

Decentralized Renewable Energy Development in China

The State of the Art

Robert P. Taylor

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ABSTRACT

In recent years, Chinese efforts to develop biogas, small-scale hydroelectric plants, and other decentralized renewable energy systems have attracted a great deal of interest in other countries. This report provides a brief description of China's achievements in the development of biogas, small hydro plants, forestry, solar energy and wind energy, based primarily on information from Chinese sources. More important, however, this report attempts to shed light on how the Chinese approached decentralized renewable energy development during the 1970s, and the advantages and disadvantages of Chinese methods. °In contrast to the approach adopted in many other countries, the Chinese placed a strong emphasis on mass-based, self-reliant development during the 1970s, and while this approach brought major achievements in the popularization of technology, it also brought a series of problems, especially concerning technical performance, planning and coordination, and local management. During the 1980s, China will continue aggressive promotion of decentralized renewable energy technologies, but as in so many areas of development, some of the previous policies have been revised in an attempt to overcome the problems experienced in the past. In order to underline some of the major lessons that can be learned from China's wealth of experience in decentralized renewable energy development, therefore, special attention has been given to analysis of the policies of the past, the pros and cons of these policies, and how and why these policies are currently being revised.

This report was completed in September 1981. For recent information concerning China's efforts to develop renewable energy, readers are encouraged to contact the author through the Science and Technology Unit of the World Bank.

TABLE OF CONTENTS

	<u>Page No.</u>
I. BACKGROUND	1
A. China's Energy Sector	1
B. Walking on Two Legs	1
II. CHINA'S PROGRAMS IN DECENTRALIZED RENEWABLE ENERGY DEVELOPMENT	4
A. Biomass Fuels	4
1. Forestry, Afforestation, and Fuelwood	4
2. Biogas	8
B. Small-Scale Hydroelectric Power Plants	12
C. Solar Energy	15
D. Wind Energy	17
III. THE CHINESE APPROACH TO DECENTRALIZED RENEWABLE ENERGY DEVELOPMENT DURING THE 1970s	19
IV. THE IMPLICATIONS OF THE CHINESE APPROACH DURING THE 1970s	
A. The Selection of Technology	24
B. Institutional Framework	26
C. Research and Development	28
D. Training	31
E. Management and Maintenance	32

I. BACKGROUND

A. China's Energy Sector

In 1979, China's production of primary, modern (commercial) energy reached 649 million metric tons of coal equivalent (MTCE), fourth highest in the world. Coal accounted for 70 percent of total production, while oil accounted for 24 percent, and hydroelectricity and natural gas each accounted for about 3 percent. 621 million MTCE of primary, modern energy was consumed in the country in 1979, third highest in the world. Per capita consumption was about 0.644 MTCE, close to the average for developing countries in 1979. 1/

Recent unofficial Chinese estimates indicate that about 300 million MTCE of traditional fuel is currently consumed every year by rural households for cooking and heating. 2/ Thus, consumption of traditional fuels accounts for about one-third of total primary energy consumption. Traditional fuels include crop by-products, firewood, charcoal, roots, twigs, brush, leaves, grass and dung. Crop by-products account for about one-half of traditional fuel consumption, 3/ while low-quality fuels gathered from local uncultivated areas, such as brush, grass, and leaves, account for most of the remainder.

When traditional fuel consumption is included, energy consumption in rural households and agricultural production represents almost one-half of China's energy consumption. Total rural household energy consumption for cooking and heating was about 370 million MTCE in 1978, or 3.4 million kilocalories per rural person. (By comparison, in rural India, where heating requirements are less significant, an average of 1.57 million kilocalories was consumed per person per year for cooking and heating during the early 1970s.) 4/ Traditional fuel accounted for some 85 percent of the energy consumed by rural households, while coal and some biogas account for the remaining 15 percent. 5/ About 72 million MTCE of primary energy was consumed in the agricultural sector in 1978, if energy consumption in nitrogenous chemical fertilizer production is included. 6/

The Chinese electric power industry generated 300.6 billion kilowatt-hours of electricity in 1980. 7/ According to Chinese reports 90 percent of the nation's communes (rural collective units of 10,000 to 80,000 persons) over 60 percent of the production brigades (village-level collective units of 500 to 5,000 persons), and over 50 percent of the production teams (sub-village collective units of 30 to 500 persons) have been supplied with electricity. 8/ However, many of the production teams that have electricity have access to only small quantities for use in agriculture. In 1980, the total amount of electricity supplied to rural areas for agricultural purposes or household lighting reached 32.1 billion kilowatt-hours, representing about 11 percent of national electricity supplies. 10/

B. Walking on Two Legs

As in many aspects of development, the concept of "walking on two legs" has been applied in China's development of energy resources during recent years. This principle basically stands for balance between large and small-scale undertakings, between advanced and intermediate or primitive

technology, and between centralized and decentralized control. Large, modern, and centralized projects and small, less sophisticated, and decentralized projects are both viewed as important and necessary in development. In the energy sector, the Chinese have emphasized development of small-scale, decentralized energy systems as well as the development of a modern petroleum and natural gas industry, large coal mines, and large thermal and hydroelectric power plants. Energy systems developed under the decentralized "leg" include small-scale coal mines, small-scale hydroelectric plants, biogas, a variety of methods for the local production of fuelwood, and, to a lesser extent, solar and wind energy systems. In terms of the actual popularization of the technologies, China currently leads the world in the development of small hydroelectric plants and family-sized biogas digestors.

With the important exception of small coal mines, all of the decentralized energy systems that China has developed rely on renewable energy resources. Except for large-scale hydroelectric power development and a few other cases, China's efforts in renewable energy development have also focused on small-scale, decentralized systems using intermediate technology.

For the most part, decentralized renewable energy systems have been deployed in China's rural areas. The rationale for their development is basically the rationale for the development of the decentralized leg in the energy sector.

During the Great Leap Forward (1958-60) and the Cultural Revolution (1966-76), political factors played a critical role in the support for decentralized energy development, as will be discussed later. However, economic factors were also important, as they are today. Rural energy development through decentralized systems entails far lower transport and distribution costs than development relying on centralized energy production. Thus, in rural electrification, for example, the development of small hydro plants may prove a viable alternative as a means to supply electricity to scattered communities where the demand for electricity is relatively low, at least initially. Small-scale energy projects employing intermediate technology also tend to have shorter lead times than large-scale projects. Thus, small-scale projects can not only provide quick returns on investment, but perhaps more important, they can alleviate local energy shortages or provide energy for development in a relatively short period. Finally, the small-scale, labor-intensive, and relatively unsophisticated nature of the energy projects that China has developed under the decentralized leg allows for a greater reliance on local finances, labor, and construction materials than more advanced and large-scale projects, creating less of a financial burden for the state.

Chinese leaders feel that the development of decentralized energy systems presents the most practical means to solve problems associated with reliance on traditional fuels for rural household needs. Over the years, China has experienced severe problems concerning shortages of traditional fuels, abuse of forest resources by rural fuel gatherers, and shortages in the amount of crop by-products available for use as animal feed or fertilizer. To ease household fuel shortages and move away from traditional patterns of household fuel supply, large quantities of energy are required,

and a reliance on centralized systems would place a great strain on the national energy economy--the energy produced in these systems is urgently needed in other sectors. Moreover, tremendous difficulties would be encountered in transportation, and it would be difficult for rural people to pay for the fuel. Therefore, China has looked toward local solutions to household fuel problems. Chinese attitudes are summarized in the following passage from a recent article in Nongye jingji wenti (Agricultural Economic Issues).

In view of the vastness of the rural areas, the size of the population and the high rate of energy consumption, it is impossible to depend on the government to supply all of the coal and oil to meet their energy needs. It is also unrealistic when we consider the amount of mineral fuel produced in our country and its limited transportation capacity. It is also impractical from the technical and economic points of view. In our opinion, the way to solve the energy problem in the rural areas lies in making use of natural resources available in rural areas by devising various means to develop and utilize the locally available energy resources comprehensively and efficiently. While it is true that the rural areas consume vast amounts of energy, we must also look at the rural areas as a vast area for the production of energy. 10/

China has gained a considerable amount of experience in the development of decentralized renewable energy systems, and this experience has recently attracted a great deal of interest in other developing countries and international development organizations. As other developing nations consider different rural energy development options and initiate or expand development programs, lessons from China's experience could prove valuable.

In this paper, a review of China's programs in decentralized renewable energy development will be presented first, followed by a discussion of the general policies and attitudes toward such development during the 1970s, and a discussion of the implications of these policies and attitudes.

A variety of information sources have been used in the preparation of this desk study, including Chinese technical manuals and books, translations of Chinese newspapers, journals, and radio broadcasts, the works of Western scholars, the accounts of various delegations and individuals who have visited China, and a few interviews with Chinese officials.

Unfortunately, little detailed data was found concerning the economic costs and benefits of Chinese systems. The data that was found has of course been included.

II. CHINA'S PROGRAMS IN DECENTRALIZED RENEWABLE ENERGY DEVELOPMENT

A. Biomass Fuels

Biomass fuels have been the primary source of energy for rural household consumption in China for centuries. However, as China's population increased, putting pressure on the land available for cultivation and the natural ecosystem, a series of problems developed concerning the traditional use of biomass fuels. By the early part of the twentieth century, shortages in fuel were evident in many areas, particularly in the heavily populated regions of North China and Sichuan. Throughout China, the process of deforestation gradually intensified, so that by 1949, only 5 to 10 percent of the nation's total land area remained forested. 11/ Deforestation not only exacerbated the shortage of fuel, but it also created severe problems in water and soil conservation. In addition, the use of about one-half of the available crop by-products for fuel 12/ limited the amount of crop by-products available for other important purposes, such as fertilizer composting or feeding farm animals. Thus, in 1949 the Chinese government was already faced with serious problems associated with the traditional patterns of household energy supply in the countryside. And between 1949 and 1979, China's rural population increased by over 80 percent. 13/

Probably the most important single factor enabling China to cope with the increased demand for rural household fuel caused by population growth over the last thirty years is the increase in agricultural production. By 1978, grain output was approximately double the 1929-33 level, and almost triple the 1949 level, 14/ signifying a growth of similar magnitude in the production of crop by-products. As much as two-thirds of the total quantity of crop by-products currently produced is used for household fuel. 15/ However, the supply of coal for rural household consumption has also dramatically increased since 1949. In addition, China has emphasized new, more rational methods of biomass energy production and utilization, through the forestry development program and the biogas program.

1. Forestry, Afforestation, and Fuelwood

Since 1949, China's leaders have put strong emphasis on forest protection and afforestation. Forestry work has been conducted as a mass campaign, in which hundreds of millions of people have been mobilized in order to "fight a people's war of afforestation." The Chinese currently claim that 12.7 percent of China's land area is now covered by forests, 16/ implying that at least 26 million hectares have been successfully added to the nation's forestland area since 1949.

If the Chinese claims are accurate, they point to a very impressive achievement--the growth of forested land during a thirty-year period in which China's population almost doubled. The success that the Chinese have had has been primarily due to firm government support, the mobilization of large numbers of people for afforestation work during seasons when the demand for agricultural labor is low, and the building of a forestry consciousness among common people. It is clear, however, that forestry development has moved along a tortuous course, with a mixture of successes and setbacks. During

the 1950s and most of the 1960s, lack of experience and technical knowledge among both professional foresters and the masses involved in afforestation work hampered success. Despite the claims of vast afforested areas, survival rates in terms of numbers of trees were notoriously low--less than 10 percent in many commune projects. 17/ In more recent years, survival rates improved somewhat, as attention to after care in afforestation work has been intensified. 18/ A large amount of practical experience has been gained over the years, and technical knowledge and forestry consciousness have greatly improved. Nevertheless, it is clear from a series of recent, frank reports that serious problems remain to be solved, and the process of deforestation continues in many areas, especially in the large state-owned forest areas in Manchuria, Yunnan, and Sichuan.

Probably, most of the forestry work that has been conducted in China has been geared toward protective forestry. The serious erosion, flooding, and desert encroachment problems caused by deforestation have made the establishment of protective forests a vital element in the drive to increase agricultural production.

The emphasis on protective forestry, however, has not meant that the development of productive forests has been neglected. On the contrary, in a country in which the availability of arable land is very limited, productive forestry has been recognized as one important way to increase rural production. While timber production still tends to be concentrated in the established, large, state-owned forestry bases, new large timber reserves are being built through afforestation. 19/ Smaller, collectively owned forests established through afforestation are also beginning to play a role in timber production. Local, collective forests probably play the major role in productive forestry development designed to supply fuel and economic crops such as fruit, nuts, or edible oil.

