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Solar Energy in China

L'énergie solaire en Chine

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Solar Energy in China

Énergie solaire en Chine

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Solar Energy in China

I. The energy resources in China and the strategy for the future development

While the energy resources are the basis for the development of the national economy, the hope for the future energy resources lies in the solar energy. China, as a developing country, with 7 % of the world's arable land, has to support 22 % of the world's population. With the rapid growth of China's economy, especially during the last decade, after the adoption of the open door policy, China has solved the basic problem of food, clothing and housing for its 1. 1 billion people. China's GNP arises to rank the eighth in the world from the 40th before 1949. According to the data from the World Bank, the growth rate of GNP of China from 1980 to 1989 ranks the second among 119 countries in the world.

1. A brief outline of China's national economy during the recent years

China's reform and open door policy started from the reform of the economic system, specifically, from the adoption of contracted responsibility system in the countryside. Then the reform in cities, covering the fields of planning, finance, taxation, pricing, commerce and salary, with the aim to vitalize enterprises, brings a flourishing economy in China. The GNP of China in 1978 is 348 billion yuan, in 1991 it rises to 1. 9854 trillion yuan and in 1992 it aproaches the figure of 2. 4 trillion yuan (RMB). During the five years the average annual growth rate is 7. 9 % (see Table I -1 and Table I - 2).

2. The energy resources in China during recent years

Generally speaking, the economical development very much depends on the energy resources. With the development of the economy and the improvement of people's living standards, the demand for the energy resources increases rapidly. Tables I - 3 and I - 4 show the energy production and consumption in China from 1978 to 1990. Taking coal and oil, the two main types of energy resources, as examples, it is shown that the production of coal increases from 620 million tons in 1978, to 1. 1 billion tons in 1990, amounting to a 1. 7 fold increase, and that of oil increases 30 %, from 100 million tons in 1978, to 138 million tons in 1990. In the meantime, the total consumption of energy resources registers a 1. 7 fold increase, that is, from 571 million tons of equivalent coal in 1978, to 987 million tons in 1990.

In China, the renewable energy resources, or the solar energy in its general sense, see also a rapid growth, in spite of the fact that they account for merely a small percentage in the total energy resources. By the end of 1990, in China's countryside, 120 million households, that is, 55 % of the total households in the countryside, have replaced their cooking stoves with those which could make a more economical use of coal or firewood, and 15 million households have turned to gasified fuel, of which 33 % have made use of biogas. Mini-hydropower stations, total of 13 GW installed capacity, together with 106, 000 small wind power electric generators, have made electricity available to 80 % of farmers in China. 120,000 solar energy stoves, 450,000 square meters of passive solar energy houses and 1 million square meters of solar energy collectors are now in use in the countryside. In addition, the exploitation of geothermal and ocean energies has entered the application stage. A new enterprise of energy resources has taken shape in China.

The reform and open door policy has vitalized the economy in China's countryside, bringing about a rapid development of rural township enterprises. In the rural economy, the non-agricultural product increases its share in the total output value, from 31.4 % in 1978 to 53.2 % in 1988. In 1989, the total output value of the rural enterprises amounts to 753 billion yuan (RMB), a 15 fold increase with respect to the figure in 1978, which is equal to China's total industrial product in 1980. The export from rural township enterprises has earned more than 10 billion US dollars of foreign exchanges for China.

With the flourishing rural economy, the rural township enterprises have also absorbed a large number of rural surplus labour forces, which in turn increases the peasant's income and improves their living standards. This poses a heavy pressure on the supply of energy resources, resulting in a big increase of the energy consumption in the countryside, from 312.8 Mtce in 1979 to 504.1 Mtce in 1987. Taking the consumption of electricity as an example, it increases from 37,280 GWh in 1980, to 95,214 GWh in 1989, in which the consumption by the rural township enterprises accounts for a prominent part. From Table I - 8, it can be seen that the rural township enterprises consume only 6,960 GWh of electricity in 1980, and by 1989, the figure is increased to 55,336 GWh, a 7.9 fold increase.

In short, our reform and open door policy leads to a rapid growth of economy and a significant improvement of people's living standards, which in turn demands a consistent development of the energy resources, as the important material basis of the national economy. Without that, the economy will be hampered. Therefore, we have to study the strategy for the development of energy resources, in which the prediction of energy demands is an important part.

3. Prediction of energy demands in China

The prediction of energy demands is a special discipline, which concerns itself with the production per capita, population, economical growth, industrial structures, the technique of the exploitation of energy resources, the consumption of energy resources in agriculture and industry, the energy consumption for special products and the energy consumption in daily life by the inhabitants. The following is the prediction of population and economical growth, and is followed by the prediction of the total demands of the energy resources.

a. Prediction of Population

Table I - 6 shows the prediction from three different assumptions made by China's National Centre of Economical Information; Table I - 7 gives the prediction made by the World Bank. It can be seen that while the figures for 2000 are almost the same, the figure of the World Bank for 2050 is higher than that of China's National Centre of Economical Information. Accordingly, by 2000, the population of China will reach 1.25 billion, which amounts to an increase of 150 million in 10 years, as compared with the figure in 1990.

b. Economical growth

The GNP of China in 1980 is 433.6 billion yuan (RMB), which is equivalent to 291 billion US dollars, calculated with the exchange rate 1.49 at that time. In 1985, China's GNP is 833 billion yuan (in current price), which is equivalent to 471.8 billion US dollars, according to the comparable price in 1980. The corresponding GNP per capita is 465 US dollars, 6.0 times lower than the average level of the medium income countries, and 13.8 times lower than the lowest level (Spain) in the industrial countries.

According to the three stage strategy for the economical construction mapped out by the Chinese government, the GNP in 1980 is to be doubled in the first stage to guarantee people's basic need of food, clothing and housing; then in the second stage, that is, by the end of this century, the GNP will be redoubled, which will enable people to lead a fairly comfortable life; in the third stage, the modernization of China will be basically completed and the GNP per capita in China will reach the level of medium developed countries by the middle of the next century. Thus, the prediction for China's GNP per capita is as shown in Table I - 8.

c. Prediction of other factors

(1) Agriculture and its consumption of energy resources

—The arable land of China will go on decreasing, with the total sown area little changed. The level of agricultural mechanization will be greatly enhanced. As a result the energy consumption of agricultural machines will be increased by a big margin.
—The area irrigated by pumps will be further increased. As the result of rising of water head for irrigation, the energy consumption per acre for irrigation may be increased.

(2) Industry and its consumption of energy resources

—At present the added value of industry in China is higher than it should be, and the energy consumption per unit of product is large, which means a great potentiality for energy saving. It is predicted that the energy saving during 1985 to 2000 will be 4 %, and that during 2000 to 2050 will be about 1.5 %.

(3) Communications and transport and their consumption of energy resources

—Railway is as yet the main means for the communications and transport in China. The total amount of passengers and freight for transport will be increased in some degree. Highway will play a more important role. The number of private cars will be increased in some degree.
—As the result of the increase of speed, the consumption of energy resources per a rail-

way locomotive will increase, but on the other hand, because the internal combustion locomotives are giving way to electrical ones, the average energy consumption will decrease.

—Because the efficiency of the highway vehicles will be improved and the percentage of diesel engines to be used will be increased, the consumption of energy per vehicle on the highway will be reduced by a big margin.

(4) The consumption of energy resources by inhabitants

—The use of gas for cooking and heating will become much more popular among urban residents and the amount of hot water used in daily life will be significantly increased. The consumption of energy resources by inhabitants will be increased by a big margin, even with the improvement of the efficiency of energy utilization.

—With the improvement of people's living standards, the use of electric heating, air conditioning in summer and other electric appliances will be more extensive, which will result in a rising of the demand for electricity.

—The commercial energy supply to rural residents will increase, in which the share of new types of energy resources will increase and the energy from biomass will play an important role.

In short, the population of China will reach 1.25 billion and 1.5 billion, respectively, in 2000 and in 2050. The income per capita will be 1000 to 4000 US dollars. With that and other conditions, the prediction of the total demands for the energy resources in 2000 and in 2050 will be, respectively, 1.4 billion Mtce (as is planned) and 3.8 to 5.4 billion Mtce. (see Table I - 9)

4. The main features of the consumption of energy resources in China.

(1) Coal Is the main type of energy resources

In China, the coal accounts for about 70 % of total energy consumption. This fact will not change until 2000 or even within the next several decades. It is a special problem to be faced by the modernization drive in China. With coal as the main energy resource, we will have to handle such difficult problems as environment pollution, low efficiency, heavy transport burden and lack of high quality fuel, etc.

—Environment pollution

Among coal used as 75 % of China's energy resources, 80 % is used as fuel. In 1990, about 13.24 Mt of dust and smoke, 6.22 Mt of SO_2 were discharged into the air. The discharge amount of CO_2 in China ranks the fourth in the world (Table I - 10). In some cities, the acid rain started to bring about destruction of forest. While Chinese, of course, will be the first victim of the environment pollution, the whole world will also be suffered by its bad effect.

—Low efficiency

The coal being mainly used as fuel and with relatively backward techniques in the energy exploitation, the efficiency of the energy utilization in China is 10 % to 20 % lower than that in advanced industrial countries (Table I - 11).

—Heavy burden on transportation

The main resources of coal in China are in the West and North-West regions, and the areas that see a rapid economical growth are located along the coast and in the South-East and the Middle regions, where the energy resources are scarce and whose demands for coal heavily depend upon the transportation of coal from the North. According to statistics, 40 % of China's total freight volume is devoted to the transportation of coal, which poses a great pressure on transportation. In Shanxi province, China's coal production base with very good conditions for coal mining, the production quotas of coal has, for a long time, to be determined by the capacity of transportation, due to the difficulty in that respect.

—Lack of high quality fuel

In the developed countries, where the main energy resources are oil and gases, a set of ready-made techniques have already been developed, with which oil and natural gases can easily be transformed into other forms, can easily be transported and stored, and can easily be put into various uses. On the other hand, the transformation of coal is difficult, requires a big investment, no ready-made techniques for that purpose are available, and those techniques now in use are in much lower level as compared with the corresponding ones in the oil and gas industries. As yet, it is still a very difficult problem to turn coal into a high quality energy resource.

(2) The low energy consumption per head in daily life

The energy consumption by the inhabitants ranks the second in China's energy consumption and shares 25 % of the total energy consumption, following that by the industrial sector with a share of 60 %. The total consumption of energy resources in people's daily life sees a big increase during 1980 to 1985, with an annual growth rate of 8.6 %. Accounting for the growth of population, the energy consumption per head has increased at the annual rate of 7.4 % during that period. Table I - 12 shows the energy consumption by the inhabitants in their daily life. It can be seen that in 1985 the energy consumption per head per year was 154 kgce, in which the electricity consumption is 21 KWh. It is indeed a very low figure, as compared with that in developed countries. The electricity consumption is especially low, 30 times to 150 times lower than the figure in developed countries.

The reasons can be attributed to the following three facts:

—Low GDP per capita value

In 1985, China, with its GDP per capita (in the price for 1980) being 465 US Dollars, fell into the category of low income countries.

—80 % of China's population live in the countryside, where people's living standards are much lower than those in cities, while in developed countries, only 10 % of their population live in the countryside and the difference of people's living standards between cities and countryside is much smaller than that in China.

—In the countryside a large amount of energy consumed by rural residents is not in the form of commodity.

With the economical development and the improvement of people's living standards, the demands for energy, especially for high quality energy will increase by a big margin. It is of utmost importance for the development of the national economy and the social stability to guarantee and improve the supply of energy for people's daily use and to enact the relevant policies.

