exploration. The fields in the northeast appeared to be so large that little attention was paid to the rate of depletion and the need to develop new fields. Even now that the situation has been recognized, China is spending only about $2 to $3 billion on oil exploration and development, about what a moderate size U.S. company would invest for a tiny fraction of China's production. In effect, China has been producing itself out of business.

This has led to an extensive reevaluation of petroleum policies in China. The Ministry of Petroleum Industry has shifted from "self-reliance" and is allowing foreign oil companies to participate in offshore exploration. More recently, as the focus of exploration has shifted to the northwest, which has a huge potential but harsh conditions, China has sought help from foreign companies in seismic surveys and exploratory drilling. Foreign oil companies may be invited to participate in exploration and production activities in 10 provinces south of the Yangtze River under arrangements similar to the offshore concessions.

Natural Gas

Natural gas production is limited to one basin in Sichuan and as a byproduct at the major oilfields. Production has been declining significantly as shown in table 2, largely because of a severe

Table 1 .—Petroleum Production by Region (thousand barrels/day)

Region	Year 1970	1978	1980	1982	1983	1984
Northeast	447.4	1,120.8	1,171.8	1,163.8	1,181.0	1,235.2
North	20.4	408.0	382.2	285.4	270.2	268.8
East	93.4	395.0	358.4	380.6	434.8	547.2
Northwest	45.8	98.8	121.2	124.0	135.4	141.4
Central-South	5.4	56.6	83.2	84.4	96.0	96.0
Southwest	0.6	21.8	2.0	2.0	2.0	2.0
Total	613.0	2,101.0	2,118.8	2,040.2	2,119.4	2,290.6

SOURCE China Energy Ventures, Inc

Table 2.—Natural Gas Production by Region (trillion cubic feet)

Region	Year 1977	1978	1979	1980	1981	1982	1983
Northeast	0.169	0.183	0.189	0.193	0.157		
North	0.028	0.030	0.034	0.029	0.026		
East	0,043	0.053	0.057	0.053	0.044		
Central-South	0.001	0.001	0.001	0.002	0.002		
Northwest	0.009	0.011	0.012	0.014	0.016		
Sichuan	0.192	0.224	0.238	0.231	0.212	0.191	
Total[a]	0.442	0,501	0.530	0.521	0.456	0.434	0.419

aTotals may not add due to rounding

SOURCE Ministry of Petroleum

undercapitalization (especially in exploration) and a failure to acquire modern technology comparable to the oil industry. There are few gas pipelines in the country to get the gas to market even if production can be increased. The gas discovered by ARCO in the South China Sea might be converted to fertilizer at coastal plants.

Coal

Currently, coal represents 74 percent of China's energy production. While the share is dropping, actual production has risen fairly steadily at an annual rate of *7* to **8** percent as shown in table **3.** Future production will be a function of the level of investment in mines, other facilities, and transportation infrastructure. The stated target for 2000 is 1.2 billion tons, about double the rate in 1980. Almost half of this goal would be met by small, local mines, but annual additions to large mine capacity will have to be 10 to 12 million tons per year. The mine at Pingshuo in Shanxi Province, to be developed by the Island Creek Coal Co, (a division of Occidental Petroleum), will have a capacity of 15 million tons per year. At present, almost all mining is underground, but some of the biggest new mines will be surface mines. Operations at most coal mines are inefficient. On the average, less than a ton is produced per man-day, versus about 10 tons for underground mines in the United States.

Very little coal (about 10 percent of output) is cleaned before shipment. In- many mines, noncombustible matter significantly increases shipping costs and causes problems in boilers when the coal is burned. It is likely that beneficiation (coal cleaning) plants will become more common, but progress has been slow.

Transportation is a major bottleneck. Coal already represents about *40* percent of all rail shipments. Many lines are being upgraded, but the process is slow and expensive. China intends to export more coal, which will depend on ports being upgraded in addition to the lines to the ports. Japan is a natural market for Chinese coal and is financing mine and port development, but the slumping price of coal on the world market has reduced the incentive to make these improvements.