At the local level, provisions for the supply of fuelwood appear to have been integrated into forestry development in four major ways: (i) Fuelwood may be supplied from "four around" plantings (plantings along roads, along rivers and canals, around homes, and around villages); (ii) fuelwood may be supplied from larger collective protective, timber, or fruit, nut, and oil forests; (iii) grass and brush fuel may be gathered by local farmers during certain periods or from certain sections of areas that have been closed off for natural regeneration; and (iv) fuelwood may be supplied from forest plots specifically designed for fuelwood production. In some cases, small-size timber from state-owned forest areas has also been collected and supplied to rural communities by the state.

Four around afforestation projects have been pursued in many parts of China, but particularly on the plains. The projects are usually designed primarily for protective purposes, but timber, fuelwood, fruit or other products may often be obtained from the trees. In some cases, private plantings by individuals around their homes may be especially important as a source of fuelwood. A study group from Nepal reported that in addition to providing wood for hand tools or house repairs, household stands in Hunan Province sometimes provided as much as 60 percent of the fuelwood needs of individual families. 20/

In many larger collective afforestation projects, fuelwood trees may be interplanted alongside other types of trees. Although the forests may be designed primarily for other purposes, a certain amount of fuelwood still may be harvested. Moreover, local farmers have often been allowed to enter local forests designed for protection or production of timber or economic crops, in order to remove dead trees, to prune branches, or to pick up miscellaneous wood for use as fuel.

Various Chinese publications describe the adoption of systems for fengshan yulin--closing the mountains to allow natural regeneration of forests and land cover. Access to local uncultivated areas is restricted, to enable vegetation to recuperate. Fuelwood gathering is still allowed, but it is organized and supervised. Fuelwood gathering may be restricted to certain areas, which are changed in rotation, or it may only be allowed during certain season. It is prohibited to pull up grass by the roots or cut young trees or bushes that are considered valuable. 21/

Finally, collective forest plots have been established in a few areas specifically for the production of fuelwood. Collective fuelwood lots have been promoted primarily in the northern and northwestern parts of China, in areas where adequate supplies of coal and biomass fuels have been difficult to obtain, but expanses of uncultivated land suitable for forestry development are available. Land availability is apparently the primary constraint limiting the construction of collective fuelwood lots. 22/ According to a survey conducted in 1976, about 3.7 million hectares of land are specifically devoted to the production of fuelwood, accounting for approximately 3 percent of China's forestland. 23/

At present, it is impossible to tell exactly what impacts the four methods for integrating fuelwood supply with local forestry development have had on rural fuel problems. Some foreign visitors have returned from China with impressive reports. In regard to the situation in Hubei Province, the FAO study group from Nepal wrote,

At present, 70 to 80 percent of the firewood requirement is supplied by plantations and household plots, and 20 to 30 percent by stems of agricultural crops. When the plantations reach the thinning age, enough fuelwood will be produced by these areas. 24/

After visiting China in 1974, Jack Westoby, former deputy to the head of the Forestry Department of the FAO, wrote, "Many, perhaps, most communes have already taken significant strides towards meeting their own needs of fuel and industrial timber." 25/

Nevertheless, recent Chinese reports indicate that fuel shortage and abuse of forest resources by rural fuel gatherers persist in many areas. 26/ Indeed, one can easily imagine how provisions for fuelwood supply in local forestry projects designed primarily for other purposes can lead to forest abuse if local fuel supplies are especially tight. For example, in regard to the common practice of allowing farmers to remove dead trees from forest plantations and to prune dead branches, S.D. Richardson wrote,

These practices have serious implications for plantation management, in that the people have a vested interest in the early mortality of newly planted trees and, also, they disfigure established trees by reckless pruning. Mutilated and unsightly saplings, even in the forest-rich areas of Manchuria, bear witness to the widespread nature of these (abusive) practices. 27/

Concerning the practice of supplying firewood from four around plantations, a report from Guangdong Province states that in some areas people have torn off the bark of the trees along roads, and dug up the roots for firewood. 28/ Although it may be prohibited, it may also be difficult to stop local farmers from cutting young trees or bushes during periods in which hilly areas, formerly closed for natural regeneration, have been opened for fuel gathering. Protection of immature collective fuelwood lots may even be difficult.

Over the years, the Chinese government has issued increasingly strict regulations concerning forest protection as a way to control abusive tree felling and mutilation. Nevertheless, illegal removals of wood for fuel and tree mutilation have continued. Emphasis must be placed on further development of alternative household fuels, such as coal or biogas, and greater attention must be given to the development of forest plots specifically for fuelwood production. Fortunately, recent reports do indicate plans for development along these lines.

The 1979 Forestry Act and directives on forestry work issued by the Central Committee of the Chinese Communist Party and the State Council in 1980 and 1981 all call for greater efforts in building collective fuelwood lots. 29/ Indeed, the most recent directive, issued on March 8, 1981, states that in places where there are shortages of firewood, priority in afforestation work should be given to the planting of fuelwood trees. 30/

The recent directives on forestry work also point to a new direction in the development of forestry for fuelwood supply--the allocation of private mountain plots for fuel cultivation and production by individual commune members. The directive issued on March 5, 1980 states,

In communes and production brigades where there is too much wasteland or too many barren hills which causes an acute shortage of firewood, it may be decided by the provincial, municipal or autonomous regional authorities to allot private plots to commune members for growing trees or grass, under the precondition that this should not affect the forestry production undertaken by the collective. Trees planted by commune members and the forestry products from them are private property. The owners are permitted to sell them on the open market. 31/

The directive issued on March 8, 1981 further reinforces this decision and adds that trees planted on private plots will belong to commune members forever, with the right of inheritance. 32/ Thus, it appears that the practice of planting private fuelwood trees will be extended to barren hill regions, in addition to household courtyards.

2. Biogas

In China, the production of biogas has been viewed as a particularly appropriate technology because it not only provides a clean fuel that can be used more efficiently than traditional solid fuels, but it also retains the quality of organic fertilizer and improves rural sanitation. During the 1970s the Chinese were remarkably successful in popularizing biogas technology in the countryside, and they are continuing to promote the technology as one of the best ways to solve rural household fuel problems.

The first attempt to popularize biogas occurred during the Great Leap Forward, following the personal instructions of Chairman Mao. Although research and promotion of biogas was undertaken in some seven provinces, 33/ the movement soon lost momentum, primarily because of a lack of expertise in building and managing the digestors. 34/ Success in biogas popularization was only achieved in the 1970s. Mianyang and Zhongjiang Counties in Sichuan Province developed successful techniques for producing the gas between 1970 and 1972, building several hundred digestors. In 1972 Chinese leaders in the State Scientific and Technological Commission and the Ministry of Agriculture and Forestry decided to launch a large movement to popularize biogas. 35/ Since then, the development of biogas has proceeded rapidly. By 1980, 6 to 7 million family-sized biogas digestors had been constructed. 36/ Biogas is now used by some 30 million commune members for cooking and lighting. 37/ The gas produced by family-sized digestors usually provides about two-thirds of the fuel required by a family. 38/ In addition, about 30,000 community digestors have been built, generally ranging between 50 and 200 cubic meters in volume, to provide power for water pumping, grain processing, and electricity generation. 39/ Thus, China is by far the leading country in the world in terms of the popularization of biogas technology.

Biogas has been introduced in over one-half of China's provinces, municipalities, and autonomous regions, and over 1,000 of the nation's 2,100 counties. 40/ However, about 70 percent of China's biogas digestors are located in Sichuan Province, primarily in the western part of the Sichuan Plain. According to available information, other leading provinces include Zhejiang, Jiangsu, and Shandong, along the central part of the eastern coast, and Hunan, Hubei, and Henan, in Central China. 41/ The present geographic distribution of digestors has been primarily due to variations in local climatic conditions, in local needs and resources, and in the importance attached to biogas development by local leaders.

Climate is an important factor influencing biogas development because of the temperature requirements for producing the gas. If above-ground temperatures drop below freezing, it is difficult to produce significant amounts of biogas by using simple Chinese methods. The only areas that have less than five freezing days per year are Fujian, Guangdong, southern Yunnan, and the Sichuan Plain. In the eastern and central parts of China, the average number of freezing days ranges between ten and seventy-five per year, while north of the Yellow River, there are more than one hundred freezing days per year. 42/ Thus, as one moves north, it is more difficult to produce biogas during the winter using simple methods, and biogas production tends to be more of a seasonal operation. Biogas has been promoted in areas as far north as Manchuria, but conditions in the south are more advantageous for year-round production of the gas.

Biogas development has usually been emphasized in areas where the provision of adequate supplies of household fuels has been particularly difficult. The Sichuan Plain provides a good case in point. The area is densely populated, reaching 600 persons per square kilometer in some rural districts, 43/ and coal, charcoal, and firewood is generally not locally produced. Prior to the development of biogas, these fuels had to be transported in to supplement the insufficient supply of crop by-product fuel. 44/ Fortunately, the supply of local materials for fermentation appears to have been sufficient for the widespread use of biogas in Sichuan, largely because of a well-developed hog industry. In some other areas, insufficient supply of fermentation materials may present a problem.

Finally, in some areas where the conditions for biogas production are particularly good, development has been slow because local leaders have not viewed biogas as important or worthwhile. In Sichuan, the provincial leadership attached great importance to biogas development from early on, district and county biogas offices were set up, propaganda work was done effectively, and a contingent of biogas technicians was trained for work in the communes and brigades. In some other places, however, leaders at the provincial, county, or collective levels have apparently not given biogas production proper consideration or implemented critical organizational measures. 45/

By far the greatest number of China's biogas digestors are small, simple digestors, designed for the needs of a single household. Family-sized digestors generally range between 6 and 12 cubic meters in volume, depending on the size of the family and climate conditions. In Sichuan, experience shows that each cubic meter of digester volume will produce 0.15 to 0.2 meters of gas per day during summer, and 0.1 to 0.15 cubic meters of gas per day during winter. 46/ As one cubic meter of gas per day is usually considered sufficient to meet the cooking and lighting requirements of a family of five people, a ten cubic meter digester should be adequate for a family of five, if properly managed. 47/

With few exceptions, the Chinese have promoted the water pressure digester design for popularization among rural families. Unlike the floating gas holder digestors constructed in India and some other countries, the gas storage area in the water pressure design is permanently fixed as the cover over the digester. The pressure of the gas is regulated to a certain degree by the automatic adjustment of water pressure. In the recent and most popular models, an increase in gas pressure forces part of the fermentation liquid into the outlet chamber. When gas pressure decreases, the liquid flows back into the main part of the digester.

The chief advantage to the Chinese water pressure digestors is that they are relatively cheap and easy to build. In the floating gas holder design promoted by the Khadi and Village Industries Commission in India, the floating gas holder, usually made of steel, accounts for 35 percent of the total cost of a biogas plant. 48/ The water pressure digestors do not employ floating gas holders, and steel or plastic is only required for piping and valves.

The chief disadvantage to the water pressure digestors is imperfect regulation of gas pressure. While pressure is regulated within a certain range, it still tends to vary, making the efficient use of gas appliances more difficult.

While virtually all of the Chinese² family-sized digestors are water pressure digestors, there is no single standard model. A wide number of variations have been developed, through local experimentation, in response to differences in soil conditions, in the water table, and in the types of construction materials available. Digestors may be rectangular, dome-shaped, vase-shaped, or spherical. There are cast-in-place, cut-in-place, and masonry digestors. Construction materials include stone slabs, bricks, cobble, bittern, pebbles, slate, concrete, precast concrete blocks, and "triple concrete," a traditional Chinese building material made from lime, sand, and clay, mixed in specific proportions with water. Some digestors are merely excavations from sheer rock or shale, with no pit lining. In some cases, old manure pits or vegetable stores have been converted into digestors. In popularizing biogas in a given area, the guiding principle is to select and develop a design that is both most appropriate to local conditions and as cheap as possible. 49/

Cooking and lighting appliances are simple, and they are usually locally made. 50/

Due to the use of the water pressure design and a reliance on locally available construction materials, the current cost of 10 cubic meter digestors is generally 30 to 60 yuan (approximately US\$18 to US\$36), excluding labor charges. 51/ Construction costs are usually borne by individual families, although subsidies may be available in some cases. Family members usually provide the labor for their own plants. Although the amount of labor needed for digester construction may be high--about 35 workers-days per plant, on average--the Chinese do not view labor inputs as a cost, but as an investment, because they help promote understanding of the technology and local expertise. 52/ 1/

A mixture of organic materials, usually including pig manure, night soil, and crop by-products or grasses, is commonly used in family-sized digestors for the production of gas. The Chinese have a strong rural tradition in the collection and fermentation of all types of human and farm wastes for use as fertilizers. According to one estimate, in 1962, 70

1/ The cost of family-sized digestors in other developing countries commonly ranges from about US\$250 to US\$500, including labor charges. It is difficult to make a strict comparison between the cost of Chinese digestors and digestors in other LDCs, because of the exclusion of labor costs in Chinese figures and the arbitrary exchange rate between the US dollar and the yuan. However, the low cost of the basic Chinese water pressure digester compared to other models can still be seen in cases where it has been built outside of China. For example, in Pura, a village in India, a family-sized biogas digester (2m² gas output per day) was recently constructed from Chinese specifications for only Rs. 900 (US\$117), including labor. (Private communication with °A.K.N. Reddy, June 19, 1980).

percent of the night soil and 60 percent of all the farm manure produced in China was collected and used for fertilizer. 53/ Because of the importance of organic fertilizer in Chinese agriculture, the advantages of biogas production as an improved method of treating organic wastes has been especially significant.