(3) High energy consumption per unit product

The energy consumption per unit product is an important index to measure a country's level in the energy utilization and the economical level in general. Take some products with high energy consumption as examples. For steel, the consumption of energy per unit product in 1990 is 1,62 Tce/ton of steel in China's key enterprises of steel production, which is, respectively, 50 %, 40 % and 28 % higher than the figures in Japan, in Germany and in France during the 1980's. For synthetic ammonia, there is a great difference between factories of different sizes with respect to the energy consumption per unit product in China. In 1990, in large factories, the figure is 1. 35 Tce and for medium and small sized factories, it is, respectively, 2. 23 Tce and 2. 37 Tce. It can be seen that for medium sized factories, the energy consumption level in China is 1. 26 to 1. 56 times as that in other countries. For small factories, we find an even wider difference. For cement, in China, the general energy consumption per ton of cement is 200 kg in 1990, which is about 60 % higher than the figure in Japan in 1980 (143 kg). As for other industrial products, the energy consumption per unit product in China is, generally speaking, much greater than that in developed countries.
The high energy consumption per unit product in China may be mainly attributed to the large number of medium and small sized factories (including rural township enterprises), whose product accounts for about 50 % of total industrial output in China in recent years. The adoption of reform and open door policy in China brings about an even greater growth of rural township enterprises, which, of course, have played a positive role in vitalizing the rural economy and in turn, helped the development of the national economy in general, absorbed a large amount of surplus labour, raised peasant's income and living standards. But, on the other hand, due to the limited scale of those enterprises, the level of technology and management is generally low, and, as a result, their products have relatively poor quality and the energy consumption per unit product is significantly higher than that of large enterprises. For example, in 1980, the steel produced by small steel plants accounts for 20 to 25 % of the total national product, but its energy consumption is 30 % higher that of large steel plants. The product of synthetic ammonia in China is 17. 16 million tons in 1985, of which 52 % are produced by small chemical fertilizer plants with the daily capacity of 30 to 100 tons, and 26 % are produced by large synthetic plants with capacity of 1000 tons. The average energy consumption of small plants is 1. 7 times as that of large plants. The bricks used in the construction industry in China are mainly produced by rural township enterprises, where backward brick kilns are operated with the energy consumption level one to two times higher than that in large modern brick factories.

Another factor is that, in China, a large amount of coal is used both as fuel and chemical raw material, where its efficiency of utilization is lower than that of oil and gas. Other factors, such as backward technology, low management level, also have their share in that respect.

(4) 85 % of China's Population Is in the Countryside

Of China's 1. 1 billion population, 0. 9 billion live in the countryside, which bears a dominant effect on China's economical development. In view of the energy consumption, the rural township enterprises and the rural residents play a significant role. As far as the present state of the energy consumption in China's rural area is concerned, before 1979 it was mainly used by rural residents in cooking, heating and lighting, and only a small part was used in production or by rural township enterprises. It was mainly in the form of crop's straws, firewood and animal dung, which accounts for 71. 3 % of the total energy consumption in the countryside and 85. 6 % of the total energy consumption by the rural residents in daily life. Table I - 14 shows the present state and the trend of the energy consumption in the rural area, from which it can be seen that:

a) The energy consumption in China's rural area increases from 313 Mtce in 1979 to 504 Mtce in 1987, a more than 1. 6 fold increase, and will be doubled and reach 673 Mtce in 2000.

b) While the energy consumption by rural township enterprises will continue to increase by the year 2000, the energy consumption in agriculture will be doubled or redoubled. The energy consumption in agriculture will sharply increase from 29. 9 Mtce in 1987 to 345. 5 Mtce in 2000, an 11. 5 fold increase.

c) While the commercial energy supply in China's rural area will increase before the year 2000, the absolute consumption of crop's straws and firewood will remain little changed, in which that used in people's daily life will account for the main part and it will also account for a significant percentage in the total energy consumption in the rural area. It demonstrates the fact that in China's rural area, due to the lack of energy resources, people will still depend upon the energy from biological materials. The growth of population and the lack of energy resources both will greatly affect the ecological environment. The cultivation of land, the building of houses, cooking and heating, the excessive cutting of trees, and the failure of crop's straws to be returned to land, all these lead to water loss and soil erosion of the land and the deterioration of its fertility. The most obvious example can be found in China's Loess Plateau region, where there used to be an area with dense forest, rich grasses, fertile lands and delightful climate and which used to be the cradle of China's civilization for many dynasties. According to historical records, during the Qin and Han dynasties (221 B. C. to 220 A. D.), the trees grew continually in several provinces in the Yellow River Valley, 50 % of the land in China's Loess Plateau region was covered with forest; the Dinxi area, that is now famous for its aridity, used to be a flourishing forest before even the Qing dynasty (1644 — 1911 A. D.). During more than 1000 years, the ecological environment has been destroyed by man's activities, and today's Loess Plateau is a region where forest can be found far and few between but many barren hills and mountains without even a grass growing become a common occurrence. The dry climate and frequent mountain torrents make that region the poorest in China, where the lack of energy resources becomes a very serious problem.

In short, the two key problems concerning China's energy resources are: 1. the serious environmental pollution, low efficiency of utilization and difficulty in transportation due to the fact that the coal is used as the main energy resource; 2. the destruction of ecological environment due to the fact that 85 % of China's population live in the rural area where the energy from biological materials are used as the main energy resources.

5. The development strategy for China's main energy resources

In order to have a consistent development of the energy resources in accordance with the economy and the society, it is important to study and establish a strategy for the development of energy resources. This strategy has to be based on a country's actual conditions, to aim at the real problems facing the country and to be realizable in the end.

(1) Put the emphasis both on development and saving, and put saving in a prominent position at present.

China's Premier Li Peng pointed out in his inscription for "Energy Saving Week" in Shanghai that it is necessary to adhere to the policy of putting the emphasis both on development and saving, and every trade and every enterprise must put the energy saving in a prominent position. Here he has thus reiterated that policy.

Generally, people tend to ignore the energy saving, while putting their emphasis on the development of energy resources. Considering China's actual conditions that the level of energy resources per head is not high, the techniques and management on the energy utilization are backward, the efficiency of energy utilization is low due to the fact that in China coal is used as the main energy resource, and the level of energy consumption per unit product is high, China has made a great effort on the energy saving during the past decade and will have to go on paying great attention to that issue for a long time ahead. There is, indeed, a great potential of energy saving in China. Table I - 15 shows a comparison of the energy consumption per unit product between some major high energy consuming products. It can be seen that during five years the figures see a general drop, and the level of energy utilization is on a rise as a whole.

The saving of energy will lead to the saving of raw materials, the saving of water and also a integrated use of resources in general, which is regarded as indirect saving of energy and has a good economical and social effect.

Putting emphasis both on development and saving is China's long term policy concerning the energy resources, and in that respect the relevant departments of the Chinese government have set up special institutions in charge of the work of energy saving and the integrated use of national resources, and have enacted relevant laws or regulations on energy saving, such as "The Provisional Regulations on Management of Energy Resources", "The Provisional Regulations on Some Problems on the Integrated Use of Resources" and "On the Development of Energy Resources in Rural Areas".

In order to implement the policy of putting the emphasis both on development and saving of energy resources, the Chinese government has adopted a series of measures including the activities of energy saving week, supporting research work on energy saving, allowing taxes exemption for energy saving products and holding special meetings every year by the State Council.

(2)The strategy for the development of energy resources, with Electrical Energy as the Centre

The level of utilization of electrical energy is an important measure of the modernization of a country. China's primary energy transform ratio is lower than the world average value, the shortage of the of electricity supply for a long time becomes an important factor that affects the growth of China's national economy. The adoption of the strategy for the development of energy resources with the electrical energy as the centre can help to find a way out for the development of China's national economy.

With electricity as a forerunner, the growth rate of the electrical energy keeps higher than that of primary energy resources. According to statistics, the world's electrical power growth rate is always higher than that of the total energy consumption. Table I - 16 gives data for the years 1960 to 1985.

China has, for a long time, been in a state of a serious shortage of electrical power, therefore, the growth trend is more than obvious. China's elastic coefficient of the electrical power is less than 1, which means that its growth rate is less than that of the national economy. That is abnormal and hampers the economical development.

According to statistics, the gross domestic product of OECD countries increases nearly 32 % during 1973 to 1985, while the amount of electrical power consumption increases 41 % during the same period. Therefore, it can be seen that, in spite of the different economical development and different energy resource and industrial structures of different countries, the increase of the share of electrical power consumption in the final total energy consumption, which means to replace the use of primary energy resources with that of electrical power, is always beneficial both in improving the economical effect or in raising the efficiency in the energy utilization.

The development of electrical power needs more coal consumption and it is the best way to use the poor quality coal. According to China's energy structure, with coal as the main energy resource, to turn more coal into electricity is beneficial to raising efficiency, reducing pollution and overcoming the difficulty in transportation.

The end use of energy resources consists of three main parts: lighting, power and heating. In the first two parts, the electricity is obviously superiors, as for heating, with the development of the pattern of joint production of heat and electricity, the total efficiency is also higher than that of the direct use of primary energy resources.

(3) The strategy: planning in accordance with actual conditions, using several energy resources to cover different needs, making an integrated use of resources, paying attention to efficiency, actively seeking for new energy resources.

With 0.9 billion people living in the countryside, with the rapid development of the rural economy and with the general improvement of peasant's living standards including the emergence of many households with more than 10,000 yuan of annual income, the demands for the energy resources see a great increase in that region. Although the commercial energy resources are increasing annually, the needs from rural township enterprises and the agricultural production can only be partly met, and the local natural energy resources, such as energy from biomass (crop's straws, firewood and animal dung), wind power, solar energy, mini-hydropower stations and small coal kilns, have still to be used for people's daily life. So the above mentioned strategy, which is based on the experience summed up during many years of energy resource construction in China, is proposed.

—Planning in accordance with actual conditions.

That is to say that in different regions there are different energy resources and different conditions for their uses. Even in different towns or villages of a same region, the conditions may be different. The problems of rural energy resources can not be solved in just one mode. One must handle scattered natural resources, which are not like the use of petroleum, natural gases or electricity.

—Using several energy resources to cover different needs

It is due to the fact that the energy density of the renewable energy resources is usually small, their use very much depends on time and seasons, and different techniques have to be adopted according to different uses, in order to have a desired effect. For example, in order to compliment the effects of different energies, solar energy and wind power energy, or, geothermal energy and biomass energy may be used at the same time. A lot of experiments have been conducted by various regions to test the usefulness of those complimentary uses of energy resources. Some of them have turned out to have good economical, social and ecological effects after repeated experiments and have proved to be worth to put into wide applications.

—Making an integrated use of resources, paying attention to efficiency

It concerns with the low economic values of renewable energy resources. With the present technology, the renewable energy resources can not be competed with the conventional ones, as far as their effect is concerned. The investment needed for developing biogas, wind power, solar energy and geothermal energy to generate electricity far surpasses that of conventional ones with respect to every KW installed capacity. That has limited the applications of those energy resources. Besides, with renewable energy resources, it is very difficult to come to a desired scale due to their low energy density. But if we make an integrated use of them, taking a comprehensive consideration of energy resources, economy and ecology, some appropriate techniques can be found on many conditions, especially, in China's vast countryside, to solve energy problems, to improve the ecological environment and to have a good economical effect at the same time.

During China's Sixth Five-Year Plan, in some demonstrative villages, experiments were conducted on the integrated use of energy resources. During the Seventh Five-Year Plan, experiments were extended to 12 demonstrative counties and conducted by research institutions and the relevant industrial units organized by the state. After 5 year's experiments, good results were obtained. The tension of the energy supply in those counties have been eased up, the ecological environment there has been improved and the output value from agriculture and sideline occupations is significantly increased. Therefore, the strategy of planning in accordance with actual conditions, using several energy resources to cover different needs, making an integrated use of resources, and paying attention to efficiency is the summing-up of China's experience in the use of renewable energy resources and is also the guideline for their utilization and further development.