Electricity

The electric power industry has been growing rapidly as shown in table 4. Present total capacity is 81,000 MW, of which 68 percent is from steam plants (mostly coal) and the rest is hydropower. There are six major regional grids and many small local grids. Twenty-two long-distance, high-voltage transmission lines have been built.[4] Others have been announced, including a 1,300 kilometer direct current line from Qinghai to Hebei,

Despite the growth, there is a severe shortage of electricity. It is estimated that only about 80 percent of the nation's industrial capacity can be operated at any one time because of inadequate electric capacity.[5] The current shortfall is about 10,000 MW. At peak consumption hours, some customers are cut off or restricted. In addition to lost production, blackouts can damage equipment.

There are 18 large hydropower stations and another 11 under construction for completion by 1990. The largest potential project, the "Three Gorges" on the Yangtze River, could produce 12,000 MW, but it is still in the planning phase. This project, estimated at $9 to $12 billion, would

[4]Fujiko Kitani, "Electric Power in China, " *China Newsletter, No.* 56, JETRO.

[5]Lu Qi, "Energy Conservation and Its Prospects, " *Beijing Review, No, 46.* November 1984.

Table 3.—Coal Production (million metric tons)

1970	353.9
1978	617.9
1980	620.1
1981	621.6
1982	666.0
1983	692.0
1984	772,0

SOURCE China Energy Ventures, Inc , and National Council for U S China Trade

Table 4.—Electric Power Production (billion kWh)

	Thermal	H ydro	Total
1970	95.4	20.5	115.9
1978	212.0	44.6	256,6
1980	242.4	58.2	300.6
1981	243.8	65.5	309.3
1982	253.3	74.4	327.7
1983	263.5	84.5	348.0
1984	289.1	85.5	374.6

SOURCE China Energy Ventures, Inc and National Council for U.S.-China Trade rank among the world's largest construction projects. Figure 1 shows some of the major hydropower sites. There are also over 100 midsized (12 to 250 MW) hydropower stations. China is the world leader in the development of mini-hydro plants, with over 80,000. This represents over one-third of all hydropower capacity, and is an important part of the rural electrification strategy.

There are about 65 large thermal plants in the country, mostly in industrial areas. Thermal power will represent the bulk of additions to the electric power system for the foreseeable future. The plants are mostly indigenously built, and they are significantly less efficient (28 percent) than new U.S. coal plants (about 40 percent). Powerplants consume over 15 percent of petroleum supplies, which is a significant loss of potential exports or alternative use in the economy.

Projections

Estimated primary energy production through 2000 is shown in table 5. These projections are based on a computer simulation done in early 1984 and are included for illustrative purposes only. Actual 1984 production for coal was 772 million metric tons and for petroleum, 114 million metric tons.

Energy Use

China uses all of the energy production discussed above except for the export of about 500,000 to 600,000 barrels per day of oil (including refined products) and 7 million tons of coal per year. Much of this use is quite inefficient. Artificially low energy prices and a shortage of capital have resulted in a vast amount of equipment and processes that was not designed to minimize energy use. It is now clear that demand for energy services will increase rapidly as the economy and standards of living rise, but that producing great amounts of additional energy will be very expensive, polluting, and in some cases, impossible. Therefore, to meet economic goals, increasing the efficiency of energy use will be necessary.

In the 1970s, China launched a major program to increase efficiency and conserve energy, a significant departure from past practices. This program has had considerable success, saving the equivalent of several tens of million tons of coal each year (cumulative). Further conservation will require increasing investment as the easy measures are taken, but it is likely that saving energy will be at least cost competitive with producing energy for many years.