Family-sized digestors usually operate under what the Chinese call a semi-continuous fermentation cycle. Major batches of fermentation material are fed into digestors and removed several times each year. Additional, smaller amounts of material are also fed in and removed frequently, usually every day. 54/ One major disadvantage to this fermentation cycle is that gas production is interrupted when large batches are removed. Thus, digestors usually only produce gas for ten months, or even less, every year. Although adoption of the semi-continuous fermentation cycle also allows for periodic cleaning of digestors, the major reason for its use is to enable most of the sludge and slurry to be removed for use as fertilizer during the agricultural planting seasons. 55/ The requirements of agricultural production are judged as more important than the continuous production of fuel. In Sichuan, for example, large amounts of fertilizer are removed from digestors twice a year--during the rice planting season in the spring, and during the wheat and rape planting season in the autumn. 56/

While the primary emphasis in China's biogas program has been placed on the construction of family-sized digestors, larger, community-operated digestors have also been built. The digestors are usually 50 to 200 cubic meters in volume. If larger capacities are desired, several large digestors are usually built together and interconnected. 57/ Designs vary, but when the gas is being used for running machinery or generating electricity, many systems employ plastic ballons to store the gas outside of the digestors. 58/

In rural areas, community digestors are collectively owned and operated. They have usually been built in conjunction with collective piggeries, but sometimes they have been constructed at institutions such as schools, factories, or hospitals. 59/ In urban areas, large biogas systems are usually built in conjunction with night soil treatment and disposal schemes.

When community digestors are built at schools, factories, or hospitals, they may provide fuel for cooking and lighting, but most community digestors are built to provide fuel for internal combustion engines or electricity generation. Although it may be simpler to use biogas in conjunction with gas or gasoline engines, most areas use biogas to run modified diesel engines because they are more readily available. Diesel engines are usually converted to dual-fuel engines, in which a small amount of diesel oil is used to ignite a compressed mixture of biogas and air. Savings in diesel oil range from 70 to 90 percent. 60/ When electricity is desired, modified diesel engines are hooked up to small asynchronous generators. In Sichuan, special generator units with capacities of 3, 5.5 and 7.5 kilowatts have recently been put into mass production for use in biogas systems. 61/

A total of 301 small biogas power stations have been built in Sichuan, with a combined capacity of 1,494 kilowatts. The smallest station has a capacity of 3 kilowatts, while the largest station has a capacity of 120 kilowatts. 62/ A recent report from Jiangsu Province states that the 8-kilowatt biogas power stations built there can be completed in only one to two months, at a cost of about 4,500 yuan (about US\$340) per kilowatt. 63/ In the suburbs of Guangzhou (Canton) in Guangdong Province, a large electricity generation system, employing a series of digestors with a total volume of 6,000 cubic meters, has recently begun power generation on a test basis. The system has a total installed capacity of 500 kilowatts. 64/

Currently, all available evidence points to continued, aggressive promotion of biogas development in China. Given the existence of rural traditions in the collection and fermentation of organic wastes and the fact that biogas production presents an effective way to use those wastes for both fertilizer and fuel, the Chinese have singled out biogas development as an especially good means to alleviate rural energy problems.

B. Small-scale Hydroelectric Power Plants

According to a recent national survey, China's verified hydropower resources total 680 million kilowatts, the largest of any country in the world. The survey concludes that about 370 million kilowatts can be utilized. 65/ In the exploitation of their large hydropower resources, the Chinese have emphasized the policy of walking on two legs--both large or medium-sized hydro stations and small hydro stations have been constructed.

Small hydroelectric power stations have been defined as stations with single generating units rated at less than 6,000 kilowatts or total station capacities (including several generating units) of less than 12,000 kilowatts. 66/ However, the vast majority of China's small hydro plants are much smaller than this definition implies. In 1979, the average capacity of the plants was about 72 kilowatts. The inclusion of a few plants with relatively high capacities makes even this average misleading. According to Vaclav Smil, most of the plants have capacities under 25 kilowatts. 67/

By the end of 1980, more than 90,000 small hydro plants had been built in rural China, with a total installed capacity of 7.1 million kilowatts, 68/ up from 6.33 million kilowatts in 1979. 69/ Although most plants are located in the southern and southwestern parts of the country, where hydropower resources are greatest, at least a few can be found in nearly three-quarters of China's counties. 70/ In 1979, China's small hydro plants generated a total of 11.6 billion kilowatt-hours of electricity or about 36 percent of the total amount of electricity consumed in agriculture, rural homes, and rural collectively owned small-scale industry. 71/ The plants are currently the main source of electricity in over 720 counties--about one-third of the total number. 72/

The first concentrated effort in small hydro plant construction occurred during the Great Leap Forward, as part of the great push in water conservation work and the drive for rural industrialization. By the end of 1960, the capacity of small hydro plants had reached a total of 520,000 kilowatts. But the campaign was abandoned during the early 1960s, and by 1966, probably less than 200,000 kilowatts of capacity remained in service. 73/ During the early and middle 1960s, rural electrification efforts

emphasized construction of transmission lines from industrial and mining centers with surplus generating capacity to the surrounding rural areas. However, contradictions developed between the power demands of factories and mines and the power demands of agricultural users, and more important, the task was so enormous that only a small fraction of China's rural areas could be adequately supplied. 74/ During the Cultural Revolution, rural electrification policy was reversed, and widespread construction of small hydro plants was taken up again. Progress during the 1970s was remarkable--total capacity grew from 500 megawatts in 1969 to 3,000 megawatts in 1975, and 7,100 megawatts in 1980. 75/

A variety of different types of small hydro plants have been constructed in China, corresponding to differences in local conditions and needs. Plants are usually considered as just one part of integrated water management schemes, and therefore decisions concerning plant type or scale involve decisions concerning water storage, irrigation, flood control, navigation, and fish industry needs. Indeed, electricity generation may be low on the list of priorities in many comprehensive water management schemes, and it may often be considered basically a side benefit. 76/

In mountainous regions, most plants employ water diversion channels and penstocks, dams or both. In some areas, however, plants have been built directly onto existing irrigation channels. One Chinese technical manual states,

Practical experience has shown that these types of small-scale hydroelectric plants have a very great and real significance. They can be scattered over a broad area and are thus suitable for the dispersed electricity consumption patterns characteristic of rural areas. In addition, except for the hydro plant itself, all other structures are necessary for the irrigation channel alone, and therefore the cost of building the hydro station is relatively low. Construction can be handled by communes, or even production brigades and teams. 77/

China has constructed a few tidal power stations along its eastern and southern coasts. The major plants have capacities in the 100- to 300-kilowatt range. Uni-directional stations have been emphasized because they are relatively inexpensive and easy to operate, but a new, 3,000-kilowatt bi-directional station is currently under construction at Yueqing Bay in Zhejiang Province. The first 500-kilowatt generator unit went into operation in May 1980. 78/

The average cost per installed kilowatt for small hydro plants tends to vary a great deal, depending on plant type and scale, the materials used, and local conditions. According to a technical manual put out by Tianjin (Tientsin) University in 1976, total costs per installed kilowatt range between 600 and 1,400 yuan (approximately US\$360 to US\$840). 79/

Development has been pursued at local levels--counties, communes, and brigades have built plants largely through their own efforts. Although low-interest loans are often provided by the state, local units have usually

covered the major share of investment costs. Local labor and materials have been heavily relied on, in order to cut costs and minimize dependence on scarce materials and equipment. Dams and various water control structures are usually built with earth or stone, and local labor is mobilized on a large scale to pursue construction with traditional methods. Conduit pipes are usually made of cement, ferroconcrete, wood, or bamboo. Steel pipes are rare. 80/

In some cases, local materials have been used to make water turbines. Turbines with wooden rotors are apparently quite common. Wooden rotors have been built with diameters as large as two meters, and they have been employed in plants with capacities as high as 100 kilowatts. Only about 10 work days and 100 to 200 yuan (US\$60 to 120) are usually required to build a wooden rotor with a 1-meter diameter. Although wooden rotor turbines have low efficiencies and are not as durable as steel ones, they are inexpensive and relatively easy to make. If carefully constructed, the turbines can last for more than ten years. In addition, some places have built water turbines with rotors made of ferroconcrete or welded steel plates. 81/

In many cases, local units have developed stations gradually, beginning with a limited amount of unsophisticated equipment, and slowly expanding and upgrading equipment as local financial capabilities increase. For example, a brigade may initially choose to build a small, earth-filled dam on a local stream, install a small, locally made wooden water turbine to take advantage of the head created, and use the turbine to run a rice-husking machine. Families within the brigade and from neighboring areas are charged a small fee to have their rice processed. In a short time, the profits realized may enable the brigade to buy a larger, steel turbine and additional processing equipment. The increased profits from this venture may enable the purchase of an electric generator, and so forth. 82/

If local conditions are suitable, small hydro plants have often been incorporated into small, local grid systems, or even large regional grids. As local generation capacities develop and the local demand for electricity increases, the advantage of grid connection as a means to alleviate the problem of fluctuations in electricity production at individual plants may become increasingly compelling. One of the major problems associated with small hydro plants has been low capacity utilization factors--in 1979 the small plants had an average utilization factor of about 21 percent, less than one-half of that in China's large and medium-sized hydro plants. 83/ The major reason is seasonal fluctuations in water flow, which are particularly marked in small rivers and streams. If small hydro plants of different capacities or small hydro plants and thermal plants are connected, greater continuity in electricity supply may be possible.

In some areas, it appears that rural electrification has proceeded along a development pattern which begins with rudimentary electrification through the construction of isolated small hydro plants and concludes with linkage to large grid systems. In a given area, the introduction of electricity may allow a cumulative type of rural industrial and agricultural development to proceed, creating greater electricity demand. In order to guarantee larger and steadier electricity supplies, small hydro development may expand, individual plants may be linked together, and eventually the

local grid system may be connected to a large grid system, allowing effective integration of large thermal or hydro plants and a large number of small hydro plants.

China's current leaders are counting on continued, rapid progress in small hydro plant construction in the future, as one important way to expand rural electrification, alleviate rural power shortages, and provide more electricity for rural industry, agriculture, and rural homes. The potential for further development is great. Recent reports state that in more than 1,000 counties adequate water power resources exist for the construction of plants capable of generating more than 10,000 kilowatts. 84/ According to a report in 1979, it is hoped that total national small hydro capacity can be increased by 1 to 1.2 million kilowatts each year during the 1979-81 period, 1.5 million kilowatts each year during the 1980s, and 2.0 million kilowatts each year during the 1990s. 85/

C. Solar Energy

Most of China has sufficient climatic conditions for the direct utilization of solar energy, but the most suitable climates for solar development are in the western parts of the country, which is sparsely populated. Insolation rates are highest in Tibet and western Qinghai, where the amount of solar radiation is between 190 and 200 kilocalories per square centimeter per year. In southwest Xinjiang, eastern Qinghai, northern Ningxia, northern Gansu, and the western part of Inner Mongolia, annual solar radiation ranges between 150 and 190 kilocalories per square centimeter. In the remaining parts of China, annual solar radiation is less than 150 kilocalories per square centimeter, reaching the lowest levels in Sichuan and Guizhou Provinces, where annual solar radiation is between 90 and 100 kilocalories per square centimeter in most areas. 86/

Compared to the development of forestry, biogas, and small hydro stations, the development of solar energy has received relatively little attention in China. Although research on solar stoves and photovoltaic cells was begun during the 1950s, 87/ most of the Chinese effort in solar energy development has occurred during the last five years. For the most part, emphasis has been placed on simple and inexpensive technologies that can be used in rural areas or urban homes. Solar cookers and hot water heaters are the most widely used technologies at present.