Table I — 1 The output values of China's agriculture in 1978 and 1992

Main Item	1978	1992	Increase (%)
Total Agricultural Product (in billion yuan)	139.7	1,396.5 *	
Grains (in Mt)	304.77	442.58	45
oil (in Mt)	5.218	16.4	214
Cotton (in Mt)	2.167	4.528	110

* According to the price of that year
Information Source: China Yearbook of Statistics

Table I — 2 The output values of China's industries in 1978 and 1992

Main Item	1978	1992	Increase (%)
Total Industrial Product (in billion yuan)	42.37	383.54 *	
Total Energy Production (in Mt) (equivalent standard fuel)	0.628	1.067	70
Coal (in billion KWh)	0.618	1.11	80
Electricity (Mt)	256.6	747	190
Steel (in Mt)	31.78	80	150
Cement (in Mt)	65.24	304	370

* According to the price of that year
Information Source: China Yearbook of Statistics

Table I — 3 The China's production of energy resources during 1978 to 1990

Year	Coal (Mt)	Crude Oil (Mt)	Natural Gases (Trillion M^3)	Electricity	
				Total TWh	Hydropower TWh
1978	618.02	104.053	13.73	256.6	44.6
1979	635.0	106.15	14.51	282.0	50.1
1980	620.0	105.95	14.27	300.6	58.2
1981	622.0	101.22	12.74	309.3	65.5
1982	666.3	102.12	11.93	327.7	74.4
1983	714.5	106.07	12.21	351.4	86.4
1984	872.3	124.89	12.93	410.7	92.4
1986	394.0	130.69	13.76	449.5	94.5
1987	928.1	134.70	13.87	497.3	100.2
1988	979.9	137.05	13.91	545.2	100.1
1989	1054.2	137.65	14.493	584.7	118.4
1990	1079.9	138.31	15.30	621.3	126.4
1991	1080.0	139.50	15.20	670	
1992	1100	140.50	15.70	700	

Table I — 4 China's energy consumption during 1978 to 1990

Year	Total Energy Consumption Mtce	Coal %	Petroleum %	Natural Gas %	Hydropower %
1978	571.44	70.67	22.73	3.20	3.40
1979	585.88	71.31	21.79	3.30	3.60
1980	602.76	72.15	20.76	3.10	3.99
1981	594.47	72.74	19.96	2.79	4.51
1982	620.67	73.67	18.94	2.56	4.86
1983	660.40	74.16	18.14	2.44	5.26
1984	709.04	75.27	17.45	2.37	5.26
1985	766.82	75.81	17.10	2.24	4.85
1986	808.50	75.83	17.20	2.26	4.71
1987	806.32	76.21	17.02	2.13	4.64
1988	929.97	76.17	17.05	2.06	4.72
1989	969.97	75.80	17.20	2.10	4.90
1990	987.03	76.20	16.60	2.10	5.10

Note: The Rate for Equivalent Coal: Coal 0.714 t/t, Petroleum 1.43 t/t, Natural Gases 1.33 t/1000 m^3, Hydropower is calculated as the coal consumption for thermal power electricity in that year.

Table I — 5 electricity consumption in China's countryside and prediction

Year	Total	Irrigation	Agricultural or Sideline Production	Rural Township Enterprises	Lighting	Others Production
1980	37,280	14,030	8,450	6,960	6,290	1,540
1981	42,620	15,340	9,840	8,330	7,510	2,100
1982	45,710	15,340	10,330	10,040	8,010	1,980
1983	49,630	14,700	10,800	12,330	9,150	2,630
1984	53,500	14,510	11,240	15,160	10,090	2,400
1985	60,300	13,290	12,220	19,540	12,530	2,720
1989	96,214	18,895	*	55,336	17,103	380
1995	145,000	17,500	*	102,000	26,000	——
2100	209,000	19,000	*	163,000	37,000	——

* Including those by rural township enterprises

Table I — 6 China's population and predictions

Year	With Assumption 1		With Assumption 2		With Assumption 3	
	Average Woman Fertility	Total Population (billion)	Average Woman Fertility	Total Population (billion)	Average Woman Fertility	Total Population (billion)
1990	1.9	1.115	2.04	1.119	2.20	1.126
1996	1.8	1.183	1.95	1.193	2.10	1.208
2000	1.7	1.239	1.85	1.331	2.00	1.370
2010	1.7	1.335	1.85	1.416	2.00	1.505
2050	1.7	1.199	1.85	1.332	2.00	1.481

Information source: National Centre of Economical Information of China

Table I — 7 Prediction of China's population made by the World Bank

Year	Population (billion)
1985	1.046
2000	1.256
2015	1.396
2030	1.512
2050	1.550

Table I — 8 Prediction of China's GNP per capita (in USD)

Year	2000	2020	2030	2050
High Estimation	800—1000	2,500	3,350	6,000
Low Estimation	800—1000	1,900	2,450	4,000

Table I — 9 Prediction of China's total energy demands

Year	1985 (actual)	2000 (as planned)	2020 (predicted)	2050 (predicted)
Population (billion)	1.045	1.25	1.38	1.50
GNP per capita (USD, 1980)	465	1,100	1,900—2,500	4,000—6,000
GNP (million USD, 1980)	48.0	125.0	262—345	600—900
Total Energy Demands (Mtce)	773	140	24—30	38—54
Energy Consumption per capita (Tce)	0.74	1.12	1.74—2.17	2.53—3.63
Energy Consumption per unit output value (Kgce/USD)	1.59	1.12	0.92	0.62
Average Energy Saving Rate (% /year)	4.0 (1980—1987)	3.3 (1985—2000)	1.0 (2000—2020)	1.0 (2020—2050)
Elastic Coefficient of Energy Resources	0.53 (1980—1987)	0.61 (1985—2000)	0.72 (2000—2020)	0.61 (2020—2050)

Table I — 10 The first ten countries in the discharge amount of greenhouse gases (1987)

Units: CO_2 equivalent heat, Mt coal

	CO_2	CH_4	CFC_3	Total	Percentage
1. The United States	100	130	350	1000	17.6
2. The Soviet Union	450	60	180	690	12.0
3. Brazil	560	28	16	610	10.5
4. China	260	90	32	380	6.6
5. India	130	98	0.7	230	3.9
6. Japan	110	12	100	220	3.9
7. Federal Germany	79	8	75	160	2.8
8. The United Kingdom	69	14	71	150	2.7
9. Indonesia	110	19	9.5	140	2.4
10. France	41	13	0.9	120	2.4

Table I — 11 A comparison of the efficiency of common industrial equipments between China and industrial countries

Equipment	Energy Utilization Efficiency	
	China	Industrial Countries
Industrial Furnace	50% — 60%	> 80%
Pump	56% — 80%	67% — 85%
Air—Blower	65% — 80%	74% — 88%
Diesel Engine (Medium, Small)	0. 19 — 0. 2 kg/HP. Hour	0. 16 — 0. 18

Information Source: Collected Data by Nuclear Energy Institute, Tsinghua University

Table I — 12 China's energy consumption in people's daily life

Year	1980	1981	1982	1983	1984	1985
1. Total Energy Consumption in People's Daily Life (in Mtce)	106. 9	113. 56	123. 62	130. 49	143. 54	161. 42
2. Its Percentage Share in China's Total End Energy Consumption	21. 7	23. 3	24. 1	24. 1	2. 47	25. 5
3. Energy Consumption Per Capita (kgce/person. year)	108	114	123	127	139	154
4. Electricity Consumption Per Capita (KWh/head. year)	10. 7	11. 8	11. 9	13. 4	15. 4	21. 2

Note:

1. The part shared by electricity is calculated also in coal equivalent.
2. Information Source: China's Annual Energy Statistics——1986.

Table I — 13 Energy consumption in people's daily life in industrial countries

Country	Year	Energy Consumption per capita kgce	Electricity Consumption per capita kwh/head. year	GDP per Capita (USD (1980 price) /head. year
Australia	1980	1,015	1,972	9,888
	1985	1,085	2,160	10,696
Canada	1980	2,637	3,524	10,934
	1985	2,659	4,087	11,768
France	1980	756	1,142	12,164
	1985	941	1,555	12,560
Federal Germany	1980	1,257	1,389	13,215
	1985	1,625	1,591	14,199
Italy	1980	695	671	7,010
	1985	638	779	7,249
Japan	1980	605	994	9,069
	1985	695	1,185	10,607
The United Kingdom	1980	1,386	1,529	9,284
	1985	1,452	1,558	10,348
The United States	1980	2,337	3,150	11,804
	1985	2,261	3,306	12,677

Information Source: From Energy Statistics 1970—1985 by OECD

Table I - 14 China's Energy Consumption in Rural Area and Prediction

Unit: Mtce

Energy Kind	1979				1987				2000 (predicted)			
	Total	Agricu-lture	Rural Industry	Daily Use	Total	Agricu-lture	Rural Industry	Daily Use	Total	Agricu-lture	Rural Industry	Daily Use
Crop's Straws	113.69			113.60	130.32			130.32	118.76			118.76
Animal Dung	6.32			6.32	3.24			3.24	6.23(1)			6.23
Firewood	103.77			103.77	132.63			132.63	114.29			114.29
Electricity(2)	16.58	6.89	6.59	3.10	30.03	6.38	18.67	4.98	70.87-78.02	7.44-8.42	47.66-53.84	15.76
Oil	14.27	12.76		1.51	24.64	5.82	16.93	1.89	35.19-39.27	5.83-6.48	28.75-32.20	0.61
Coal	58.15		25.58	32.58	183.20	17.73	105.89	59.58	287.54-315.53	17.59-19.67	198.52-224.43	71.43
Sum	312.78	19.65	32.16	260.97	504.06	29.93	141.49	332.64	911.52-884.00	308.6-345.50	274.94-310.47	327.98

Note: 1) Including that used for generating biogas

2) According to the rate 400 gce/kwh

Information Source: <New Energy Resources and the Use in Countryside> by Department of Planning, Ministry of Energy Resources

Table I — 15 Energy consumption per unit product and energy saving rate during Seventh Five—Year Plan

Product	Energy Consumption per Unit Product (Tce)		Energy Saving Rate (%)
	1985	1990	
Steel (tons)	1.75	1.62	7.43
Nitrogenous Fertilizer (Large Plants)	1.38	1.35	2.17
Plate Glass	30.76kg	29.1kg	5.4
Cement (tons)	205.1kg	200kg	2.49
Electrolyzed Aluminum (tons)	15,047KWh	14,555KWh	3.27

Table I — 16 World consumption of electricity and energy resources

Year	1960	1970	1980	1982	1985
Consumption of Primary	4,120	6,440	8,540	8,400	10,570
Energy Resources Average Annual Increase Rate (%)	——	4.57	2.86	−0.05	7.96
Consumption of Electricity (Trillion KWh)	2.35	5.05	8.32	8.64	9.27
Average Annual Increase Rate (%)	——	7.95	5.12	1.90	3.50

Ⅱ. The exploitation and application of renewable energy resources in China in the last twenty years

1. Introduction

China is a developing country with large population and was lack of industry foundation before 1949. Since then, she has already established her independent industry systems of coal, petroleum as well as electric power, and their annual outputs had reached 1.10 thousand million tons of coal, 1.40 hundred million tons of petroleum, 15.7 thousand million cubic meters of natural gas and 700 thousand million KWh of electric energy generation at the end of 1992. However the demand for energy still far exeeds its supply owing to the rapid development in national economy caused by the policy of reforming and opening to the outside world in the last decade. The energy shortage is even more serious in rural region, whose population is about 85 % of the total, for it always takes the firewood as its main fuel. Now its energy consumption increases rapidly, particularly, the demand for electric power becomes far more urgent owing to the development of diversification of town snd township enterprises, and also owing to the significant increasing of energy consumption for daily life use. Since the state annual production increasing in conventional energy source is even difficult to meet the increasing demands for energy consumption cased by the industrial and city uses, the problem of energy shortage in rural region had to be alleviated by the local government by taking corresponding measures that are in line with its local conditions such as building small scale coalpits, hydroelectric power stations and wind-power stations.