In the industrial sector (which uses 72 percent of China's total primary energy), only about 40 percent of the energy is converted to useful service.[3] Improving this record would have a double benefit: reducing the cost of production and freeing the energy for other purposes. Prioritization of energy allocation is an important inducement. The most efficient plants are assured a supply of energy, while the least efficient ones are closed in times of shortages. Not only does this mean the most efficient plants operate the longest, but it provides incentives for plant managers to fix their problems. Fuel switching from oil to coal is also encouraged to reduce energy costs, especially in facilities that changed from coal to oil in the 1960s and 1970s. So far, however, conversion has been slow, as it has been in the United States. Improved energy management is another priority, using audits, energy measurement instruments, and analysis to identify conservation opportunities. Old equipment and plants are being renovated (e. g., with insulation or air preheater) or even replaced to achieve large savings. Cogeneration and residual heat recovery are being emphasized. The recent emphasis on light industry is also helping slow the growth rate of energy demand.

The commercial/residential sector used only 14 percent of China's total commercial energy.[4] Coal is the major fuel for cooking and heating. In rural areas, noncommercial fuels (wood, crop byproducts, biogas) are very important, but it is possible that this dependence will drop as incomes rise and more convenient fuels become available. In any event, neither technology nor equipment is likely to be exported by the United States. One-third of the peasants have no electricity.[5] It is a national goal to electrify all rural villages by 2000.

[3] "Energy Conservation," *The China Business Review,* January-February *1982,* p. 12.

[4] Ibid., p. 18.

[5] Qi, op. cit., p. 20.

Table 5.— Projected Primary Energy Production[a]

Year	Coal Baseline (mmt)	Coal Plan (mmt)	Crude petroleum Baseline (mmt)	Crude petroleum Plan (mmt)	Natural gas Baseline (bcm)	Natural gas High (bcm)	Hydropower Baseline (bkWh)	Hydropower Plan (bkWh)	Total energy Baseline (mmtce)	Total energy Plan (mmtce)
1975	(484)		(77)		(9)		(47)		(472)	
1980	(620)		(106)		(14)		(58)		(620)	
1983	(692)		(106)		(12)		(84)		(671)	
1985	743	700	109	117	12	14		100	713	698
1990	821	850	115	132	12	19	123	140	771	838
1995	895	1,000	122	156	16	27	175	210	847	999
2000	966	1,200	131	210	21	38	228	300	924	1,245

aThese projections are based on a computer simulation done in early 1984 and are included for illustrative purposes only Actual 19&l production for coal was 772 mmt and for petroleum, 114 mmt

SOURCE China Energy Ventures, Inc

In the transportation sector, demand for liquid fuels is expected to rise rapidly. Railroads are being electrified, but the increasing number of diesel locomotives, automobiles, airplanes, trucks, and buses will put considerable pressure on the oil industry. The Ministry of Transportation is retrofitting most of the older engines in its trucks, in large part to reduce fuel consumption. This one step is estimated to save 60,000 barrels of fuel per year. ’

“’Refit Gives More Power to Old Trucks, ” *China Daily,* Mar. 14, 1985, p. 2.

TRENDS IN ENERGY TECHNOLOGY TRANSFER

Technology acquisition has been a central feature of China’s energy programs for many years, but until 1980, direct sales of equipment and even entire factories were far more important than technology transfer. In some cases, China tried reverse engineering (reproducing a finished product without access to design and manufacturing information, such as was done with oilfield equipment). Many of these efforts were not very successful though some products are being used. The Chinese petroleum industry, at least, has decided it is less costly and more effective in the long run to procure technology directly.

Petroleum Exploration and Production

The offshore oil exploration projects have stimulated petroleum technology transfers, including training, joint technical services, and joint management. Many of the smaller U.S. oilfield service companies are now participating. Contracts for licensing to manufacture equipment have been rare for offshore technology production, largely because the market is limited (only 19 rigs were active in 1984, and this number will not grow in the next year or two).

The situation is reversed onshore, where foreign participation has been limited to specialized services and equipment supply. Onshore activity is much greater, with about **800** to **900** active rigs. All of China’s production has been onshore. Licensing arrangements have been more attractive than for offshore technology, especially as a way of gaining access to the market. The prime example is the drill bit factory established under a licensing contract by the Hughes Tool Co. Hughes was paid a fee for the transfer and still receives royalties for the production. In addition, it is allowed to sell large quantities of U.S.-made drill bits in China because far more are needed than the factory can supply (although some appear to have been exported).