A variety of different solar cookers have been developed, including both box and focusing types, and a few models have been put into mass production. Several thousand cookers are reportedly in use. 88/ Quoted costs for small, family-sized cookers range from 15 to 50 yuan (approximately US\$9 to US\$30), probably excluding any labor required for assembly. 89/ Special attention has been given to the development of light and portable small cooker designs which are durable enough for rural use. 90/ Large, concentrating solar cookers have also been developed. One design has a parabolic concentrator with a diameter of 5 meters, and it can boil water and cook rice for one hundred persons. 91/

Recent reports state that over 70,000 square meters of solar collectors are currently used for heating water in China. 92/ In Beijing alone, almost 40,000 square meters of flat plate collectors have been installed to provide hot water for restaurants, barber shops, office buildings, public baths, and individual homes. 93/ In some rural areas, solar water heaters have been used for public baths or baths in individual homes. Most Chinese water heaters operate with simple thermosiphon systems, and they do not use pumping equipment, and therefore it is difficult to operate them in colder regions during the winter. 94/

Most Chinese solar water heaters employ tube-and-plate or corrugated-sheet collectors, which are already in serial production. Research is currently being conducted on the use of a variety of different materials for the tube-and-plate collectors. Glass vacuum tube collectors and all-glass vacuum collectors are presently being developed. 95/

Although the Chinese have employed techniques for passive solar energy utilization in building construction since ancient times, work on the development of active systems for space heating has just begun. Tests have recently been completed on China's first experimental solar-heated building--a five-story office building located in Xining, Qinghai Province. 96/

A very limited amount of work has been conducted on solar refrigeration, air conditioning, and ice production. So far, only ammonia absorption cooling systems have been tested. 97/ The Chinese are also interested in the use of solar energy for desalination of sea water. The Guangzhou Institute of Energy Sources has developed a simple desalination device which has been put into operation on an island in the South China Sea. The installation can produce one ton of fresh water per day. 98/

A considerable amount of research has been conducted on solar equipment for drying grain, other agricultural products, and wood, but few systems appear to have been popularized. Because grain drying is a seasonal operation, the Chinese have emphasized systems in which the solar collector and the grain drying equipment are separate, so that the collectors can be used for other purposes when grain drying is not necessary. One multipurpose installation constructed in Daxing County, near Beijing, provides greenhouse facilities, grain driers, and hot water for a shower room. 99/

Very little attention has been given to the development of solar irrigation pumps in China. 100/

In some areas, solar energy systems have been integrated with biogas digestors. In Daxing County, warm water from a bath employing a solar water-heating system is used in a biogas digester, in order to increase the temperature in the digester and improve gas production. 101/ In Jilin Province, where temperatures often fall to minus 20 degrees Centigrade during the winter, fifty biogas digestors have been constructed with plastic housing that covers the above-ground portion of the digestors. On the coldest days, the temperature inside the digestors remains at 18 degrees Centigrade. 102/ At a commune in Guangdong Province, simple pond-type solar water heaters have been constructed on the roofs of residences to preheat water, which is then boosted to cooking temperatures through the use of biogas. 103/

Most work in China on solar technology for power generation has emphasized photovoltaics. Solar cells were first developed for aerospace applications, and according to one American visitor, Chinese solar cell systems are still "basically modified space technology system." 104/ Although single wafer silicon cells with a conversion efficiency of 15 percent have been developed in the laboratory, 105/ costs per peak watt still range between US\$120 to US\$150. 106/ Cadmium sulfide cells have been developed, with efficiencies ranging between 5 and 8 percent, and preliminary research on gallium arsenide cells has begun. 107/

Several factories now mass produce silicon cells, but most use monocrystalline silicon rejected from other industrial processes. Although the use of rejected material decreases costs, the conversion efficiency of the cells produced is low--sometimes as low as 5 percent. Nevertheless, solar cells have been used for some land applications, primarily in conjunction with railway signals, navigation markings, or electric fences in livestock grazing areas. 109/

Due to the high costs involved, the Chinese view solar thermal power generation only as an option over the long term. Nevertheless, basic theories are being researched. A 1-kilowatt installation using both flat plate collectors and a columnar parabolic collector was built by the Shanghai Machine Building Institute in 1975, and the construction of an experimental 1-kilowatt tower-type power station is currently being planned at Tianjin University. 110/

Although the level of solar energy development in China is low at present, the Chinese government has expressed a desire to accelerate solar R&D efforts and to popularize solar technologies on a wider scale, particularly in rural areas. More aggressive development and promotion of solar cookers, water heaters, and grain drying equipment in particular can be expected in the future.

D. Wind Energy

Wind energy has been used in China since ancient times for tasks such as pumping water, threshing grain, and powering boats. While a few reports do mention attempts to improve traditional wind machines, 111/ recent research and development has focused on the conversion of wind energy to electrical energy.

Wind-powered electric generators are still primarily in the research stage. Nevertheless, more than 200 small systems, with capacities ranging between 100 and 250 watts, have already been installed on the plains of Inner Mongolia, where wind speeds exceed 3 meters per second on more than 200 days a year. 112/ These wind have been used for lighting, projecting movies, and electrifying corral fences. 113/ A portable wind generator has apparently been developed in the region, which can be easily assembled and disassembled, and therefore carried by nomadic herdsmen. 114/

A few larger wind-powered electric generators have also been constructed in China. An 18-kilowatt installation has been completed on Sijiao Island, off China's eastern coast. The three blades on the machine were made from old helicopter blades. 115/ A 20-kilowatt wind generator has also been built near Harbin, in Manchuria, 116/ and a 40-kilowatt installation is currently under construction in Zhejiang Province. 117/

Although research and development of wind generators has only been pursued during the last few years in China, expanded efforts can be expected in the future. As with solar energy, China's current leadership has stated that the development of wind energy systems should be accelerated, as one way to meet energy demands, particularly in isolated rural areas.

III. THE CHINESE APPROACH TO DECENTRALIZED RENEWABLE ENERGY DEVELOPMENT DURING THE 1970s

During the 1970s, China achieved remarkable progress in the development and popularization of decentralized renewable energy systems. Success was particularly outstanding in the biogas and small hydro programs, but a certain degree of success was also achieved in programs for the supply of fuelwood, and, to a lesser extent, in solar energy development. How have the Chinese achieved success? What strategy did the Chinese adopt, and what are the advantages and disadvantages of this strategy?

The development of decentralized renewable energy systems has been promoted under the policy of walking on two legs, as mentioned previously. During most of the 1970s (and the Great Leap Forward), the fundamental policy for rural development, including development under the decentralized "leg", was zili gengsheng--"rebirth through one's own efforts," or self-reliance. In China's rural areas, local units were encouraged to take the development of small-scale, intermediate technology systems into their own hands, adopting a "do-it-ourselves" approach.

A central aspect of the Chinese concept of local self-reliance is local participation in development--the planning, control, and management of local development projects is largely delegated to local units. ^{2/} Emphasis is also placed on local sources of funding. ^{3/} Moreover, in order to reduce capital costs and the pressure on the state for necessary materials, strong emphasis is placed on the use of local materials and labor-intensive techniques. The watchword is yinlou jiuojian, or "make do with whatever is available."

^{2/} It should be noted, however, that during most of the 1970s, the planning and control of local projects may often have been in the hands of a few local political leaders.

^{3/} Every production team has a capital accumulation fund, into which a certain percentage of the team's collective income is placed each year. The capital accumulation fund can be used for team projects, or it can be drawn on by the brigade or commune with the consent of the team. (Illegal use of team funds by higher units, however, was one of the excesses that occurred under the Gang of Four, according to the Chinese press today.) Brigades and communes also have their own capital accumulation funds, derived from their activities. County governments, in turn, rely on contributions from communes and brigades for some of the financing needed for even larger projects. In this way, surplus local funds are used for local development projects.

Although the doctrine of local self-reliance stresses local efforts in development, the state and Communist Party also play important roles. Central or regional governments and the Party have made vigorous efforts to promote programs in a variety of ways, ranging from the exertion of strong, top-down pressures on local units to pursue specific programs to the provision of information and guidance, often through the mass media, concerning the possible programs that local units might wish to pursue. In addition, various government departments and special organizations have provided support for local programs, by training local people, by providing advice and literature concerning technology, planning, and management, and by arranging exchange visits and conferences. In cases in which local funds are judged insufficient, the state has sometimes given financial assistance to local units, primarily in the form of low-interest loans or matching grants. The state may also provide equipment in some cases, or help arrange the supply of certain types of materials or machinery that cannot be easily produced at local levels.

A major part of the rationale for China's pursuit of local self-reliant development during the early and middle 1970s had to do with the political attitudes which were dominant at that time. During the 1966 to 1976 period, the role of the technocratic elite and specialized institutions in development was downplayed. Accent was placed on the role of the human will of the common man, and the mobilization of the strength and creativity of the masses was made the focal point of development.

An example of the role of political ideas can be seen in the arguments for the self-reliant development of small hydro plants and a reversal of the 1962-66 rural electrification policy. Specialized and centralized control over rural electrification was criticized as the promotion of "capitalist trusts and monopolies." Former policy-makers were attacked for furthering the "mystification of electricity" in the people's minds, and supposedly stating that the masses could not be responsible for managing electricity. It was stated that the masses could conduct rural electrification by themselves, the self-reliant construction of small hydro plants being one important means to this end. 118/

Equally important, however, in a situation in which the human, financial, and material resources of the state were severely limited, local development through self-reliance was perceived as an effective strategy for achieving rapid, although rudimentary, development in critical sectors of the rural economy. It was felt that high-speed development could not be achieved if local units persisted with the philosophy of shenshou xiangshang, or "waiting with out-stretched hands for help from above." The case of rural electrification again provides a good example. Sole reliance on the extension of state-owned grids was perceived as both too much of a burden on the state and too slow of a strategy. To quickly raise rural electrification levels, local units were encouraged to develop electricity supplies through their own efforts, if feasible.

In addition to the doctrine of local self-reliance, the science policy of the Cultural Revolution also helped shape China's approach to the development of decentralized renewable energy systems. Because of the devastating effect on China's centralized scientific and technological

infrastructure and on the nation's capabilities in advanced research and development, the policies pursued between 1966 and 1976 have been sharply criticized by China's current leadership and scientists abroad. However, the observe side of the coin must also be viewed. While work in the basic sciences, theoretical research, and advanced R&D in the centralized technological infrastructure was downplayed, emphasis was placed on highly applied research, the development and diffusion of intermediate technology for immediate needs, and the strengthening of local technological capacity. When elite science and the training of advanced scientists were criticized, emphasis was put on mass science--mass participation in scientific experimentation and research--and the training of low-level technicians among the workers and peasants. Thus, while the policy of local self-reliance called for mass-based development, the science policy of the Cultural Revolution called for mass participation in scientific and technological work, and provided support for such participation through various reforms.

With the emphasis on mass science, local people were encouraged to play a large role in the adaptation of new technology to local conditions, through scientific experimentation and incremental innovation. Thus, the process of technology diffusion in China's rural areas during the 1970s tended to involve local "adaptive" R&D, as well as training and extension. 119/

During the Cultural Revolution, the focus of work in the national technological infrastructure was shifted toward the provision of assistance to local mass-based efforts in scientific and technological development. Many of the central research institutes were decentralized and firmly linked to the existing network of rural scientific experiment stations. Indeed, some of the central institutes were moved, lock, stock and barrel, to the countryside. 120/ In addition, professional scientists and research workers were periodically required to leave their laboratories and travel into the countryside, often for "ideological remolding," but also to involve local people in research problems and help radiate the available expertise into the countryside. As a general rule, scientists who were not involved in key research projects, such as the development of nuclear weapons, were required to spend one year in the laboratory, one year in a specific rural locality, and one year traveling in rural areas. 121/ Educated youth were also required to settle in rural areas after graduation from high school or college, often permanently. Since the beginning of 1973, two million educated youth were transferred every year to the countryside for more or less permanent settlement. 122/

To help strengthen local technological capabilities, efforts were also made to provide a variety of short training courses at research institutes and various state organizations, and the number of low-level rural technical schools and worker's colleges was rapidly increased, along with the expansion of correspondence education. An assortment of technical literature was published and widely disseminated, and frequent conferences were held at the county, district, province, or national level, providing a forum for exchanging knowledge and experience.

In sum, the science policy of the Cultural Revolution both helped encourage local innovation and experimentation in rural technological

development, and provided assistance for such efforts, primarily through reforms designed to achieve closer integration between the local and the centralized, more advanced technological infrastructures.

Taken as a whole, the science policy and the policy of local self-reliance appear to have provided a very effective framework for the rapid popularization of decentralized renewable energy systems. The speed of development and the creativity of local people in overcoming local obstacles, particularly financial ones, were truly remarkable. However, the policies prevalent during the early and middle 1970s also involved major disadvantages and caused a series of problems. The most important problems associated with the science policy of the Cultural Revolution are fairly well known, and will not be detailed here. Concerning the policy of local self-reliance, the wide application of the policy--in both agriculture and rural industry--caused a lack of proper integration, and pushed the rural economy in a cellular direction. With the stress on local self-sufficiency associated with the policy, specialized development relying on interdependence was deemphasized, and inadequate attention was given to local comparative advantage, coordination between localities, and economic efficiency. In the specific case of the development of small-scale, decentralized enterprises, local self-reliance often led to technical deficiencies, waste through duplicated effort (caused by poor coordination), a lack of standardization in technology, and mismanagement.