As a consequence, China is suffering serious ecological and environmental problems. Though the Chinese government has been encouraging afforestation, the forest still often suffers felling. In the past fifty years, fertile farm-lands or grasslands of about 0.5 million square kilometers have become sandy land or desert. Nowadays, the annual straw yield of crops in the rural area of China is about 5 hundred million tons, while its least amount of demand from forage, industrial raw material and fuel is about 7 hundred million tons each year. If the first two demands enjoy the first priority in distribution, then the fuel shortage in countryside is quite serious. Average speaking, there are about 80 million peasant families are short of fuel for 50 days per year.

Facing so serious a problem, the chinese government started, in seventies, to pay attention to exploit renewable as well as new energy resources and has taken a series of supporting and encouraging policies to solve it. Arrangement was first made in the research of science and technology as well as its popularization through demonstration. Since the Sixth Five-Year Plan (1981—1985), the research and development on new and renewable energy resources have been brought into the scope of the national project on solving key problems and difficulties in science and technology, and the central government has allocated funds for it regularly every year. In the period of the Eighth Five-Year Plan (being executed from 1991 to 1995), special fund was and still will be allocated to support such kinds of research and development, and in the meantime, the government also encouraged and promoted the extensive international exchange and cooperation and persisted in introducing the necessary advanced techniques and equipments.

In the past twenty years, there was great development in exploiting new and renewable energy resources. More than twenty specialized institutes or departments have been established in this field, besides, the research works in this direction were also supported to carry out in many universities and enterprises. Taking as example the Chinese Academy of Sciences, there have been fourteen specialized institutes and departments engaged in this field. There have been about altogether 3000 professional engineers and technicians working in this field within China, besides, the local governments also have established hundreds of factories to produce equipment such as solar collectors, solar cells and wind-powered generators. On this basis, several national technique-exploiting centers as well as research and trainning centers have been established under the cooperative effort of both the local governments and the corresponding central ministries, such as Chinese Wind Energy Technique-Exploiting Center, Chinese Biomass Energy Technique-exploiting Center, Chinese Photoelectric Technique-Exploiting Center, Small-Scale Hydroelectric Project Research and Trainning Center of Asian-Pacific Region, Chinese Energy Research and Trinning Center of Rural Region, Chengdu Marsh Gas Research and Trainning Center and Tianjin Geothermal Research and Tiainning Center etc..

In the same time, China has carried out 23 items within the field of new and renewable energy resources in collaboration with UN, European Community, Italy, The Federal Republic of Germany, Belgium, Great Britain, Denmark, Holland and Japan etc.. In these cooperations, Chinese government has put into a great deal of labour, material and financial resources, and in the meantime a lot of equipments and techniques have been received from foreign countries. All of these have been making an active effect in promoting the development of China in this field, and enhancing the friendship as well as mutual understanding among the peoples all over the world.

Now these established centers have provided services not only for China but also for other countries all over the world. We warmly welcome the foreign experts come to China and make their contribution in cultivating technical personels for the developing countries. China has already carried out some regional activities under the support of UN, and got high opinion from the participants. We will continue to do our part, to extend service items and to enhance the international technique exchange, in doing so, we sincerely hope the suuport from the international society. Recently, we also have had more contact with Soviet Union and East European countries in the field of new energy resources. The general situation of new and renewable energy resources in China is as follows (by the end of 1992) according to incomplete statistics:

Table Ⅱ—a

Item	Amount	Rmarks
methane-generating pits for peasant household	4. 6 million sets	
small scale hydroelectric generating capacity	12. 4 million KW	production 34. 3 thousand million KWh
small scale wind generator groups	125 thousand sets	total capacity 15 thousand KW (including medium-scale wind generator group)
wind-powered water lifting machines	2. 0 thousand sets	total power 2. 11 thousand KW
geothermal water lifting machine	20 thousand KW	
directct use of low temperature geothermal energy	380 thousand KW	(thermal power)
tidal electric station	8. 3 thousand KW	
solar hot water heater	1. 8 million square meters	
solar house (passive)	1. 185 million square meters	
solar greenhouse (agriculture use)	1. 09 million hectares	
solar stoves	150 thousand sets	
solar drying	1. 314 thousand square meters	
solar cell	3. 1 MW	

Recently, we are exploiting a varieties of new techniques such as gasification oven for biological materials, alcohol fuel made from Chinese sorghum, wind assisting sail and wave activated power generation etc..

The following research works have been already started, they are: amorphous silicon solar cells, making diesel oil from biological materials, city garbage disposal, wind-induced heating, new techniques for hydrogen production and storage etc. .

The general policy of Chinese Government on exploiting new and renewable energy resources, in short, is: suiting measures to local conditions, realizing mutual complement of various energy sources, making comprehensine utilization of energy and striving for efficiency. At the level of central government we give play to the cooperative effect of various government departments, to support the key research and development in this field, as well as to promote international exchange and cooperation. At the level of local governments, we pay attention to tests, demonstrations, setting up factories and maintenance station as well as formulating some financially preferential policies in the local regions.

Since the problem of energy shortage in china couldn' t be solved with short period, the way, the central government takes to deal with it, is to increase the production of conventional energy sources on the one hand, and on the other hand to take various energy saving measures as well as to utilize the new and renewable energy resources as more as possible. Since the energy supply in China is fundamentally self-sufficient, at this moment, the fluctuation in petroleum price in the international market does not exert significant effect on the development of new and renewable energy resources. Chinese population is about twenty percent of the total in the world. Though the Chinese Government has taken an unyielding policy on family planning, its population base is quite large, and the absolute increase in its population is an unavoidable trouble and will inevitably affect the future of human race. Suffering the common worldwide difficult problems-population, energy resouces and environment, China is also confronted with the transition of proportion of energy sources, and with the paticipation of worldwide energy cycle. Hence China supports the corresponding proposals of UN, firmly expliots and develops new and renewable energy resources, and sincerely hopes that the Nairobi Programme of Action will be carried out better. In short, China is willing to do his part with the peoples all over the world for the realization of peace, progress and economy prosperity.

2. Solar energy

2. 1 Solar energy resources

China is situated in the east of Eurasia within the Northern Hemisphere with wide territory, and is plenty of solar energy resources. Owing to the difference in latitude, topography and climate conditions, the distribution of solar energy resources in China also differs significantly. The annual output of solar radiation in different place of China varies from 3. 3 milliom to 8. 4 million Kilo-Joule per square meter, and the average aunual output is about 5. 9 million Kilo-Joule per square meter. The distribution of solar energy resources in different regions of China is shown in Table 1. The regions of type Ⅰ, Ⅱ or Ⅲ are plenty of solar energy resources, its area is greater than 2/3 of the totol area, and the type Ⅳ or Ⅴ are regions of average or inplenty solar energy resources.

The distribution of solar energy resources in China is shown in Fig. Ⅱ-1.

Table II —b The classification and distribution of solar energy resources in China

classification of regions	accumulated radiation hours per year	annual total amount of solar radiation (large calorie per square centimeters)	region (the place names here are all the names of provinces)
I	3200—3300	160—240	north part of Ningxia and Gansu, southeast part of Xinjiang, west part of Qinghai and Tibet.
II	3000—3200	140—160	north part of Hebei and Shanxi; south part of Nei Monggol and Ningxia, middle part of Gansu, east part of Qinghai, southeast part of Tibet, and south part of Xinjiang
III	2200—3000	120—140	southeast part of Shandong, Henen and Hebei; south part of Shanxi; north part of Xinjiang and Shaanxi; Liaoning, Yunnan and Jilin; southeast part of Gansu; south part of Guangdong and Fujian; Beijing.
IV	1400—2200	80—120	the north of Jiangsu, Anhui, Hunan, Jiangxi, Zhejiang, Guangxi and Guangdong; the south of Shaanxi; Heilongjiang.
V	1000—140	50—80	Sichuan, Guizhou

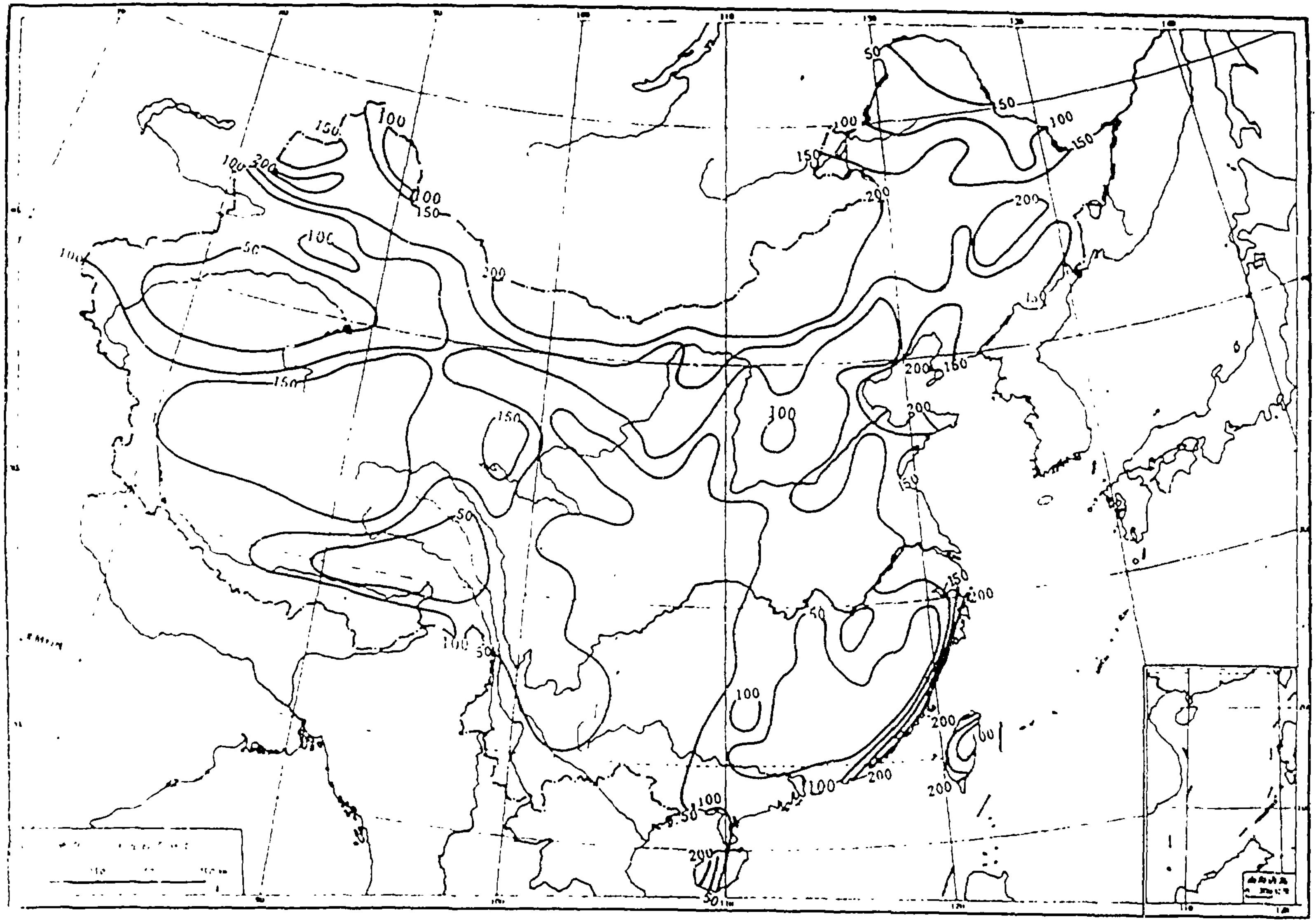


Fig.Ⅱ-1 The distribution of solar energy resources in China unit: Kcal/cm^2.yr.