The total commercial value of technology transfer and training programs in the 1980-85 period is estimated to be $100 to $125 million. While this may appear small compared to the $1 billion spent by foreign companies for exploration offshore, or the $250 million imports of equipment and services for the onshore market in 1984 alone, the technology transfer component has major long-term implications. Furthermore, contracts signed but not yet implemented are not included, and there are many contracts being negotiated, a long-term process itself, Estimated values for the next 5 years are $500 to $900 million, as shown in table 6. Key items are likely to be:

- advanced geophysical technology such as seismic equipment and computer hardware and software;
- manufacturing technology for land drilling rigs, downhole completion equipment, and pressure control equipment;
- steam injection and enhanced recovery technology; and
- instrumentation.

U.S. companies will be in a strong position to compete for this business (which may diminish in the 1990s as the Chinese increasingly master the technologies). The Chinese are also particularly interested in technology to meet materials requirements for the manufacturing capabilities they are purchasing, such as high-grade metallurgy, specialized rubber, and other elastomers. It should be noted that all these basic materials technologies have military as well as energy applications.

Petroleum Refining and Petrochemicals

China is a net exporter of refined petroleum products, including $300 million of gasoline to the United States in 1984.[10] The need to earn additional foreign exchange (which is crucial to the purchase of more foreign technology to continue the modernization program) is a strong motivation for accelerated technology acquisition to improve refineries. Import substitution is the motivation in the case of petrochemicals and fertilizer. China spends about $2 billion annually in foreign exchange on these items.

Licenses for chemical processes are now increasing because SINOPEC, the corporation with control over China's refineries and related facilities is engaged in a $3 billion refinery modernization program. If production of offshore oil starts, construction of coastal refineries is likely, possibly under joint management or even as joint ventures. The worldwide glut of refining capacity argues against any near-term construction of much additional capacity, however. License agreements have been signed for the manufacture of various pieces of equipment for chemical plants, but the combined value of the licenses is probably only about $5 million,[11] Specific technologies of interest include:

- secondary refining technology, such as hydrocrackers;
- process licenses for specialized petroleum products, pesticides and agricultural chemicals, and synthetic materials such as elastomers; and
- engineering and construction technology for plant design and pipelines.

U.S. companies have a long record of involvement in this-area of the Chinese market. They are likely to make significant sales, perhaps $50 to $100 million over the next 5 years, not including sales of equipment.

[10] This may drop to zero next year because the phasing out of lead in U.S. gasoline makes the low octane Chinese gasoline useless even for blending. The Chinese are likely to resent the loss of a major market.

[11] Woodard, op. cit., p. 16.

Table 6.—Estimated Values of U.S. Technology Transfer to China[a]

	1973-80	1980-85	1986-90
Petroleum exploration and production	marginal	$60-70 million	$300-500 million
Refining and petrochemicals	$15-20 million	$15-20 million	$ 50-100 million
Coal	marginal	$10-15 million	$ 50-100 million
Electric power	marginal	$20-25 million	$100-200 million
Total	$20-30 million	$100-125 million	$500-900 million

aEstimated values, do not necessarily total Includes only money actually spent by China or its foreign Companies on technology transfer and training during periods in question.

SOURCE: China Energy Ventures, Inc

Coal Mining and Transportation

China produces almost as much coal as the United States, but its coal mining technology continues to lag, U.S. companies are becoming involved in every level of the Chinese coal industry including large mine development, engineering contracts for mines and transportation, and licenses for mining and beneficiation equipment.

U.S. technology transfer for coal development has generally lagged behind that for oil, despite the considerably greater importance of coal in China's energy system. This is because coal exports create relatively small foreign exchange earnings ($500 million in 1984, or 10 percent of the earnings from oil exports) and because coal technology is not as esoteric. Another reason for delays in coal technology transfer is that the mimes that will be opened by U.S. companies are the subject of protracted negotiations, as is much of the foreign investment in China.