Since the death of Mao in 1976, the dominant political attitudes in China have changed dramatically, bringing widespread reform of government policies. The role of the technocratic elite in development has been strongly reaffirmed, and China's new leadership has established a new policy for scientific and technological development, which places special emphasis on the strengthening of China's capabilities in advanced scientific work, and thus, the achievement of a better balance between the advanced and centralized sphere and local sphere in technological development. As a comprehensive strategy for rural development, the doctrine of local self-reliance appears to have been dropped as China's leaders move to achieve greater specialization, coordination, and economic integration in the rural economy. Particularly in the case of small-scale, decentralized enterprises, however, aspects of the former policy can be expected to continue to figure prominently in development. Clearly efforts are being made to raise technical levels, achieve greater coordination, and improve management. However, it is unlikely that the stress on the use of local sources of funding for local projects will be changed substantially. Moreover, although local control, management, initiative, and participation in development may be altered and take some new forms, mass-based development can also be expected to continue. However, in cases in which the policy of "making due with whatever is available" has led to particular inefficiency, one can expect changes.

The advantages and disadvantages of the policies of the 1970s in decentralized renewable energy development will be discussed in greater detail in the next section. Before moving on, however, a final aspect of the Chinese approach to renewable energy development which has less to do with Chinese political shifts should be discussed. This is China's emphasis on the promotion of decentralized renewable energy systems as part of well-integrated, multipurpose programs.

The small hydro and biogas programs, and many schemes to provide fuelwood through afforestation, the supply of energy is just one consideration. China's small hydro plants have usually been developed as one aspect of multipurpose water management schemes, which may be designed to improve flood control, water storage capabilities, irrigation and drainage, navigation, and fish industry, in addition to providing power. In developing biogas plants, attention has been given to both the provision of a new fuel source and the improvement of rural techniques in the management of fertilizer and organic residues. In many local forestry projects, including "four around" plantings, the development of larger collective forests for protective purposes or the production of timber, fruit, nuts, or oils, and systems for closing uncultivated areas to allow natural regeneration, provisions for the supply of fuelwood have often been an integral part of the projects, although they have been designed primarily for other purposes.

In solar energy development, it may be difficult to develop systems which can serve other purposes in addition to the supply of energy. Nevertheless, the Chinese have expressed an interest in developing systems which can provide energy for several purposes, and they have begun to develop schemes which integrate solar and biogas systems.

In many ways, the promotion of programs which are designed to obtain multiple benefits from a given resource represents an extension of traditional Chinese attitudes toward the use of available resources. The Chinese have been confronted with the problem of population pressure for centuries, and over the years the Chinese have developed a keen eye for conservation and methods to gain the maximum benefit from limited resources. In addition, with the transformation of the political and economic system in the countryside, local leaders now have the responsibility for a wide range of rural development programs, leading to a more holistic approach to local development and facilitating the pursuit of integrated, multipurpose programs.

IV. THE IMPLICATIONS OF THE CHINESE APPROACH DURING THE 1970s

The implications of the approach to decentralized renewable energy development adopted by the Chinese during the 1970s will be considered in five general areas, including the selection of technology, institutional infrastructure, research and development, training, and management and maintenance.

A. The Selection of Technology

In many developing countries, leaders have recognized the importance of developing low-cost, labor-intensive systems which use local materials, but in China these priorities have been pursued with a degree of intensity that is rarely found in other nations. In turn, China's strict attention to low cost, simplicity of design, and reliance on local materials and labor has been a major factor in China's ability to rapidly diffuse the renewable energy technologies which she has aggressively promoted. This approach has sometimes caused levels of quality, technical performance, and efficiency to be lower than one might desire. However, there are distinct advantages. If capital costs can be lowered to the point at which local people can afford them, development can proceed rapidly, local funds can be relied on, and heavy state subsidies, which place a burden on the state, can be avoided. In addition, when technology is relatively simple and emphasis is placed on the use of local materials and labor, technology is easier to diffuse because local people can pursue projects largely by themselves, without waiting for the supply of scarce materials or equipment.

In their biogas program, the Chinese have selected the basic water pressure digester for popularization among rural households. When compared to other common designs, the technical performance of this digester may be inferior, but it is far cheaper and can be built by local people with local materials. The Chinese have been able to construct some seven million digesters in less than a decade. In the small hydro program, local units have often substituted local materials or locally made machinery for higher quality materials or machinery, reducing technical performance and efficiency, but also capital costs. These types of substitutions have put small hydro development within the grasp of many units which could not have afforded higher quality plants, at least initially.

In some areas of rural industrial development, emphasis on the use of local materials and a high degree of self-sufficiency has led to a degree of waste and neglect of quality and efficiency that is currently judged as unacceptable by China's leaders. Although problems may be less severe in the decentralized energy programs, China's current leaders have pushed for greater attention to quality and efficiency than in the past. Current attitudes display a recognition of the tradeoffs involved in a stress on low-cost, labor-intensive technology and the use of local materials.

During most of the 1970s, localities were encouraged to develop their own capabilities for manufacturing small hydro plant equipment, and many small-scale rural enterprises were founded to produce simple water turbines and generator sets. Currently, this type of decentralized,

self-sufficient production of plant equipment is apparently being emphasized, in order to help improve technical levels and the quality of equipment. For example, in Sichuan Province, a specialized company had recently been formed to coordinate the production of small hydro equipment in the more than ninety factories that had previously been established in the province. In the past, production was poorly organized and the equipment produced was of low quality. The new specialized company will apparently enable production of complete, standardized equipment sets of higher quality, and will assist in marketing, so that any locality can apply to the company to purchase complete equipment sets. At the national conference held in Chengdu, Sichuan during January 1980, the new company received a great deal of praise. 123/

With the current trend toward more specialized and coordinated production of equipment and the improvement of technical levels, the use of primitive, locally made equipment such as wooden water turbines will probably become more a phenomenon of the past. In many ways, however, the current policy may have more to do with the present stage of development, rather than a criticism of previous attitudes toward the selection of technology. Initially, both local and national capabilities in the small hydro field were weak, so that a reliance on locally made equipment may have been the only way in which local units could begin development. At present, however, small hydro development has already proceeded in many areas, and as the benefits of projects are being realized and local capabilities have strengthened, it may be more possible and highly desirable to place greater emphasis on improving technical levels. In addition, as the national development infrastructure and capabilities in the production of equipment have gradually developed and become more advanced, opportunities for raising technical levels and improving quality have increased.

Recent reports on biogas development state that too little attention has been given to quality as opposed to quantity in digester construction, resulting in the proliferation of what have been called "sick digestors." One report states that in 1979 only some 55 percent of all the digestors in China could be "used normally." 124/ While problems concerning quality in digester construction appear to have more to do with a lack of technical expertise or care in construction at the local level than problems in digester design or the use of local materials, reports do mention that some units have overemphasized low-cost construction. One recent report states, "With the prerequisite of guaranteeing quality, the cost of building pits can be lowered. However, we cannot one-sidedly emphasized lowering construction costs and should not overemphasize practicing economy so that the quality of construction of the pits might be lowered, thus creating difficulty for management afterwards." 125/ On the whole, however, the use of water pressure digester design and a heavy reliance on local construction materials have brought good results and can be expected to continue.

Chinese experience in decentralized renewable energy development shows the definite advantages of a strong emphasis on low-cost technology and the use of local materials and labor as a means to achieve the rapid diffusion of technology on a wide scale. However, Chinese experience also shows that there are tradeoffs in this approach, and in some areas of rural industrial development, heavy reliance on low-cost methods and local materials may have been counterproductive. In viewing tradeoffs, it may be

best to both carefully consider the alternatives for different technologies on an individual basis and the current stage of development.

B. Institutional Framework

In keeping with the doctrine of local self-reliance, much of the development effort in decentralized renewable energy has been undertaken by rural collective units (communes, brigades, and teams). In the case of small-scale hydroelectric power, development has also been undertaken by county governments, the lowest administration level of the state. Local units have usually played the major role in the planning, management, control and even initiation of specific projects.

One of the major advantages to local participation in development and the delegation of responsibility to local units is that strict attention can be given to local conditions. In a country as large as China, local needs and resources vary dramatically, and attention to variations is critical in the decentralized renewable energy systems that China has promoted.

Although more apparent in development outside of the energy sphere, local initiative in development may have been neglected in some cases, even though projects may still have been managed and controlled at the local level. The problems encountered show by negative example the importance of local initiative as a means to maintain proper consideration of local conditions. A recent article on biogas development implies that in some areas biogas has been promoted by rigid administrative decree, with poor results. The article states, "Disregarding objective conditions and popularizing by rigid administrative decree is wrong and will get us nowhere." ^{126/} On the whole, however, a great deal of flexibility has been maintained in the promotion of renewable energy systems, so that attention to local conditions has been a strong point in the Chinese development effort.

Although the accent has been placed on local self-reliance, state institutions have provided critical assistance to local units, particularly in the training of local people in new technology. In areas where development has become particularly advanced, state institutions have been firmly linked to special groups within collectives.

In areas where biogas development has been especially successful, such as in parts of Sichuan Province, a complete top-to-bottom development and management infrastructure has been established. Such an infrastructure includes specialized biogas promotion offices at the provincial, district, and county levels, and special groups of full-time and part-time technical personnel at the commune, brigade, and team levels. The state-administered biogas promotion offices play a critical role in biogas development by arranging for the training of people from the collectives, arranging for the supply of necessary materials and the extension of bank loans for local units when required, conducting biogas research, and preparing technical literature for use by local people. The special groups in the collectives consist of local people who have received training either outside or inside of the collective, and they play a key role in supervising digester construction and management. They may also be involved in adaptive

research. In Mianyang District, Sichuan Province, small groups of three or four technicians at the team level cut, prepare, and store crop by-product set aside by the team for fermentation, record the amount of grass and manure collected by individuals, arrange for the biannual loading and unloading of digestors, repair leaks in digestors, pursue biogas research, popularize knowledge concerning the safe use of the gas, investigate and eliminate safety hazards, and promote movements for improvements in sanitation. 127/

Special groups have also been organized at commune and brigade levels for conducting forestry work, except for in areas where forestry is still of minor importance, in which case work may be undertaken by local agricultural departments. 128/ The grass roots workers who make up these groups sometimes have received long- or short-term training at formal forestry education institutions, but state forestry departments, at provincial, district, and county levels, and the various state forestry organizations under their control (such as state forestry farms, forest industry enterprises, and forestry research institutes) have usually played the key role in assisting rural collectives. They have provided short training courses; arranged for one-day or one-week technical consultations; promoted exchange visits and on-the-job training in sawmills, timber yards, forest farms, and research institutes; prepared information sheets and technical pamphlets; set up demonstrations; and provided on-the-spot advice for collective units experiencing problems. State forestry organizations have involved local people in practical research work and supported research projects at the grassroots level. They have also given advice on management, and in some cases they have actually provided management services until collectives have acquired their own nucleus of trained and experienced workers. 129/

After his trip to China, Westoby wrote, "The relationship between the state and collectively owned sectors in forestry--at least in the areas I visited--is a living and fecund one." 130/

Little information is readily available concerning the institutional framework for small hydro development. It is clear that specialized groups of local full-time or part-time technicians exist at the administration level at which a plant is operated, and these groups probably receive training and assistance from local or regional departments of the Ministry of Water Conservancy or Ministry of Electric Power, from state research institutes, or from technicians at other hydroelectric power stations.

From scattered Chinese reports, it appears that provincial or county scientific and technological committees have played the most important role in the very limited popularization of direct solar or wind technologies. However, a variety of state-administered research institutes and academic institutions have been involved in researching these technologies.

The degree of state support given to local units during the 1970s was in many ways impressive, but there is currently a definite need to strengthen the state-administered support infrastructure. Weaknesses in state assistance can in some ways be attributed to a natural difficulty to

quickly fulfill an enormous task, but the strong emphasis on local self-reliance, and the tendency to deny the importance of specialized institutions in development, also seem to have caused a certain lack of attention to infrastructural development.

Although recent reports also call for the need to strengthen state assistance for local units in planning, financing, and arranging equipment purchases in the small hydro program, the need to strengthen the support infrastructure is particularly evident in the biogas program. While biogas promotion offices have been established in nineteen of China's thirty provinces, autonomous regions, and independently-administered municipalities, many offices are understaffed, and lack sufficient operating funds or materials. 131/ In addition, many areas that have developed biogas have not established permanent specialized groups for digester management at the commune, brigade, or team levels, or technicians in these groups have not received adequate training. If greater attention is given to proper infrastructural development, problems concerning a lack of planning for the supply of necessary materials, lack of progress in training local technicians, mismanagement, and poor construction of digestors should diminish, as the experience of localities that have been especially successful in biogas development clearly shows. 132/

In addition, the emphasis on local self-reliance in pursuing development appears to have caused a weakness in national planning and coordination in renewable energy development. One symptom of this can be seen in the biogas program--in many parts of China where conditions are particularly advantageous for biogas development, popularization of the technology has been slow, because regional and local leaders have not viewed biogas development as important. Moreover, throughout most of the 1970s, no permanent institution existed for the integrated planning of renewable energy development at the national level.