2. 2 Brief introduction

China is one of the earliest countries in the world that make use of solar energy. According to the records in ancient books, even as early as three thousand years ago, our ancestors were able to make fire by focusing sun light. This is a kind of primitive appliance for solar energy utilization, and it occupies an important position in the history of worldwide inventions. The wind power is another form of solar energy, it has been utilized for quite a long time in human history, and in China, sail driven by wind has already had a long history of about there thousand years.

Owing to the yoke of feudal system, the development of science and technology in China was restrained for quite a long time before 1949. Since then, the exploitation and utilization of solar energy have made rapid progress. Along with the change of worldwide situation in energy resources, more and more people pay attention to the utilization of new and renewable energy resources. In 1973, the first "World Solar Summit" was held in Paris and its main theme is "let the solar energy resources serve the human race ". In 1974, the Chinese Premier Zhou Enlai advocated to the whole nation the exploitation and utilization of solar resources, then in the same year in Shanghai and next year in Anyang of Henan province, two national conferences for exchanging experiences on utilization of solar resources were held. After that, a series of specialized research institutions and equipment producing factories in this field were established one after another, and the international exchange and cooperation also become more frequently. In order to promote the development of solar resources utilization in China the State Council Sponsored itself in Xi'an the Second National Conference For Exchanging Experiences and Illustrating Achievements in this field in september 1979. In the meantime, the "National Science and Technology Development Plan for Utilization of Solar Resources" was drafted, and the "Chinese Solar Energy Society" was established. Thereafter, a new era started in the utilization of solar energy resources in China. In the past twenty years, especially after 1980, the utilization of varios solar energy resources had a certain extent of popularization and application in our country, and this in turn alleviated more or less the pressure caused by the shortage in conventional energy resources and by the destruction in ecological evironment. Nowaday, the various ways for solar erergy utilization have been being a common sense for many people in China.

2. 3 Technology for Photovoltaic electric power generation.

a. The research and development on photovoltaic technique

China started its study on solar cells in 1958, nowaday, there are about 38 Universities and institutions worked in the field of photovotaic technique. China as a developing country, the most of its research funds has to be invested in the technical items that are recognized to have good prospects in production. Since there is certain basis in semiconductor industry, China owns some favorable conditions in both equipments and materials to develop the research on photovoltaic techniques. On the other hand, taking into account the significance of photovoltaic technique from a strategic viewpoint, the vast area of countryside and electricityless region in China, as well as the clear objective of the research in the near future, as the largest developing country in the world, the Chinese Government gives some preference for this photovotaic technique in investment. The money invested by the Chinese Government in the photovoltaic field in the latest four Five-Year-Plans is listed in Table Ⅱ-1.

Table Ⅱ-1 the research and development funds supported by the Chinese Government in the research of photovoltaic techniques (with unit of million yuans of Renminbi)

the fifth Five-Year Plan (1976-1980)	central government: 7.0 (including 1.5 for popularization) local governments as well as ministries and commissions: 2.0
the sixth Five-Year Plan (1981-1985)	central government: 7.0 (including 2.5 for popularization) local governments as well as ministries and commissions: 2.0
the seventh Five-Year Plan (1986-1990)	central government: 18.0 (including 2.0 for popularization) local governments as well as ministries and commissions: 3.0
the eighth Five-Year Plan (1991-1995)	central government: 20.0 (including 2.0 for popularization) local governments as well as ministries and commissions: 19.01 (including 17.0 for popularization)
total	central government: 62.0 local governments as well as ministries and commissions: 28.0

The following items are within the field in which Chinese researchers now play an active part. They are: practical solar cells of monocrystalline silicon, high efficiency monocrystalline silicon cells, solar cells of polycrytalline silicon, solar cells of amorphous silicon, GaAs solar cells, monocrystalline silicon cells and the systems made of them for space applications, CuInSe and CdTe chemical compound solar cells, silicon solar cell system of low concentration, the growth of silicon ribbon and the applications of photovoltaic systems such as water pump, inverter, control system, illumination system, etc.. Besides, there are some research works that aim at making all of the key materials used in cells to be Chinese built. The highest efficiencies that could be reached by different types of solar cells are listed in Table Ⅱ-2. Other research works that have been carried out for a long time include: monocrystalline silicon solar cells with MIS configuration; ion implantation for manufacturing P-N junction and for purification of polycrystalline silicon cells.

Table Ⅱ-2 the highest efficiencies of different solar cells realized in laboratory

Type	Maximum efficiency (%)	
monocrystalline silicon cell	20.4 14	2×2 Φ10(practical type)
GaAs cell	20.1	1×1
Polycrstalline	13.1	2×2
silicon cell	12.0	10×10
Concentrator silicon cell	17.0	2×2
Cds/CuXS cell	12.0	several square cm
$CuInSe_2$ cell	8.0	1×1
CdTe cell	5.8	3 square millimeter
Amorphous silicon cell	11.2 (unijunction)	several square millimeter
	11.4 (bijunction)	several square millimeter
	8.55	10×10
	7.88	20×20
	6.17	30×30

China started to produce crystal silicon cells in 1985 by vacuum-coated electrode with antireflection, now the technology has been improved to make electrode by silk-screen printing Ag and Al thick liquids which is of high productivity, and spraying Tiox anti-reflection coating. In addition, both Ag and Al thick liquids are made in China. The area of monocrystalline-silicon cell has reached 10 cm×10 cm. Besides, a lot of new technology have been developed by ourself and popularized to some factories, such as: plasma itching cell's periphery, laser cutting silicon slice, and laminate molding packaging technology for solar cells, and in the meantime, some of the foreign advanced technology on producing monocrystalline silicon cell also have been imported for factories.

In the field of polycrystalline silicon cell, China has developed two kinds of ingot casting technology: unidirectional solidification and casting method. The silicon ingots of 2 kilogram level were produced by the latter method, only for the sake of lacking funds we stoped to develop unidirectional solidification methed. With this methed, square silicon ingots of 15 Kg in weight and 220 mm×140 mm in size have been produced, and the crucible for melting it can be used repeatedly. Besides, this methed also has the advantages of less investment in equipments, stable technology, lower cost and particularly suitable for the application in developing countries. In short, this method has its own features in technique and is not completely similar to the mithod adopted by many other countries in the world. Up to now, two preproductive lines of polycrystalline silicon solar cells have been built, and the productive capacity of one of them has reached 100 KW/

year.

Another important research is to make much of the key materials used in making solar cells being Chinese built, such as the packaging materials EVA and PVF composite film used for solar cell module, the Ag and Al thick liquids for silk screen printing, and now both of them do can meet the domestic demands for large batch process.

China invested more funds on the development of amorphous silicon solar cells in 1985-1990, and built up a rather integrated, medium-sized preproductive line (with cell size of 30 cm×30 cm). All of the equipments used in this line are made in China. Nowaday, our main research object is P-i-n single junction cells, and the efficiency of amorphous silicon cells with size of 30 cm×30 cm reaches 5-6 %. The decay rate (in one year) of cells with high efficiency is 15～20 %, then a relatively steady state in efficiency will be reached. In addition, there is another productive line of amorphous silicon of area 30 cm ×30 cm imported from American Chronal Corporation and owned by Harbin-Chronal Chinese-American Joint Venture Corporation.

The area of monocrystalline silicon solar cells for space application is of 2 cm×4 cm, and its efficiency is 12 %. As to the research on thin film cells, there are several universities engaged in it and its result is still in the primary stage of laborotory scale. In the respect of CdTe cells, primary research on silk screen printing has been carried out ; and in the respect of concentrator solar cells, research and development were carried out on the low concentration ratio solar cell system.

In the field of silicon sheet growth, we have already developed a first generation of special-purpose oven for experiment which is now in trialing, and the project adopted is continuously stretching the sample in transverse direction with carbon screen as substrate. Besides, there are also several universities exploring the possibility of forming silicon sheet by rotating a drop of dripped melt silicom.

The research objectives we plan to reach at the end of 1995 are that: the highest efficiency for monocrystalline silicon cells of size 10 cm×10 cm reachs 15 %; for polycrystalline silicon cells 13 %; the cost of crystal silicon cell module decreases to 13～14 Yuan RMB per watt (the currency value of 1990); the domestic materials used specially for solar cells should further improve its performances; the weight of casting ingot of polycrystalline silicon will reach 20-25Kg and its production will arrive large-scale level; the steady efficiencies of amorphous silicon cells (exposed to outdoor illumination more then one year or experienced certain extent of speeding up aging test) should be ≥8 % (corresponding the initial efficiency of 9～10 %) for cell area ≥100 square centimeter as well as should be ≥6. 5 % (corresponding the initial efficiency of 8 %) for cell area ≥900 square centimeter; and the research on amorphous silicon cells with large area will enter the stage of bi-junction configuration in order to improve its steadiness of performances.

b. The production of photovoltaic cells

China has altogeter twelve productive lines of solar cells for ground application, their productive capacities range from 30 KW to 1000 KW per year, and the totol capacity reaches 5. 5 million watt each year. In addition there are two lines of silicon solar cells for space application. Among the twelve lines, four of them are run in the form of joint venture with foreign funds; another four of them are equipped with imported techniques and facilities. Among the four joint venture lines, two of the amorphous silison cells productive lines are all equipped with the techniques and facilities of American Chronar Corporation. Most of the other products are solar cell modules of monocrystalline silicon, whereas solar cells of polycrystalline silicon count only a small proportion. There are only four factories that can produce slices of monocrystalline silicon with sizes of Φ100 and 100×100. Recently the Chinese exported silicon slices and ingots of single crystal each year can be used to equip a lot of photovoltaic cells, whose total electric power arrives 500 KW.

The large-scale production of solar cells for ground application was started in 1976 in China. The variation in outputs of various solar cells from 1983 to now is shown in Fig. Ⅱ-2. The total output of Chinese solar cells was 700KW in 1991, and was about 1 million watt in 1992. About 1/3 of the output was exported and most of them are amorphous silicon solar cell module. Since the cost of Chinese amorphous silicon solar cell modules is market, it has potential for export. Now, the annual productive capacity in China is far greater than its output, this is because that part of the productive lines do not form a complete system. For example, the productive capacity of the process for making silicon sheet is rather weak and the work for its application and popularization is also a weak link. The efficiencies of Chinese commercial solar cells are shown in the Table Ⅱ-3.

Table Ⅱ-3 The efficiencies of Chinese commercial solar cells

Type	Efficiency	Area
monocrystalline silicon cell	12% (average)	diameter of 10 cm or 10 cm×10 cm
polycrystallinesilicon cell	9. 5% (average)	10 cm×10 cm
amorphous silicon cell	5~6% (average) 8. 9% (maximun)	30 cm×90 cm

c. The applications of photovoltaic system

The application field of photovoltaic system in China spreaded gradually in the past 20 years. In space use, China successfully launched 5 communication satellites. All of them use solar cells as electric power supply and meet the staudards of international Ⅳ level for satellites. As to its ground uses, it has already extended all over the fields of agriculture, stock raising, communications and transportation, communications, meteorology, seismics, medical and health work, military, national defence and farm- family uses etc..