Meeting the goal of 1.2 billion tons of coal by 2000 will require an expansion of capacity of about 50 percent or about 30 million tons per year, On the average, at least one very large mine, several medium-sized ones and a lot of small local mines must be added each year, as well as a vast infrastructure of beneficiation plants, transportation systems and port facilities. Technologies that are already being imported or discussed include:

- engineering for large open-pit mines;
- slurry pipelines and unit trains;
- mine safety technology;
- manufacturing licenses for equipment; and
- beneficiation technology,

U.S. companies have an edge on surface mining and short wall underground mining equipment and beneficiation plants. Most long wall mining equipment is still made in Europe. Total value of technology transfer from the United States over the next 5 years may be **$50** to $100 million.

Electric Power

U.S. technology transfer in the electric sector has been concentrated in a few large contracts for modern generator and boiler technology, These licensing contracts are intended to improve the efficiency and increase the size {from 250 to as much as 600 MW) of China's standard generating plant. China has also begun importing electric transmission technology from U.S. firms, and this is likely to increase as the voltage of the lines increases. Important technologies are likely to include:

- boiler retrofits and other thermal efficiency technology;
- design and engineering technology for large powerplants and particularly for hydropower stations (and also tidal powerplants);
- high-voltage transmission and switchgear and control systems; and
- pollution control equipment.

U.S. companies will be competitive in these markets. Total value could be $100 to $200 million from 1986 to 1990. Nuclear power technology is also a possibility that is covered in the next chapter of this technical memorandum.

Conservation

Technologies to improve the efficiency of energy use can be sold in their own right or as part of a larger package, such as a steel mill, a powerplant, or an oil refinery. The largest gain in efficiency comes when a completely new plant is built, incorporating the best of modern technology. This is also a very capital-intensive approach which normally cannot be justified simply on the grounds of energy efficiency. As demand for production increases, however, new manufacturing facilities will be required, and average efficiency will improve, but most gains in the near-term will come from retrofits, China's program to increase efficiency has had considerable success, but after the easy housekeeping measures (simple insulation, adjusting combustion conditions, cleaning steam traps, etc.), identifying opportunities and implementing solutions becomes much more difficult and costly. This next stage of energy conservation may provide many opportunities for the sale of equipment and the transfer of technologies. Some of the technologies are:

- monitoring equipment;
- air preheater and heat recuperators;
- process controls;

- cogeneration equipment;
- high efficiency motors and pumps;
- energy management techniques and systems, including instrumentation and control equipment;
- energy auditing techniques and analysis; and
- high efficiency lighting.

No estimate is available for the potential value of such technology transfer because it covers such a wide range, and each sale might be relatively small. In some cases no single company has enough vested interest in the technology to warrant marketing it in China, or there is no clear customer. In many of the industrial applications, however, U.S. companies would be competitive,

Solar

The only solar technology that is likely to be at all significant is photovoltaics. At least one U.S. company is discussing the possibility of setting up a manufacturing plant in China. Other solar technologies are either not competitive or are already being implemented in China (e.g., flat-plate collectors). The technology that has been developed in the United States over the past 10 to 15 years would probably be helpful, but it is not clear if it will be economical for industry to provide it to China. This may suggest a greater role for the Department of Energy. China is also exploring the possibility of tapping its geothermal resources. This could be a significant area in the future, since the United States has done considerable R&D as well as limited exploitation.

CHINA'S PROBLEMS WITH TECHNOLOGY TRANSFER

The discussion above indicates China's need for foreign energy technologies, and its intense drive to acquire technology. China's ability to choose technologies wisely, assimilate them, and diffuse them are also questions which have concerned students of technology transfer to China. These are germane questions in light of China's modern history–its quest for technology since the 19th century, its concerns about the corrupting influences of foreign material culture which accompanied that quest, massive technology imports from the Soviet Union which occurred in the 1950s, and the confused technology policies of the government in the post-Mao period.