China's leaders are currently moving to address these problems. Recent policy statements call for a strengthening of the development support infrastructure, a new Energy Commission has recently been formed, and the Second Bureau of the State Scientific and Technological Commission has been charged with the responsibility for studying and developing a national strategy for exploiting "new forms of energy," i.e., biomass, solar, geothermal, and tidal energy.

C. Research and Development

Largely as a result of the policy of local self-reliance and the science policy of the Cultural Revolution, China has developed strong capabilities in R&D work that is closely connected to the diffusion of known technology in rural areas--highly applied R&D, incremental innovation, and the adaptation of technology to local conditions. On the other hand, fundamental weaknesses exist in advanced and theoretical research work, with the exception of a few high priority areas. Thus, China provides an interesting contrast to most developing countries in that local "adaptive" R&D capacity is relatively strong, while national, advanced R&D capacity is especially backward.

As in many aspects of rural technological development, local adaptive R&D has been integrated into the technology diffusion process in the development of renewable energy systems. The encouragement of local applied research and incremental innovation has been part of regular training and extension.

China's biogas program provides a particularly good example. The technology diffusion process rarely involves a group of outside experts, who come to a locality, build a number of digestors, train people to manage them, and then leave. Instead, a few local people are usually trained on the outside, and when they return, they are in charge of training others and adapting the technology to the local setting. 133/ Thus, the accent is placed on training local people to pursue development themselves. And this emphasis has resulted in the proliferation of a wide assortment of design variations, as a product of local adjustments and innovations.

After a trip to China in 1977 to investigate family-sized digestors, an FAO study tour wrote,

Modification and improvement of design is a continuing exercise in China and this is the responsibility of special organizations, committees or departments set up at the Commune, or even County, level. Furthermore, individual Production Brigades and Production Teams have their own small groups of technicians for investing the design and operation of units which results in continued modification to existing designs. 134/

Concerning cooking and lighting appliances, the FAO group noted,

Each Commune, or even each Production Team, designs its own appliances, and burners were seen of several different kinds and sizes. Designs are constantly being improved and distributed for the users' reaction before being locally manufactured in quantity. 135/

In addition, there are also indications that local people have been involved in other types of biogas research work, such as research on gas production rates or the elimination of pathogens in the slurry or sludge from digestors. 136/

In forestry development, highly applied research has been emphasized, and research has also been fused with training and extension. An FAO/UNDP study group that toured China in 1977 wrote,

"The orientation of forestry research in China is practical, that is, it is directed to solving the problems the people are facing or encountering during their work. Research work is integrated with teaching and training, and more particularly with production...As seen in nearly all the places visited, at brigade, commune and production team levels, there was always some kind of research work being done...Research work has gradually been developed not only by the professional people but also through the field work and the experience gained at different levels by the field workers."

Although little information is available concerning the research and development of small-scale hydroelectric equipment, there appears to have been greater central involvement in R&D work than in, say, the biogas program. After 1958, special research institutes equipped with test facilities were set up to design medium- and small-scale hydroelectric power equipment, such as water turbines, generators, automatic voltage regulators, speed governors and auxiliary devices. 138/ In addition, departments of the Ministry of Electric Power and the Ministry of Water Conservancy have played a major role in helping local units design small hydro plants. Nevertheless, local innovation in adapting the technology, and particularly in substituting local materials or locally made equipment for more expensive items, has still been an important part of the program. 139/

Research and development in the solar and wind energy fields is fundamentally different from that in the biogas, forestry and small hydro fields because the promotion of solar and wind systems was begun only recently, and systems are still basically in the research stage. Solar and wind systems have been viewed primarily as long-term options, and efforts have not yet been made to popularize these systems on a wide scale. Thus, most research on solar and wind energy has been concluded in the state research institutes or academic institutions. In the few cases in which attempts have been made to popularize technologies in rural areas, collective units have apparently worked closely with these state institutions or provincial or county scientific and technological committees.

In summary, with the exception of the incipient solar and wind energy programs, China's decentralized renewable energy programs have generally been characterized by a heavy involvement of local people in adaptive R&D and incremental innovation. Such involvement has important advantages in that it helps the development of local technical abilities and understanding of a given technology, which can be critical in management and maintenance, and it also helps to maintain a close linkage between technology and local conditions. Indeed, unleashing the creativity of local people in overcoming local technical problems and developing different designs and techniques that are least expensive for given local settings appears to have been a major factor in China's success in small hydro and biogas development.

An important disadvantage exists, however, in that an encouragement of local innovation and development of different local designs leads away from standardization of technology. Standardization can help ensure that certain technical criteria are met, prevent a multiplicity of effort, resulting in waste, and help guard against serious mistakes in design and construction. In their efforts to improve quality levels, China's current leaders are attempting to sum up and consolidate past experiences and move toward greater standardization of technology in the biogas and small hydro program. While local innovation and the development of different designs and techniques corresponding to local conditions clearly had some beneficial impacts, Chinese leaders apparently feel that a movement toward greater standardization could produce a better balance in the tradeoff between standardization and local technological development at this point, thus benefiting the programs.

China's leadership has also recently moved to strengthen the nation's capabilities in advanced and theoretical scientific work. In the renewable energy field, greater attention is currently being given to relatively sophisticated R&D work in solar and biogas energy. The strengthening of solar energy research has recently been described as a key project in the current drive for the modernization of science and technology. 140/ An article by the Office of the National Methane Production Leadership Group recommends the establishment of a new national methane research institute in the northern part of China. The article also notes that there is currently a serious lack of research personnel in the biogas field, and proposes the addition of special courses on biogas production in certain colleges and universities. 141/ One of the most important areas where further research is needed is in methods of producing biogas in cold temperatures.

D. Training

Given the policy emphasis on local self-reliance, the training of local people has been a key element in the technology diffusion process for the decentralized renewable energy systems that China has aggressively promoted. With the accent on local control, management, and participation in development, the transfer of knowledge to residents has been critical. Given the enormous scale of the task, China's achievements have been remarkable, but it is clear that a great deal of work remains to be done.

One of the most important duties of specialists or the institutions for which they work has been the dissemination of knowledge to other people. Biogas promotion offices, state-administered forestry, water conservancy, and electric power departments, and the various organizations and institutes under their control have provided a wide range of training services, including demonstrations and medium- and short-term courses, seminars, and workshops. Specialists and technicians have also toured rural areas to set up demonstrations, and provide on-the-spot training and advice. In addition, special teams of commune members have been frequently organized to visit areas that are particularly advanced in the development of a certain technology, to learn from the experience of those areas.

The Chinese have also published an assortment of technical literature and distributed it widely. Technical manuals are written in simple and straightforward style. They present useful technical data, and give practical and detailed advice concerning planning, design, construction, operation, maintenance, and so forth.

The training process that the Chinese have adapted in the biogas program is particularly interesting. Usually only a few local people in a given rural collective receive training from visiting technicians or on the outside. This small group then trains others within their locality in management and construction techniques. Newly trained people then train others and supervise the construction of small-scale digestors, which are usually built by individual families. Thus, the process assumes the form of a pyramid, with only a few persons who were trained on the outside at the top. 142/

The experience of Shachiao Commune in Guangdong Province described by Ariane van Buren provides one example of how effective this method can be. Originally, three people in the commune read a technical manual on biogas production and traveled to Sichuan Province to spend fifteen days with families who were building and operating digestors. When they returned to Shachiao, they built a few experimental digestors and devised a new technique of digester construction suitable for the local area, which had a high water table. The three people then trained seventy others in the technology, and thus seventy technicians supervised an active construction campaign in the brigades and teams of the commune. Just two years after the original three persons traveled to Sichuan, 1,640 biogas digestors had been built in the commune, 1,300 of which were built by individual families. The seventy technicians are now in charge of safety and management, working full-time to check on maintenance and help with repairs. In addition, they have passed on their expertise to another three hundred people, who work as part-time biogas technicians. 143/

Recent reports describe problems concerning low quality levels and mismanagement in the biogas, small hydro, and forestry programs. It is clear that local people have made mistakes in pursuing local projects, and lack of sufficient knowledge regarding effective operation and management often exists at the local level. While China's achievements in providing training and technical assistance have in many ways been impressive, efforts must be made to expand and intensify training, so as to improve both quality in construction and management.

E. Management and Maintenance

In China, the building of local management and maintenance capabilities has been viewed as an integral part of the technology diffusion process. As a result of the heavy emphasis on local involvement in developing a given technology, a local contingent of low-level technicians is built up, which trains others and plays the key role in operation, management, and maintenance. Expertise in management and maintenance is often gained through "learning by doing".

The Chinese have clearly experienced problems in the local management of renewable energy programs. In some ways, deficiencies stem from the prevalent attitudes during the 1970s which tended to stress quantity and rapid construction, as opposed to quality and after-care or effective management. In the forestry program, for example, accent was placed on planting large numbers of trees, and although some improvements may have been made, attention to effective aftercare and maintenance of new plantations was still inadequate. As one report states, "In spring, the mountains are covered with green trees; in summer, half of the trees are dead; in autumn, there are scarcely any; in winter, not even one can be seen." 144/

Cases of local mismanagement have also been caused by a lack of knowledge at the local level. In the biogas program, some digestors are apparently out of commission because local people do not know how to operate them properly. 145/ In the small hydro program, some plants are also not operating at their full potential because of inadequate understanding of proper operational management. 146/

Local management problems may also be compounded by the emphasis on multipurpose systems. While these systems allow several benefits to be gained from the same resource, effective systems management can be tricky. Systems must be planned and managed so that one function is not overstressed to the detriment of another.

In pursuing the development of family-sized biogas digestors, many local units have had difficulty balancing the use of digester slurry and sludge for fertilizer and the production of biogas fuel. Problems are intensified by the fact that the production of gas involves the interests of individual households, while the use of digester sludge and slurry primarily involves the interests of the collective. Some units have focused their attention on the use of fermentation materials for fertilizer, and neglected the fuel needs of families, while other units have only paid attention to fuel production, resulting in problems concerning the supply of fertilizer. Biogas digestors can be used in a way in which both fertilizer and fuel needs are met, but careful planning and management are critical. 147/

In many local forestry development schemes, provisions have been made for the supply of fuelwood from forests which are designed primarily for other purposes. In theory, a certain amount of fuelwood can be harvested from local forests in a way in which those forests are not harmed, or may even benefit. In practice, however, it is very easy to step over the vague line which distinguishes the multiple use of forests from forest abuse. For example, a brigade may periodically allow its members or a special team to enter a local shelterbelt to pick up dead wood or prune and thin trees, and use the wood for fuel. Supplementary fuel can be provided without harm to the shelterbelt--indeed, the shelterbelt may be improved with effective pruning and thinning. However, especially if the brigade members are suffering from a serious shortage of fuel, the opportunity to enter the shelterbelt may be abused, and the trees severely harmed.

China's leaders have recently stressed the need to strengthen scientific management at the local level. In the biogas program, the government has emphasized a strengthening of the development and management infrastructure, following the model of advanced areas in Sichuan Province. State-administered offices have been encouraged to improve the quality of training, and local units have been encouraged to establish special groups for managing family-sized digestors at the team level. In small-scale hydroelectric power development, the government is promoting closer coordination between counties and rural collectives in developing and operating plants, as one way to improve local management. 148/ In forestry development, strong emphasis has been placed on improving after-care in local afforestation projects. In addition, chronic problems in forest abuse seem to have prompted a movement away from attempts to supply fuelwood from forests designed primarily for other purposes. At present, greater stress appears to have been put on the establishment of collective or individual forest plots which are specifically designed to produce fuelwood.

In summary, the most salient aspect of China's approach to decentralized renewable energy development during the 1970s was the strong emphasis on mass-based development, pursued through local efforts. The role

of government was focused on encouraging and assisting local units to undertake development themselves. Thus, the technology diffusion process tended to involve the building or strengthening of a variety of local capabilities necessary for highly self-reliant development.

The strong points of the Chinese approach--the ability to achieve rapid popularization of technology through reliance on local funds, labor, and resources, and the integration of technology with local conditions--have attracted a good deal of interest outside of China. However, the problems that the Chinese experienced in renewable energy development during the 1970s have only recently begun to be understood. These problems include low technical performance or inadequate attention to quality in many local projects, a certain lack of attention to regional or national planning and coordination, and problems concerning effective management at the local level.