Now 3 photovoltaic power plants each with power of 10 KW and all equipped with photovoltaic modules, have been built up. In addition, one photovoltaic power plant of 20 KW was just established also, which is the largest stand alone photovoltaic power plant in China this time, and is used to supply the electric power for the county in Tibet which has no electric power available. The following items are more attractive in China recently, they are: the microwave relay station with power level of several KW, the photovoltaic power plants and illumination systems for household uses both with power level of 10 KW etc.. Owing to the shortage of funds, there is still a gap in the demonstrative enginering for parallel operation. By the end of 1991, the application areas of photovoltaic systems that are already in service is shown in the Table Ⅱ-4.

Table Ⅱ-4 The distribution of photovoltaic systems already in service by 1991

Application areas	Power installed (KWp)
Communication: microwave relay stations, TV trasmitters, satellite terrestrial stations, carrier telephony systems	710 KW
Civil and agricultural uses for remote border provinces: stand-alone photovoltaic electric power installation, power installation in a household scale for illumination and TV set, small scale charger, stockade surrounding with low voltage, water pumping system etc.	760 KW
Traffic: lamp for navigation mark, lighthouse, traffic signal system for railroad or highway	130 KW
Cathodic protection: switch, petroleum pipe line	45 KW
meteorological observatory, fire warning system for forest, seismograph station, high water warning system for hydrologic station etc.	85 KW
Others: military uses, yacht, lamp for street illumination, clock, toys, sun helmet, calculators etc.	50 KW
Export: mainly for yard illumination, emergency latern, portable latern, charger (small scale), electric fan (for car) etc.	740 KW
total	2550 KW

As to the photovoltaic application systems, a lot of inverters and charging controllers have been developed for forming various complete systems in various applications. Besides, we have carried out the site testing of photovoltaic system monitored and tracked by microcomputer, developed the software packages for optimizing the design of photovoltaic application systems, for water-pumping systems as well as for electric power generating systems that run on the basis of mutual complement between wind power and photovoltaic power. We have also developed the high efficency sine-waveform inverters of 10 KW or 15 KW based on different technical project. In the field of applied research, the following items advanced quickly in the recent years: the photovoltaic illumination with solar energy, the electric power supply for television station, communication station and meteorological observatory as well as the photovoltaic water pumps.

In the period of the Eighth Five-Year Plan, we will do our best to raise the production of photovoltaic systems to the level of batch process, and by the end of 1995 we will build 7 ~8 stand alone photovoltaic power plants each with the power 20~30 KW. Among them one is equiped with a mutually complementary photovoltaic and wind power system. These plants are set up to provide energy for the counties in the west of China where no electric power is available. Correspondingly, the microcomputer controlling facilities as well as the inverters of 30 KW should be developed in order to complete the electric power supply systems. In the same period, we will also popularize the small-scale photovoltaic system for household use, and make its production serialization, standardization and industrialization.

As far as cost is concerned, for the cell factories of crystal silicon mainly equipped with domestic techniques (only with the key equipments imported), the total cost of its module is about 20 yuan RMB per watt. Among the total cost, the cost of silicon sheet making process is 8 yuan per watt, the cost of cell making process is 5. 4 yuan/w and the cost of module packaging process is 6. 6 yuan/w. If the productive line of one million watt output is equiped with both imported techniquies and facilities then the cost will decrease to 15~20 yuan/w, and the cost of productive line for amorphous silicon with output of one million watt will decrease to 12 yuan/w. Among the 12 yuan/w, the cost for materials and power consumption is 6. 2 yuan/w, the cost of both administration and labour's wage is 2. 2 yuan/w, the price of land (for factory building) and equipments is 3. 6 yuan/w. The cost of the necessary accessories for the photovoltaic system is greater than 35 yuan/w now (not including the cost of solar cell module). If the industrialization, standardization and serialization are realized, hence its production will be in batches, then the cost for the necessary accessories will decrease to about 20 yuan/w.

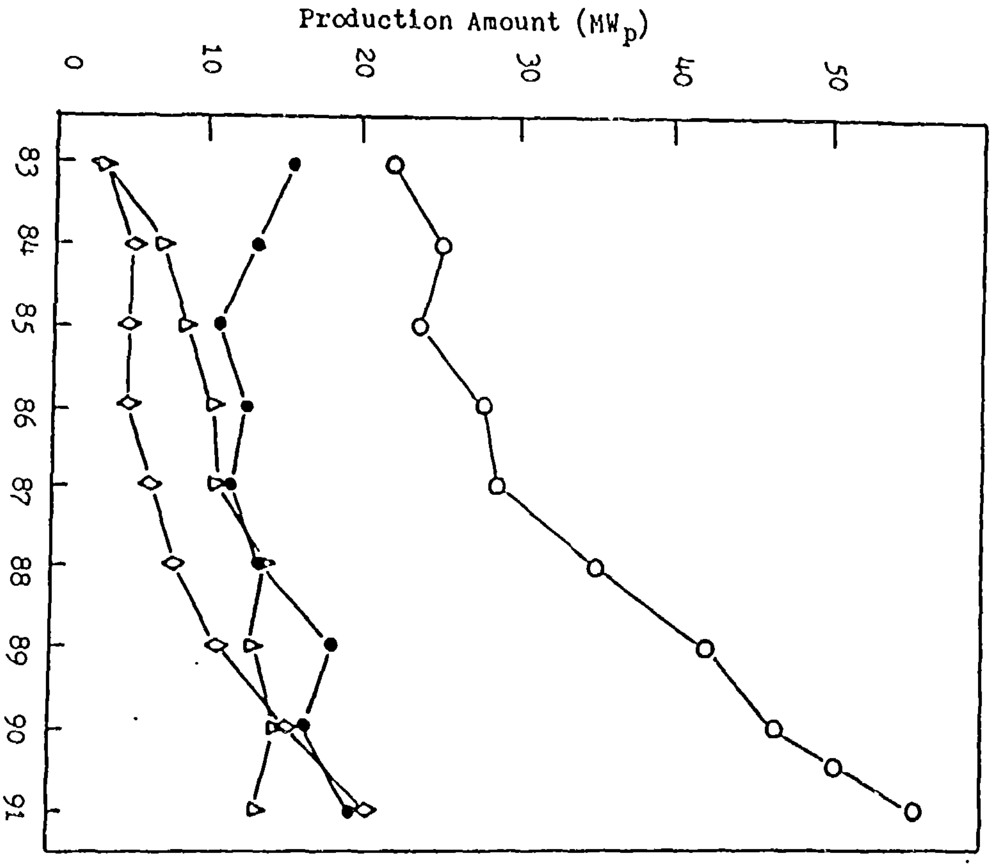
Let us take the 10 KW stand alone photovoltaic electric power installation as an example, which was set up in 1990 in the Ali district of Tibet, to analyze the economical performances of such photovoltaic system.

The annual radiation of this district is about 190 large calorie per square centimeter, its annual sunshine time is about 3400 h (average value), and its height above sea level is greater then 4500 m. this district is poor in economy, and the cost of coke transported from outside is as high as 800- 1000 yuan RMB per ton. There are only few counties in this district that are supplied with electric power, and the annual subsidy for the expenses of electric power consumption in civil uses in the whole district by the government is greater than 3 million yuan, while the cost of electric power is as high as 2. 0~2. 5 yuan/KWh. The 10 KW photovoltaic installation is installed in the Geji county (it has no electric power supply available), and its main load consists of 198 fluorescent lamps, 42 color TV sets, 44 radio-recorder sets, 5 video recorders, 29 sets of washing machine and one set of 2. 5 KW water pump (only use in the noon for 1. 5 hours). The engineering expenses of this demonstration installation are shown in Table Ⅱ-5.

Table Ⅱ-5 The engineering expenses of the 10 KW demonstrative photovoltaic electric power installation in Ali district of Tibet

Items	expenses (yuan/W_p)
solar cell modules	37
support and electric wires	3. 62
systems for controling, measuring and testing and instruments for special purposes	9. 93
inverter	14. 0
transport expenses (including premium)	1. 49
expenses for civil engineering	10. 0
traveling expenses on business leave	2. 40
expenses for design	3. 00
expenses for installation and administration	6. 79
and other unpredictable expenses	0. 57
in total	111. 83

Fig. Ⅰ—2 The production amount of solar modules for each calendar year in China from 1978.



Calendar Year

○ ---total amount

● ---single crystal Si solar cell

◇ ---polycrystalline Si solar cell

△ ---amorphous Si solar cell

Since this demonstrative testing installation was the one with the highest photovoltaic power output in China at that year, the expenses for its applied research, for the special-purpose instruments and for an extra standby 10 KW inverter (70 thousand yuan, to insure the reliability of the system) were also included in the engineering expenses this time. If the production in batch is realized for such kind of photovoltaic electric power installation, then the cost will decrease to 82. 4 yuan/W_p and the cost of electric power will be about 2. 8 yuan/KWh.

d. The main problems in exploitation and application of solar cells.

There are three key problems for the application of solar cells at this stage, which are common in the world, they are the efficiency, lifetime and cost. They can only be solved by the progress of technique. Besides, though China did get a lot of progress in this field in the past ten years, she still has to confront with the following additional probioms:

(1) The productive capacity is far greater than its actual output. Now the annual productive capacity of our country has already reached 5. 5 million watts, while the annual output in 1992 is only one million watts. Many of the productive lines that were set up by imported techniques still can not make profits nowaday owing to their inadequate output ; while some of the productive lines, that were set up mainly by domestic techniques and were equipped with key facilities imported, do can make certain profits from products owing to their less investment. Hence, as long as no new factories are set up again, the large difference between productive capacity and output will be decreased year by year.

(2) the works for demonstration and popularization are inadequate. Though there are plenty of solar energy resources in the northwest provinces, and the cost of solar cell becomes economically attractive now for certain special applications in many remote regions and regions where no electric power supply is available, many potential customers still don' t know what the solar cell products are. Some prospective applications such as photovoltaic water pump are only just started, and the application in medical and health work such as solar energy refrigerator for preserving vaccine is still a gap in China.

(3) The high price of solar cell modules is now the most restrictive factor that limlts its sales volume. The price of Chinese solar cell made from crystal silicon is now 10% greater than the one in the world market, and if it is ordered in large quantities, the difference in price will further increase. The high price originates from its high cost. The price of amorphous silicon solar cells in China is lower than the one in the world market. Though the price of Chinese solar cell module has become nearly the same as its counterpart in the world market, it still could' t make obvious progrees in the domestic market owing to the low purchasing power in the remote border provinces. Nowaday, the development of solar cell in China is mainly dependent on the financial support from the government, nevertheless, the amount of fund is quite limlt. Especially, the preferential treatment in tax policy for this risk and high technology products is still inadequate.

(4) The funds for research and development are rether inadequate. The further decrease in price of solar cells depends on the progress of technique and technology and hence on

the support of funds. In addition, the application and exploitation of this kind of installations as well as its demonstrative engineering, all of these need money to drive. Besides, there are varieties of solar cells, its content of research is quite wide, hence the shortage in funds is really a serious problem.

2.4 Solar energy thermal uses

a. Solar water heaters

A variety of solar water heaters have been produced in China for twenty years and now is at commercialization stage with a gradual increase of annual output, altuough its technology has to be improved. At present, there are more than a hundred of small factories and workshops manufacturing solar water heaters with a yearly output of 400,000 m^2(aperture area). The total amount of installed solar water heaters reaches 1.5 milliom m^2, mainly for domestic hot water supply while a few for public bath rooms and other commercial uses in rural as well as urban area for saving conventional energy and improving hygienic condition.