Finance

In comparison to other developing countries which are recipients of transferred technology, China has both distinctive advantages and disadvantages in dealing with technology from the international economy. First, as noted elsewhere in this memorandum, China is in a relatively favorable position in terms of its foreign exchange holdings, and has in its energy resources for export a source of foreign exchange earnings (the latter accounts for 20 percent of China's foreign exchange earnings). But China's energy needs are so great that it is difficult to find the necessary financial resources. Foreign exchange reserves could be dissipated quickly with major purchases (e.g., nuclear powerplants), and the uncertainties of the export potential of the energy industry for the remainder of the century in the face of rising domestic demand induces caution in the use of foreign exchange.

China's energy sector remains severely undercapitalized in spite of the fact that it receives 45 percent of industrial investment. This affects China's ability to solve the technological needs of its energy sector through technology transfer. While the energy industry is a foreign exchange earner, reportedly only 10 percent of the foreign exchange it generates is reallocated to the energy sector for its foreign procurement uses. Thus, financing is an important constraint on *energy* development, but it is one with a differential impact. Chinese investment decisions favor foreign exchange earners, and exportable energy sources —oil and coal—also have attracted private funds from abroad. Financing is a greater constraint in the electric and hydropower areas, where the Chinese have sought and are receiving concessionary loans from abroad.

Manpower

A second constraint facing many developing countries is a shortage of technical manpower, and a lack of a scientific tradition. These problems affect a country's ability to absorb foreign technology. China does have something of a manpower problem, and it also has technology absorption problems in the energy sector. Yet in absolute terms, China has a large pool of scientists and engineers (over 2 million).[12] Even though the quality of training received by those in the pool varies a great deal, and the distribution of talent by region and economic sector is unbalanced, China does have a cadre of technical specialists to facilitate technology transfers.

China is also rapidly expanding the technical manpower ranks through its own new educational policies, and by taking full advantage of educational and training opportunities offered abroad by institutions of higher education, companies, and foreign governments. Thus, while manpower inadequacies do appear in the context of technology transfers, China is also preparing itself for assimilating technology and benefiting from learning curve effects.

In contrast to many developing countries, China has an established energy industry, and an extensive R&D network. Thus, in the energy area, all sectors have research, design, and educational institutes which typically have more than 25 years of experience. Many of these had experience with technology transfers from the Soviet Union in the 1950s, and all of them had experience with technological self-reliance since 1960. This R&D system was terribly disrupted during the Cultural Revolution, and its capabilities were reduced. But it is important to recall the evolution of this system since 1949, and the many achievements it has made. It is a significant resource which should aid China in assimilating foreign technology, and avoiding technological dependency. China's technology absorption problems, thus are likely to be short-term problems; its technical community is extant and must be brought up to world levels. It does not have to be created de novo.

Ironically, the existence of an established energy supply industry and R&D system at times works against technology transfer. The domestic industry has a vested interest in domestic supply, and thus China is faced with "make or buy" questions which would not trouble other developing countries. In addition, China's domestic industry has had trouble converting the results of its research into serially produced new products. Moreover, there has been a resistance to innovation on the part of Chinese managers. These problems, and the more general relative technological backwardness of the domestic industry, provide opportunities for the foreign suppliers of technology at the present time. It is likely, however, that effective international technology transfers will also stimulate the domestic industry to improve its capacity for indigenous innovation.

Internal Transfers

The question of how effectively foreign technology is diffused within China remains uncertain. Foreign firms have been concerned that technology licensed to one enterprise may illicitly be transferred to another, in the absence of effective patent protection. China's new patent law and other recent policies designed to encourage technology transfer, should help alleviate some of these concerns. A separate question, however, is the capability of the Chinese system for internal technological diffusion.

Chinese organizational life is excessively bureaucratic and compartmentalized. The Chinese themselves often lament what they refer to as "departmentalism." The result of these organizational characteristics is that there is often little effective horizontal, interorganizational communication. Instead, communications follow the strong vertical orientations according to which Chinese organizations were designed.