As in many aspects of economic development, China's current leadership is attempting to consolidate past gains in decentralized renewable energy development, address the problems that surfaced in the past, and put the program on a new, more solid footing, so they can fully contribute to the country's modernization. In general, the government has placed greater emphasis on the role of the state-administered infrastructure in development. While it appears that development efforts will still be focused at the local level, recent reports and official statements call for more effective planning and coordination, greater emphasis on fundamental research, improvement in training programs for local people, and the provision of more effective assistance to local units in the application of technology and in the arranging of supplementary financing, the supply of necessary construction materials, and purchases of equipment. In addition, the government appears to have placed greater emphasis on the recognition of the tradeoffs involved in previous attitudes toward the selection of technology. In the interests of improving quality and technical performance in renewable energy systems, the government has pushed for a better balance between the pursuit of low-cost technology and the pursuit of efficient, high-quality technology, and between local innovation and standardization.

In recent years, the Chinese have expressed both a willingness to share their experience in renewable energy development with other countries, and a desire to learn from the experience of other countries. In cooperation with the United Nations, one-month training seminars in biogas technology have been held for persons from other developing countries in Sichuan in 1979 and 1980. China has also agreed to establish development, research, and training centers in both the biogas and small-scale hydroelectric power fields, under the auspices of the United Nations Development Programme. 149/ In solar energy development, China has sought assistance from other countries, particularly the Federal Republic of Germany.

NOTES

- 1/ The World Bank, China, Socialist Economic Development, Annex E, The Energy Sector (Washington, D.C., The World Bank, 1981), pp. 1-2.
- 2/ At the Third National Biogas Conference, held in Beijing in June 1979, it was stated that consumption of traditional biomass fuels accounted for one-third of total national energy consumption [New China New Agency (NCNA), 6/4/79, reported in Foreign Broadcast Information Service (FBIS), China: Daily Report, 6/5/79, No. 109, p. L7]. An authoritative report by Wu Zhonghua gives current traditional energy consumption as 290 million MTCE per year ("The Way to Solve the Energy Crisis as Seen from Energy Science and Technology," Hongqi (Red Flag), 9/1/80, pp. 31-43, translated in Joint Publications Research Service (JPRS), China Report: Red Flag, 12/5/80, No. 76948, p. 49). An article by Shangguan Changjun gives a figure of 310 million MTCE ("Ways Must be Found to Solve Energy Problems in Rural Areas," Nongye jingji wenti (Agricultural Economic Issues), 1980, No. 4, pp. IV-56 to IV-58, in JPRS, China Report: Agriculture, 5/28/81, No. 78176, p. 5), while an article by Xu Junzhang and Huang Zhijie gives a figure of 210 million MTCE ("The Way to Solve Rural Energy Problems," Remin Ribao (People's Daily), 10/27/80, p. 5, in JPRS, China Report: Economic Affairs, 3/18/81, No. 77615, p. 61).
- 3/ Several Chinese reports estimate that about 300 million tons of crop by-products are burned for fuel every year. They also state that some 600 million tons of crop by-products would be needed to meet total rural household fuel requirements. See Xu Junzhang, Zhang Zhengmin, Yang Zhirong, and Zhu Bin, "On Energy Construction for China's Modernization," Ziran bianzhengfa tongxun (Journal of Natural Dialects), 4/80, pp. 16-22 (JPRS, China Report: Economic Affairs, 11/5/80, No. 76760, p. 60); Xu and Huang, "The Way to Solve Rural Energy Problems," pp. 60-61; and Huang Zhijie and Zhang Zhengmin, "The Development of Methane is an Important Task in Solving the Rural Energy Problem," Hongqi, 11/1/80, pp. 39-41, 29 (JPRS, China Report, Red Flag, 1/19/81, No. 77195, p. 61). However, one article does state that only 230 million tons of crop by-products are available for use as fuel every year (Shangguan, "Ways Must Be Found to Solve Energy Problems," p. 4).
- 4/ Revelle, Roger, "Energy Use in Rural India," Science, Vol. 192, No. 4 (June 1976), pp. 969-975.
- 5/ Taylor, Robert P., Rural Energy Development in China (Washington, D.C., Johns Hopkins Press for Resources for the Future, 1981), pp. 45-48. Two recent Chinese reports state or imply that traditional fuels account for 94 percent of total rural household fuel consumption, while coal supplied by the state accounts for 6 percent (Xu and Huang, "The Way to Solve Rural Energy Problems," p. 62; Shangguan, "Ways Must Be Found to Solve Energy Problems," pp. 4-5). These reports are confusing, however, because they do not mention coal which is not supplied by the state, but by collectively owned and operated small coal mines. Coal from collective mines is clearly a major source of household fuel.

- 6/ Taylor, Rural Energy Development in China, pp. 61-62.
- 7/ State Statistical Bureau of the PRC, "Communique on the Fulfillment of China's 1980 National Economic Plan" (FBIS, 4/29/81, No. 82, p. K8).
- 8/ NCNA, 12/29/80 (JPRS, China Report: Economic Affairs, 1/15/81, No. 77182, p. 30); NCNA, 1/8/81 (JPRS, China Report: Economic Affairs, 1/30/81, No. 77285, p. 50).
- 9/ State Statistical Bureau, "Communique on the 1980 Plan," p. K10.
- 10/ Shangguan, "Ways Must Be Found to Solve Energy Problems," p. 5.
- 11/ In Forestry in Communist China (Baltimore, Johns Hopkins University Press, 1966) S.D. Richardson lists a variety of estimates made during the 1950s concerning China's forested land area, which range from 5 to 10.1 percent of the total land area. In recent years, Chinese reports have stated that in 1949 or the early 1950s, China's forestlands accounted for 5 percent of the total land area (e.g., Beijing Review, 3/2/79, p. 4), 7.8 percent of the total land area (e.g., NCNA, 9/22/79, in FBIS, 9/26/79, No. 188, p. L11), and 8.6 percent of the total land area (e.g. NCNA, 3/10/80, in FBIS, 3/11/80, No. 49, p. L5). The 5 percent figure was compiled by the Nationalist Government before the war (Richardson, Forestry in Communist China, p. 159).
- 12/ See Buck, John Lossing, Land Utilization in China (Nanking, China, University of Nanking, 1937), p. 238.
- 13/ China's population in 1949 has been estimated at 534 million persons [U.S. Central Intelligence Agency, China: A Statistical Compendium (Washington, D.C., CIA, July 1979), p. 5]. China's population in 1979 was reported at 982.55 million persons (State Statistical Bureau, "Communique on the 1980 Plan," p. K16). There has been virtually no change in the breakdown between urban and rural populations.
- 14/ Buck, John Lossing; Dawson, Owen L.; and Wu Yuan-li, Food and Agriculture in Communist China (New York, Praeger Publishers, 1966) p. 58; State Statistical Bureau of the PRC, "Communique on Fulfillment of China's 1978 National Economic Plan" (FBIS, 6/27/79, No. 125, p. L14).
- 15/ See Xu and Huang, "The Way to Solve Rural Energy Problems," pp. 60-64, and Xu, et. al., "On Energy Construction," p. 60. Shangguan estimates that only about 50 percent of the crop by-products produced is available for use as fuel ("Ways Must Be Found to Solve Energy Problems," p. 4).
- 16/ Recent Chinese reports quoting the 12.7 percent figure are too numerous to list. Perhaps the most important is "The Directive on Afforestation Issued Jointly by the CCP Central Committee and the State Council, 3/5/80" (FBIS, 3/11/80, No. 49, p. L10).
- 17/ Richardson, Forestry in Communist China, pp. 55, 62-63.

- 18/ After an extensive trip to China, Jack Westoby wrote that areas which had been badly stocked in the past have been replanted, and survival rates in these areas and new afforestation areas are satisfactory. See Westoby, Jack, "Whose Trees? Whose Science?," New Scientist, vo. 72, No. 1013 (August 12, 1976), p. 341.
- 19/ A good example is the Chinese fir afforestation campaign in Hunan Province. See Westoby, Jack, "Forestry in China," Unasylva, Vol. 27, No. 108 (1975), p. 27.
- 20/ United Nations, Food and Agricultural Organization (FAO), "Nepal Multiple-use Mountain Forest Development: Report on a Study Tour to the People's Republic of China, 11/26/78 - 12/11/78 (Rome, FAO, 1979), p. 7.
- 21/ See Niu Chengzhi, Zenma yang fengshan yulin (How to Close the Mountains for Natural Regeneration) (Shanghai, China Books, 1953); and Zaolin: Nonglin shengchan jiben zhishi (Afforestation: Fundamental Knowledge for Agricultural and Forestry Production) (Beijing, Agricultural Publishing House, 1973), pp. 67-69.
- 22/ Unofficial communication with Zhang Dongming, Director of the Bureau of Foreign Affairs of the Chinese Ministry of Forestry, in Washington, D.C., May 17, 1980.
- 23/ The 3.7 million hectares are described as xintanlin. See Zhonghua nongye jingji dili (The Economic Geography of Agriculture in China) (Beijing, Agricultural Publishing House, 1980), p. 261.
- 24/ FAO, Nepal: Multiple-use Mountain Forest Development, p. 11.
- 25/ Westoby, Jack, "Making Green the Motherland: Forestry in China," in Maxwell, Neville, ed., China's Road to Development, (New York, Pergamon Press, 1979), p. 243.
- 26/ Some recent reports that note continuing forest abuse by fuel gatherers can be found in Renmin Ribao, 6/15/79, p. 2; Renmin Ribao, 10/8/79, p. 1, and JPRS, China Report, 2/24/78, No. 70685, p. 97. Numerous reports point to continuing shortages in rural fuel supplies.
- 27/ Richardson, Forestry in Communist China, pp. 168-169.
- 28/ Local broadcast, 1/28/78 (JPRS, China Report, 2/24/78, No. 70685, p. 97).
- 29/ See "The 1979 Forestry Act" (FBIS, 3/2/79, No. 43, p. E6); "Directive of Afforestation Issued Jointly by the CCP Central Committee and the State Council, May 5, 1980" (FBIS, 3/11/80, No. 49, pp. L11-L14); and "Decisions Made on March 8, 1981 by the CCP Central Committee and the PRC State Council on Some Questions Concerning the Protection of Forests and the Development of Forestry" (FBIS, 3/12/81, No. 49, p. L12).
- 30/ "Decisions Made on March 8, 1981," p. L12.
- 31/ "Directive on Afforestation, March 5, 1980," p. L12.

- 32/ "Decisions Made on March 8, 1981," p. L7.
- 33/ See Zhu Ke and Zhou Wenhai, Zenma yang liyong zhaoqi fadian (How to Use Biogas to Generate Electricity) (Beijing, Water Conservancy and Electric Power Publishing House, 1958), p. 1.
- 34/ Beijing Review, 12/15/78, p. 17.
- 35/ Lecture given by Professor Chen Ruchen of the Guangzhou Institute of Energy Conversion, U.S. AID Bioenergy Conference, Washington, D.C., April 17, 1980.
- 36/ During the Second National Biogas Conference, held on August 1978, it was declared that 7 million biogas digestors were in operation (NCNA, 8/22/78, in FBIS, 8/23/78, No. 164, p. E11). At the Third National Biogas Conference, held during June 1979, it was stated that over 7.1 million biogas digestors had been built (NCNA, 6/4/79, in FBIS, 6/5/79, No. 109, p. 27; and NCNA, 6/5/79, in FBIS, No. 112, p. 26). Between the summer of 1978 and the summer of 1980, Chinese reports have invariably stated that 7 million or more than 7 million digestors have been built. During the fall of 1980, however, several reports have declared that over 6 million digestors have been constructed. See Wu, "The Way to Solve the Energy Crisis," p. 65; Xu and Huang, "The Way to Solve Rural Energy Problems," p. 63; and Huang and Zhang, "The Development of Methane is an Important Task," p. 64. It is clear, however, that biogas development has continued between 1978 and 1981. The 7 million figure was probably based on inaccurate statistical reporting, and the Chinese may have recently investigated biogas development more thoroughly, and concluded that a figure of "more than 6 million" digestors is most accurate.
- 37/ Office of the National Methane Production Leadership Group, "Methane Production Should be Energetically Developed in a Planned Manner," Guangming Ribao (Illumination Daily), 7/13/80, p. 3 (JPRS, China Report: Economic Affairs, 9/26/80, No. 76505, p. 52).
- 38/ Chen Ruchen and Xiao Zhiping, "Design, Construction and Opoeration of Digestors in China." Paper Presented at the Bioenergy 1980 Conference, Atlanta, Ga., April 1980, p. 2.
- 39/ Office of the National Methane Production Leadership Group, "Methane Production," p. 26; NCNA, 7/19/80 (FBIS, 7/22/80, No. 142, p. L18).
- 40/ NCNA, 6/5/79 (FBIS, 6/8/79, No. #112, p. 26); NCNA, 5/20/78 (FBIS) 5/22/78, No. 99, p. E16).
- 41/ See Taylor, Rural Energy Development in China, p. 182.
- 42/ Smil, Vaclav, "Intermediate Energy Technology in China," World Development, Vol. 4, Nos. 10-11 (November 1976), p. 934.
- 43/ Buchanan, Keith M., The Transformation of the Chinese Earth (London, G. Bell and Sons, Ltd., 1970), p.28.