The solar water heaters developed in China could be classified into integrated and separated systems. For integrated water heaters, a solar collector and hot water tank are integrated into the same unit, simple to install, and cheaper in price. So they are of interest to the domestic sectors, of which around 15 % of solar water heaters produced in China pertain to integrated type. Separated systems, with collector and storage tank, can be operated either on pumped or natural (thermosyphon) circulation. In China most of them are of thermosython type.

During the last decade, research and development were focused on design optimization of various kinds of solar water heaters. In early years, the collector absorbers were made of steel and in tube-in-sheet structure in which round tubing is mechanically fitted by clamps or wires leading to a bad thermal bond conductance. Based on heat transfer analysis and thermodynamic tests on the existing panels, the processing technology has been greatly improved, for instance, the extruded fin-tubing and continuous soldering now are used in collector absorber processing. A SUNSTRIP production line mainly consisting of a rolling machine and a inflating-cutting machine was imported from Canada in 1986. It produces the aluminum fin-copper tubing SUNSTRIP absorber strip in excellent quality with high thermal bond conductance and fewer copper consumption meeting the international quality standard. Some aluminum fin-copper tubing production technology similar to SUNSTRIP's has been domestically developed in Shanghai, Liaoning and Yunnan. Owing to the corrosion problem in water passage of steel or aluminum absorber, copper water paeeages are now widely used and become popular. Plastic absorbers are still under development and the R&D work is focused on screening the materials which are able to stand ultra-violet radiation and high stagnation temperature. However, at present it seems promising to install plastic collectors without glazings in some locations of Southern China. Scientific investigation on the collector's optimized design has been carried out, and it is found that the optimal spacing between absorber and glazing is recommanded as 4-6 cm where heat transfer is mainly conducted by natural convection. The performance of the collector with transparent honeycomb structure sandwiched between the spacing of absorber and glazing to suppress collector's heat loss was proven positive in the laboratory. However its commercialization still needs further efforts. Besides, a mathematical model for collector optimized design has been worked out.

The collectors available in China's market are usually coated with black paint. As a result of computer simulation, it is indicated that for low temperature heat collection, or not for year round use, the black paint is in practice a cost-effective option. Selective coatings with various preparation methods are still in laboratory stage, The radiation properties of PbS selective paint on polished aluminum of galvanized steel reaches $\alpha_s = 0.85 \sim 0.91$, $\varepsilon = 0.23 \sim 0.40$. For black chrome and black nickel, $\alpha_s = 0.91 \sim 0.98$, $\varepsilon = 0.06 \sim 0.14$, but their durability and cost effectiveness are still not proven, while the anodized electroplating colored selective absorption coating on aluminum surface ($\alpha_s = 0.92 \sim 0.96$, $\varepsilon = 0.1 \sim 0.2$) has been successfully developed and serves as selective coating on SUNSTRIP absorbers.

The national Standard for Rating the Thermal Performance of Flat Plate Collectors (GB 4271 -84) and National Standard for Evaluating the Quality of Solar Collector Products (GB 6424-86)were published in 1984 and 1986 respectively. The National Supervision Bureau of Products Quality conducts spot check on flat plate collectors once every year based on the guidance of these Standards. The typical efficiency parameters of the flat plate collector products made in China are reported as: $F'(\tau\alpha) = 0.6 \sim 0.8$ and $F'U_L = 6.0 \sim 8.5 W/m^2 {}^\circ C$.

The dynamic characteristics of thermosyphoning system and the effect of various factors (e. g. climate, design parameters of the system etc.) on the system behavior were studied in connection with computer modeling as well as experimental methods for obtaining a clear picture of its operation mechanism in order to provide performance prediction for different designs and guidance for correct installation. An once through type solar water heating system operating with a thermostat was suggested with its remarkable advantage of flexible siting of the water tank at a suitable location instead of placing it well above the upper part of the collector like the thermosyphon systems do. Through theoretical and experimental study, it was indicated that the once through type and the thermosyphonic system have the same whole day performance if thay operate under same conditions (including weather, cold tap water and hot water temperature level, collector and water tank structure, and ratio of collector area to water caoacity). In recent years, the once through type water heating system has been installed in newly built solar water heating systems. In addition, the demonstrations of domestic solar water heating integrated with the multi-story apartment building have been undertaken in Beijing, Tianjin and Lanzhou with 1 m^2 collector, 70 liter water tank for each residential flat. The flow distribution in large collector system is often a significant design problem. Hydraulic modelling for such systems has been conducted and provides the useful results for collector arrangement and layout.

For producing hot water at a temperature around/above 100℃ as well as for year round use, two types of evacuated tubular collector in flat plate pettern are under development. The R&D of all glass concentric tubular collector started in 1979. During the past decade, numerous fundamental research on its coating preparation method, glass-work technology, collector tube assembly and system design were carried out. A small scale of trial production and demonstration of this type of evacuated collectors are under way. A China-Germany international co-operation project on heat pipe evacuated tubular collectors started in 1986. However, there are still lots of work to do for practical uses as well as economic feasibility study of this kind of higher operation temperature collectors.

b. Passive solar houses

Passive solar house is new category of energy saving building combining the effective collection and storage of solar radiation and thermal insulation technique into a specially designed house structure. reducing conventional energy consumption and improving environment protection issues.

In China, since 1979 when five experimental passive solar houses were built in Qinghai, Gansu and Tianjin, passive solar heating technique has got a rapid development. Before 1985, passive solar houses were mainly located in the stipulated winter space heating regions and provinces. Since 1986, they have been expanded to the "space heating transition region" (say the region between stipulated space heating region and none space heating region). According to the statistics made in the end of 1989, there are 800 sets of passivs solar house with a total floor area of 290,980 m^2 built nationwide covering the varieties of rural residential houses, urban apartment, school, hospital, as well as commerical buildings with the enerey saving fraction of 60-80% and the payback time of 2. 5-10 years for excessive solar investment. The passive solar house at Shiquanhe city, Tibet is the most successful demonstration. It can save 66 kg coal/m^2 year. The economics of some typical solar house in different areas is listed in Table Ⅱ-8. According to the experimental performance data obtained from a passive solar house group in free operation mode, located in Gannan, where the transportation is difficult, fuel price is expensive and the heating season is long, its initial investment was only 10-12 % higher than that of a conventional building with same size and style, and its payback time can keep in a reasonable lower level, say 2-5 years.

The inhabitants living in their passive dwellings express their satisfaction with the thermal comfort as well as energy conservation effects.

The research and development of passive solar heating design and its thermal performance also steps forward in parallel to the demonstration practice. A simplified calculation method developed by Dr. J Douglas Balcomb is widely used by Chinese enegineers nad architects in passive solar house thermal design. Some detailed physical and mathematical dynamic models and computer analysis softwares for predicting the thermal behavior and performance of passive solar houses in Chinese architectural style have been worked out. A technical document of test method for reting the thermal performance of passive solar houses as well as evaluating their thermal comfort and economics has been drafted.

Besides adopting the traditional passive solar heating techniques, such as direct gain, Trombe Wall and attached sunspace etc. , have developed some new passive solar heating structures and components such as lattice storage wall and rapid heat collection and transmission wall (without storage) as well as using local available low cost insulation materials for ceilings and floors. Night insulation shades, air tight door/window and selective film are being developed and tested in laboratories, and have yet been commercialized.

Among the passive solar houses in Chinese architectural style, a record of minimum diurnal temperature swing of 4℃ has been created, due to their construction traditionally made of heavy thermal mass.

Two international cooperative projects on passive solar heating started in early 1980's and completed in recent years. One is the China-Germany Governmental cooperation project for construction of demonstrative renewable energy village located in Daxing County, Beijing and the other is the Lanzhou Experimental Demonstration Center for Passive Solar Heating and Cooling in Gansu financially supported by UNDP. At present, in China, there are 39 institutions, widely spread in 13 provinces, autonomous regions and municipalities engaged in research, architectural design, construction and special structural components production for passive solar buildings.

Contrary to the passive solar heating solar heating development, few work has been done in passive cooling field. However, in southern China, there are great potential need for low cost cooling on the use of renewable energy. More R&D projects in passive cooling are expected in near future.

Table Ⅱ-8 The Economics of the Passive Solar Houses in China

Location	Investment Increment (%)	Annual Fuel Saving (kg coal/m year)
Lhasa, Tibet	15 - 25	30
Naqu, Tibet	27 - 39	70
Shiquanhe, Tibet	20 - 40	60 - 75
Beijing	15 - 26	22 - 30
Hualong, Qinghai	18	25
Germu, Qinghai	18	22
Weifang, Shangdong	13	12
Yingkou, Liaoning	12 - 20	25 - 35
Shijiazhuang, Hebei	15 - 20	20 - 30
Tianjin	20	34
Dunhuang, Gansu	18 - 25	30 - 40
Hezuo, Gansu	18 - 27	45 - 65

c. Solar Cookers

Solar cookers is an applinance which converts solar energy into thermal power for cooking. In recent years, the development and dissemination of solar cookers have been proceeded rapidly due to the fuel shortage becoming serious in rural/remote areas as well as the attentions from the Government. There are more than 150,000 sets of solar cookers produced and used in rural households totaling about 270,000 m^2 of aperture area and saving around 70 million kilograms of stalks every year. They make contribution to alleviation of the sever shoryage of firewood for cooking in some rural/remote areas where solar resources are rich.

The development of solar cookers experienced a long history in past decades. The first solar cooker was produced in Shanghai in 1956. Later on, a variety of prototypes appeared at the Solar Energy Technology Symposium and Exposition held in Shanghai in 1973. During the 1st National Solar Energy Congress in Anyang, Henan Province, in 1975, a report dealt with the trial use of "Breadbox Type" solar cookers developed in Anyang was issued and its prototype was demonstrated to the participants. Meanwhile, the concentrating solar cooker with a lotus pattern from Shanghai, the concentrating solar cooker with concave glass mirror from Beijing, ladderlike concentrating solar cooker from Gansu, automatic tracking solar cooker driven by clock mechanism from Anyang and sided axis parabolic dish cooker from Zhenzhou were displayed during the Congress. During the 2nd National Solar Energy Congress, in Xi'an, in 1979, more solar cookers for practical use were developed and displayed, such as cement back shell cookers, off- axis concentrating cookers with hard paper shell, cookers with plastic shell, portable folded cookers ··· etc. They all performed better than breadbox cookers and gradually replaced the laters. After then, there appeared 40 institutes and manufacturers developing and producing various kinds of concentrating solar cookers with novel designs. Among them, two types of solar cooker were shown at Tennessee World Fair, U. S. A. in 1982. The development on design theory and method promcted the solar cookers mature in technology improvement as wellas convenient in use. A plastic thin film reflective material with aluminum deposition was developed and produced in Shanghai. During 1980-1982, a massive dissemination of about 20,000 solar cookers was undertaken in Yongjing County, Gansu Province, where the rural households suffered badly from fuelwood shortage, while the land is bathed in bright sunshine. The encouraging results showed the vital role of solar cookers in easing up the tension of energy supply for daily life as well as improving the eco-environment system.

From 1983 to 1985, with the support of State Science and Technology Commission, the State Planning Commission and Ministry of Agriculture, the Chinese Academy of Agricultural Engineering Research and Planning took the resposibility of organizing a joint R&D team in which 18 units from nationwide took part to conduct further study on design theory, testing method, optimization of design parameters and structure, material selection ··· etc. After three year joint R&D, the design and manufacture technology of concentrating solar cookers in China was further improved and was able to be produced with acceptable quality. The main points of the achievement are concluded as follows:

(1) A "Three Circle Drawing Design Method" was invented for determing the profile of the concentrator of solar cooker. A computer program was complied for mathematical solution of the "draw method". So now the solar cooker degign can be worked on CAD level.