The Chinese have attempted to overcome these features by creating mechanisms for cross-cutting

[12] See Leo A. Orleans, *The Training and Utilization of scientific and Engineering Manpower in the People's Republic of China,* U.S. House of Representatives, Committee on Science and Technology, October 1983.

technological communications. The first of these are the professional societies organized around academic disciplines and industrial technologies. The professional societies, uniquely, draw individuals from different vertical systems (different ministries, academies, and universities) into a common forum. A second mechanism is a network of scientific and technical information services that have been established, the development of which has been aided since 1979 by cooperation with the U.S. National Technical Information Service. In addition to these two mechanisms, in recent years, a large number of technical consulting organizations have been formed, and other organizations, including production enterprises, universities, and research institutes, have been active in establishing consultancies as well. Recent policy has also sanctioned individual consulting.

Thus, while the formal structure of the Chinese economic and research systems works to inhibit the diffusion of technology and ideas, the climate for the domestic supply of technical services and the diffusion of technology has improved markedly in recent years. Thus, the likelihood that China's investment in foreign technology will have more of a payoff—with advanced technology filtering out through the economy—is now greater than would have been the case in the immediate past.

Decision making

Decisionmaking is another constraint on effective technology transfer experienced by developing countries, and China too has its share of decisionmaking problems. For instance, there has not always been good coordination among central ministries in the energy sector, and between decisionmakers in Beijing and those at the province level. Decisionmakers in Beijing making purchasing decisions about foreign technology have not always had a good understanding of the technical problems in the field. Perhaps most importantly, China's economic system has over the years structured incentives in such a way that decisionmakers are often risk averse. Individuals have been unwilling to make decisions without collective consensus. The resulting delays in decisions are costly to foreign companies who face high daily expenses to maintain representatives in China.

The current economic reforms promise some improvement in decisionmaking, however. In an effort to put China's energy industry on more of a business-like footing, management has in many cases been removed from government ministries and vested in new corporate entities, such as the China National Oil Development Corp., which in principle, are to run as profit-making organizations. Efforts are being made throughout the government and the economy to promote younger, more technically qualified and more entrepreneurial individuals into managerial positions. The mechanisms for horizontal technical communication, noted above, also serve to aid in Chinese decisionmaking. It seems to be the case now, although this was not true in the late 1970s, that decisionmaking about what types of technology to import is informed by some of the best technical judgments available in China. This is largely a result of the growth of consulting and advisory services.

This is not to say, however, that such decisionmaking is now problem free. The best technical judgments do not necessarily result in the most appropriate technology decisions, and it does seem to be the case that the full integration of technical, economic, and political criteria remains something of an ideal. China's increasing exposure to the international economy, and particularly to international organizations, has now sharpened the Chinese sense of the importance of project planning and analysis, and efforts have been made by both the Chinese themselves, and with the assistance of organizations like the World Bank, to strengthen central analytic capabilities, and capabilities for coordinated decisionmaking, on technology transfer decisions.

The current economic reforms should improve China's ability to absorb and diffuse technology in other ways as well. Technology as an economic concept has undergone a fundamental change in Chinese thinking. Whereas in the past it was regarded as a free public good, which in a socialist society is available to any and all, technology now is regarded as a commodity to be bought and sold through market transactions. The Chinese hope that this new conception of technology will provide better incentives for those who produce technology, and will make those who would procure and use it, more conscious of its economic value. More effective internal technology transfers, and sharper macroeconomic decisionmaking are expected.

Conclusion

On balance, in spite of financial, manpower, and decisionmaking problems which limit its ability to procure and assimilate technology, China also **has** capacities which make these limitations less of a problem than they have been in other developing countries. These include an expanding pool of trained personnel, an established energy industry with an extensive R&D system, and new policies to encourage foreign investment and technology transfer, as well as those for economic, administrative, and educational reform, which seem appropriate for China's current needs. Whether these policies will succeecl and whether the associated political and social costs can be managed are major uncertainties.

China's leaders, however, have incentives to maintain an environment favorable to technology transfer and absorption. China's rate of economic growth for the remainder of the century will be constrained by energy production, yet the ability to maintain political support for the policies of modernization and reform is to a large extent a function of economic performance. Improving performance through the use of foreign technology thus has great domestic political significance for China's current leaders.