- 44/ Private communication with Prof Jerome Chen of York University, who has visited Sichuan twice during recent years; Beijing Review, 12/15/78, p. 16.
- 45/ See Renmin Ribao, 8/21/79, p. 2 (FBIS, 8/30/79, No.170, pp. L9-L11; Office of the National Methane Production Leadership Group, "Methane Production," pp. 26-27; and FAO, China: Azolla Propagation and Small-scale Biogas Technology: Report on an FAO/UNDP Study Tour to the PRC, 5/21/78-6/11/78, FAO Soils Bulletin No. 41 (Rome, FAO, 1979), p. 24.
- 46/ van Buren, Ariane, ed.; Crook, Michael, trans., A Chinese Biogas Manual: Popularizing Technology in the Countryside (London, Intermediate Technology Publications, 1979), p. 30.
- 47/ Ibid., pp. 21-30; Sichuan sheng mianyang diqu keshui jishu weiyuanhui (The Scientific and Technological Committee of Mianyang District, Sichuan Province), Zhaoqi de zhiqu liyong (Biogas Production and Use) (Beijing, Agricultural Publishing House, 1977), p. 1.
- 48/ Prasad, C.R.; Prasad, K. Krishna; and Reddy, A.K.N., "Bio-gas Plants: Prospects, Problems and Tasks," Economic and Political Weekly, August 1974, p. 1355.
- 49/ For detailed information on the design and construction of different types of biogas plants in China, see van Buren, Ariane, ed., A Chinese Biogas Manual, and Xinan jianzhu sheji yuan (The Southwestern Architectural Design Institute), Jianyi zhaoqichi tuji (A Collection of Simple Biogas Digester Diagrams) (Beijing, Agricultural Publishing House, 1979).
- 50/ FAO, China: Azolla Propagation and Small-scale Biogas Technology, p. 53.
- 51/ Ibid., p. 35. See also Beijing Review, 12/15/78, p. 17 and Chen and Xiao, "Design, Construction and Operation of Digestors," p. 2.
- 52/ van Buren, ed., A Chinese Biogas Manual, p. 13.
- 53/ Jain, Netral Pal, Rural Reconstruction in India and China (New Delhi, Sterling Publishers, Ltd., 1970), p. 234.
- 54/ The Chengdu Institute of Biology, "The Bio-gas Digestion Process and Digestion Mechanism," in the Sichuan Provincial Office of Biogas Development, ed., Biogas Technology and Utilization: Chengdu Seminar, 1979 (Sichuan, SPOBD, 1979), pp. 1-2.
- 55/ Ibid., p. 2.

- 56/ Sichuan sheng mianyang diqu keshui jishu weiyuanhui (The Scientific and Technological Committee of Mianyang District, Sichuan Province), pp. 85-86; van Buren, Ariane, "The Chinese Development of Biogas and Its Applicability to East Africa," Paper Presented at the Energy and Environment in East Africa Conference, Nairobi, May 1979, pp. 9-10.
- 57/ See Xinan jianzhu sheji yuan (the Southwestern Agricultural Design Institute), Jianyi zhaoqichi tuji, p. 2; Renmin Ribao, 6/13/79, p. 2; and Beijing Review, 12/15/78, pp. 16-17.
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- 62/ NCNA, 4/18/80 (FBIS, 4/18/80), No. 77, p. Q1).
- 63/ NCNA, 7/3/80 (JPRS, China Report: Economic Affairs, 7/21/80, No. 76081, pp. 90-91).
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- 66/ NCNA, 7/18/79 (FBIS, 7/18/79, No. 139, p. L7).
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- 68/ Beijing Review, 2/16/81, p. 6; NCNA, 12/31/80 (JPRS, China Report: Economic Affairs, 1/15/81, No. 77182, p. 30). One report states that as of April 1979, more than 88,000 small hydro plants had been built (NCNA, 6/18/79, in FBIS, 6/22/79, No. 122, p. L16). Other recent reports have stated that the number of plants at the end of 1979 was "nearly 90,000" or "almost 90,000" (NCNA, 1/20/80, in FBIS, 1/22/80, No. 75003, p. 18; NCNA, 1/20/80, in FBIS, 1/22/80, No. 75003, p. 18; NCNA, 1/11/80, in JPRS, China Report: Economic Affairs, 1/25/80, No. 75003, p. 18), or "exceeded 90,000" (NCNA, 1/10/80, in FBIS, 1/17/80, No. 12, p. L4). Beijing Review 2/16/81, p. 6) declares that more than 4,000 stations were built during 1980, but reports still state that the total number of stations is "90,000" or "more than 90,000."
- 69/ NCNA, 1/20/80 (FBIS, 1/22/80, Mo. 15, p. 2).
- 70/ NCNA, 1/10/80 (FBIS, 1/17/80, No. 12, p. L4); Guangming Ribao, (1/18/80, p. 1 (JPRS, China Report: Economic Affairs, 3/21/80, No. 75345, p. 39).
- 71/ On January 11, 1980 the New China New Agency reported that small hydro plants generated 11.6 billion kilowatt-hours of electricity in 1979 (JPRS, China Report: Economic Affairs, 1/25/80, No. 75003, p. .18). Chinese statistics on rural power consumption, however, are confusing because of a lack of definition of "total rural power consumption," "electricity consumed in rural areas," and so forth. In the annual communiques published by the State Statistical Bureau, "total electricity consumed in rural areas" is listed as 25.3 billion kilowatt-hours in 1978, 28.27 billion kilowatt-hours in 1979, and 32.10 billion kilowatt-hours in 1980 (FBIS, 4/30/80, No. 85, p. L4; FBIS, 4/29/81, No. 82, p. K10). However, another report gives the figure for just "electric power used for agricultural purposes" in 1978 as about 25 billion kilowatt-hours (NCNA, 6/18/79), in FBIS, 6/22/79, No. 122, p. L16). Other reports issued in December 1980 and January 1981 state that according to the Ministry of Power Industry, "rural consumers of electricity in China used 37,000 million kilowatt-hours of electricity in 1980, 13.8 percent more than in 1979" (NCNA, 12/29/80, in JPRS, China Report, Economic Affairs, 1/30/81, No. 77285, p. 50). These reports go on to state that if electricity used by county-run industries directly serving agriculture is included, rural power consumption in 1980 accounted for a quarter of the nation's total (i.e., some 70 billion kilowatt-hours).
- The December 1980 and January 1981 reports seem to imply that total electricity consumption in agriculture, rural households, and collectively run small-scale industries was 37 billion kilowatt-hours in 1980 and 32.5 billion kilowatt-hours in 1979. Total small hydro generation in 1979 was 35.7 percent of the 1979 figure. It is important to note, however, that a portion of the electricity generated by small hydro plants was used in county-run industries.
- 72/ Renmin Ribao, 8/6/80, p. 1 (JPRS, China Report: Economic Affairs, 3/18/81, No. 77165, p. 47).
- 73/ CIA, China: The Role of Small Plants in Economic Development (Washington, D.C., CIA, 1974), p. 11.

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- 76/ See El-Hinnawi, Essam, China Study Tour on Energy and Environment (Nairobi, United Nations Environment Programme, 1977), p. 25; and Huadong shuilixueyuan xiezu xiaozu (The Writing Committee of the East China Water Conservancy Institute), Nongcun xiaoxing shuidianzhan (Rural Small-scale Hydroelectric Plants) (Shanghai, People's Publishing House, 1973), p. 7.
- 77/ Huadong shuilixueyuan xiezu xiaozu (The Writing Committee of the East China Water Conservancy Institute), Nongcun xiaoxing shuidianzhan, p. 12.
- 78/ NCNA, 5/11/80 (JPRS, China Report: Economic Affairs, 6/3/80, No. 75812, p. 89).
- 79/ The total cost per installed kilowatt is defined as $\frac{I}{K}$ where K represents the installed capacity and I represents the total investment cost, including "landing construction costs (such as the construction costs for dams, station houses, water discharge structures, water diversion structures, etc.), compensation for reservoir inundation, labor costs, the costs of mechanical and electrical equipment for the plant, etc." See Tianjin daxue shuilixi (the Water Conservancy Department of Tianjin University), Xiaoxing shuidianzhan (Small-scale Hydroelectric Plants), vol. 1 (Beijing, Water Conservancy and Electric Power Publishing House, 1976), pp. 41/42.
- 80/ See Huadong shuilixueyuan xiezu xiaozu (The Writing Committee of the East China Water Conservancy Institute), Nongcun xiaoxing shuidianzhan, p. 357.
- 81/ Ibid., pp. 135-136, 147, 150.
- 82/ A few examples are translated from Shuili dianli bu xiezu xiaozu (The Writing Committee of the Water Conservancy and Electric Power Ministry), ed., Jiji fazhan nongcun xiaoxing shuidianzhan (Actively Develop Rural Small-scale Hydroelectric Plants) (Beijing, People's Publishing House, 1972), in Taylor, Rural Energy Development in China, pp. 165-166.
- 83/ NCNA, 1/11/80 (JPRS, China Report: Economic Affairs, 1/25/80, No. 75003, p. 18). See also CIA, Electric Power for China's Modernization: the Hydroelectric Option (Washington, D.C. CIA, 1980) p. 9.
- 84/ NCNA, 7/24/79 (FBIS, 7/26/79, No. 145, p. L12); NCNA, 8/23/79 (JPRS, China Report: Economic Affairs, 9/19/79, No. 74210, p. 106).
- 85/ CIA, The Hydroelectric Option, p. 9; NCNA, 7/24/79 (FBIS, 7/26/79, No. 145, p. L12). In 1979 and 1980 total small hydro capacity increased by 1.07 million kilowatts and 0.77 million kilowatts, respectively.

- 86/ A map depicting the annual distribution of solar radiation in China can be found in Dili Zhishi (Geographical Knowledge), 12/77, p. 27.
- 87/ Beijing Radio, 3/19/80 (JPRS, China Report: Economic Affairs, 4/7/80, No. 75453, pp. 65-66).
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- 98/ Ibid., p. 27; Simon, ed., International Solar Energy Society World Congress, p. 3, Beijing Radio, 3/19/80 (JPRS, China Report: Economic Affairs, 4/7/80, No. 75453, p. 66).
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Number 3: Sanitation and Disease: Health Aspects of Wastewater Management

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Witold Rybczynski,
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A comprehensive bibliography that describes alternative approaches to the collection, treatment, reuse, and disposal of wastes.

A joint World Bank/International Development Research Centre publication. 1978. Available from International Development Research Centre (IDRC), P.O. Box 8500, Ottawa K1G 3H9, Ontario (Canada).

Low-Cost Water Distribution— a Field Manual

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Provides nonengineers with the information necessary to design and implement simple water distribution systems for small communities.

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Technical and Economic Options

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World Bank Research in Water Supply and Sanitation— Summary of Selected Publications

A bibliography summarizing the papers in the Water Supply and Sanitation Series, as well as the World Bank studies in Water Supply and Sanitation published for the

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The Johns Hopkins University Press, 1980. 344 pages (including tables, maps, index).

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Argues the merits of relating the price of electricity to the marginal or incremental cost of supply and deals with interactions between pricing and investment decisions, income distribution, and distortions in the pricing system of the economy.

The Johns Hopkins University Press, 1977. 382 pages (including tables, maps, index).

LC 76-9031. ISBN 0-8018-1866-4, \$30.00 (£13.50) hardcover; ISBN 0-8018-1867-2, \$12.95 (£5.75) paperback.

French: L'économie de l'électricité: essais et études de cas. *Economica*, 1979.

ISBN 2-7178-0165-0, 58 francs.

Spanish: Electricidad y economía: ensayos y estudios de casos. *Editorial Tecnos*, 1979.

ISBN 84-309-0822-6, 710 pesetas.

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Mohan Munasinghe

World Bank Staff Working Paper No. 340. July 1979. 56 pages (including 2 appendixes, references).
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Village Water Supply: Economics and Policy in the Developing World

Robert J. Saunders and Jeremy J. Warford

Addresses the problem of potable water supply and waste disposal in rural areas of developing countries where the majority of the poor tend to be found. Emphasizes the economic, social, financial, and administrative issues that characterize village water supply and sanitation programs.

The Johns Hopkins University Press, 1976. 292 pages (including 4 appendixes, bibliography, index).

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