(2) For reaching the destination of commercialization of the solar cookers, the right material and manufacture technology was screened. From the feedback anformation from the consumers and test results, it was concluded that the casting pigiron, glassfibre rienforced cement and glassfibre reinforced plastics are the suitable raw materials for solar cooker shell. For reflective surface, the aluminum deposited plastic thin film and glass mirror are both the ideal material for obtaining good performance and low cost. Besides, a special gelatine for adhering between reflective sheets and back shell and well insulated pot for efficient cooking were also successfully developed.

(3) Five series of standard design of solar cookers were proposed for meeting different cooking power demands and habits of consumers as well as suitable for scale production.

In China, the agricltural sector of local governments takes the resposibility of dissemination of solar cookers. The related ministries and commissions play the role of coordinator and advisor responsible for monitoring and quality control as well as providing certain support for production and demonstration.

(1) Ministry of Agriculture organized nationwide quality appraisal activities in 1983 and 1986 respectively. There were around 130 sets of solar cooker from various localities sent for testing each time. After appraisal made by the specialists from administrative sectors and research institutes, some awards were delivered to those cookers which performed the best. Through these efforts, the quality of solar cooker products has been greatly improved.

(2) In rural villages, some technical teams were sent by Ministry of Agriculture and provincial agricultural sector to condust demonstration, maintenance and training as well as to collect the feedback information from customers for manufactures.

The figures of diffusion of solar cookers in recent yrars are listed as follows:

Table Ⅱ-9 Diffusion of Solar Cookers in Recent Years

Year	1979	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Amount (10 sets)	0.2	4	6	8	10	10.6	9.8	10.8	11.34	12.5	13.5	15

The locations where the solar cookers mainly be popularized are concentrated in Gansu Province (50, 000 sets), Hebei and Qinghai Provinxes (20,000sets each), Inner mongolia, Liaoning, Shangdong and Heilongjiang Provinces, as well as Tibet and Xinjiang Autonomous Regions (around 3,000 sets each).
(3) The payback period is estimated of 1-2 years for saving firewood from buying one solar cooker. The economic benefit of developing solar cookers is apparent in fuelwood lack-

ing area where is rich in solar resources.

d. Solar drying

The traditional method of drying agricultural crops and by-products use in China's rural area is open air sun drying which mostly depends on weather and environment condition and has little control over the drying quality. For instance, the dried products are often contaminated by sand, dust and insects. Sinse 1980's the renewable energy application has been progressively widespread in China's rural area. Solar water heaters, solar cookers and passive solar houses are appreciated in improving farmers daily life, while solar dryers are used in some process of production activities.

In China solar drying is a lately commenced program in the scope of solar thermal application. In 1970's a few institutions engaged in the R&D of solar drying, at that time there were only 7 sets of solar dryer for pilot study with a total aperture area of 479 m^2. However, in recent years, solar drying application has got a rapid development under the active support of Chinese Goverment. Up to now, 108 sets of solar dryer in different types have been built with a total aperture area of 10,178 m^2, 85% of which were built after 1983.

All the solar dryers for drying a varieties of products, such as agricultural by-products, foods, lumber, medicine herbs and industrial materials, have got positives of results and good economics with a short payback time of less than 3 years according to special survey.

The advantages of solar dryer can be concluded as follows:

(1) Saving energy and reducing environment pollution;
(2) Improving quality of dried product and reducing cost;
(3) Less investment and short payback time;
(4) Better processing condition.

The solar dryers developed in China can be classified into five types. They are: the green-house type, the air collector type, the combination type, the concentrator type and the integrated type. The amount of different types of solar dryers is listed in Table Ⅱ-10.

Table Ⅱ-10 Amount and Types of Solar Dryers

Types / Amount	Collector	Green-house	Combination	Concentrator	Integrated	Total
sets of dryer	42	24	8	5	29	108
Aperture area (m^2)	3.096	2.720	1.298	213	2.851	10.178

(1) Green-house type solar dryer

This type of dryer has the advantages of simple strusture and low cost. Its structure is somewhat like a conventional greenhouse. The drying materials in the greenhouse absorb solar radiation directly. Most od this kind of dryer are operated in passive mode. The moisture evaporated from the drying material flows out through natural ventilation. More than ten sets of greenhouse solar dryer have been built in the rural area of Shanxi Province for dryind red dates, cotton, fur and day-lilies ect. since 1970s.

A large size greenhouse solar dryer with 543 m^2 of aperture area was built at the forestration station in Yiwu County, Zhejiang Province in 1985 for drying wooden boards of packing cases. The greenhouse solar dryers are also used to dry rabbit fur skin and preserved fruits in Hebei Province. For example, a greenhouse solar dryer was built in Pingshan Cool Storage Plant, Shijiazhunag City. The dryer itself has an aperture area of 212 m^2 and another of 638 m^2 is added as an air preheater, so its total aperture area is 850 m^2 ranking first in size of the present solar dryers in China. There are three axial blowers installed inside the greenhouse in order to increase the air flow rate for enhancing the dehyration process. This dryer is operated in an active mode and its performance is further improved. The sketch of this solar drver is shown in Fig. Ⅱ-3.

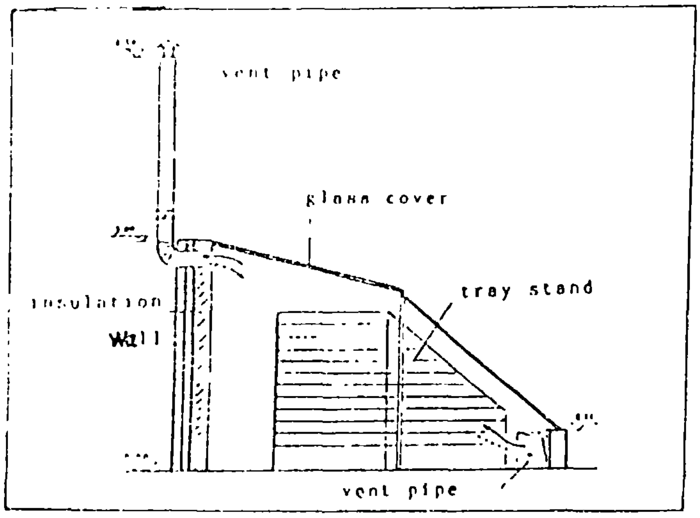


Fig Ⅱ-3 Opposite direction of greenhouse type solar dryer

(2) Air collector type

The so called air collector type solar dryer means the drying objects are dried by the hot air heated through solar air collector. The air is heated up to 60-70℃ and then enters the drying chamber. The drying process in the chamber is a convective heat and mass transfer process. A blower is installed in the collector system for enhancing the drying process. Several large size air collector type solar dryers are under operation in China, such as a timber dryer in Ganzhou Second Timder Factory, Jiangxi Province; a solar drying kilm for candied fruit in Xinhui county, Guangdong Province; a medicine herb dryer in Shanghai First Pharmaceutical Factory; a solar drying cabinet in Loyang Ceramics Arts and

Crafts Factry and a melon seed dryer in Longfong Food Factory in Lanzhon etc.. Fig. Ⅱ-4 shows the typical air collector solar dryer built at Loyang Ceramic Arts and Crafts Factory. Diversified varieties of solar air collectors have been used in this dtying system, suah as corrugated plate, integrated assembled flat plate and overlapped metal mesh absorber etc.

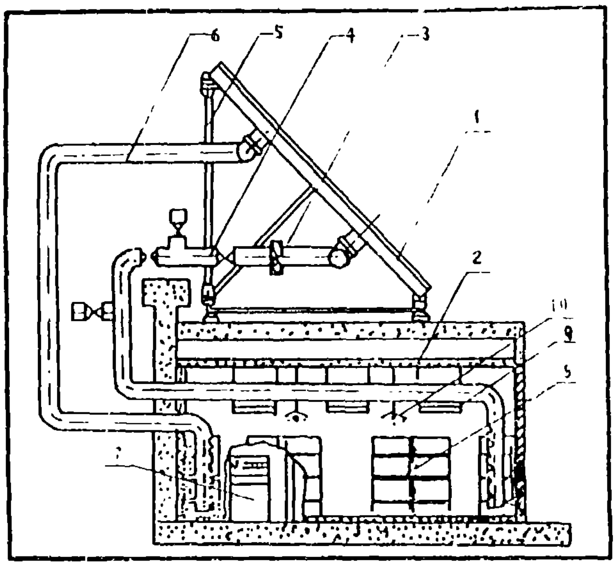


Fig Ⅱ-4 Solar dryer at Loyang Ceramic Arts and Crafts Factory
1. solar air heater; 2. drying chamber; 3. axial fan;
4. inlet pipe system; 5. support; 6. exhaust pipe;
7. operation controller; 8. unbaked ceramic stand;
9. infrared ray heating plate; 10. lighting lamps.

(3) Combination type

The greenhouse solar dryer generally can not meet the requirements of drying moisture content objects, such as fruits and vegetables etc. due to its small air temperatuer rise despit its high efficiency. Hence, a kind of greenhouse-air collector combination design is suggested for supplying more energy as well as keeping the system in higher efficiency. A few sets of combination type solar dryer have built, the typical one is located in Dongguan County, Guangdong Province.

(4) Concentrator type

Using solar concentrator would be an option to obtain much higher air temperature for fast drying. During 1979- 1981, five sets of pilot concentrated solar dryer were built for grain drying. After a period of operation, no encouraging results were reported. So this type of solar dryer has been given up for further development due to its complicated structure, high cost, difficult operation and maintenance problems.

(5)Integrated type

In this type of solar dryer, the solar collector are integrated with drying cabinet. Fig. 3 shows a cross section of such drying system which has two arrays of drying unit (collector/cabinet) with a height of 0. 7 m. An axial blower is mounted at the connection passage between two arrays. Since this unit has a higher aperture area/air space volume ratio, say 3-4 times larger than that of conventional greenhouse type, hence, a rapid temperature rise can be obtained. The objects for drying loaded on a tray with four rollers can be pushed into the dryer along a rail track. The forced air flow circulates through the tray. The moisture released off the materials is carried away by exhausted damp air. A part of damp hot air can be recirculated and mixed with the fresh air flowing into the system through a controllable exhaust flap. Hence, a better performance of the system can be obtained.

The integrated solar dryer has the advantage of low thermal inertia, high and rapid temperature rise, higher thermal efficiency, simple structure, low cost and flexible combination. It has been widely disseminated since it was first built in Guangzzhou in 1983. At present, this type of solar dryer takes a ratio about 30% of the total amount of solar dryers in China due to its cost-effectiveness.

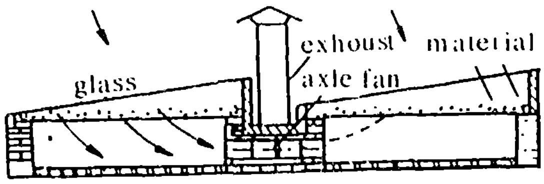


Fig. Ⅱ-5 Sketch of integrated solar dryer

3. Wind energy

3. 1 Resource and its characteristic

China is located in a region with the monsoon weather. Generally speaking, the wind direction is around the north in the Winter and is around the south in the Summer. Because of the effluence of the Qinghai-Tibet Plateau, the monsoon occurs only in the eastern China. This determines that the distribution of wind energy resource in China can be divided into two main regions: one is the northern China, another is the coastal areas and islands in the southeastern China. Besides these regions, because of the effluence of local landform, there are some areas with quite strong wind power, such as, on some high mountains and in some valleys. According to efficient wind energy density, duration percentage of the efficient wind power and total hour numbers with wind speed larger than 3 m/s and 6 m/s in a year, the distribution characteristics of wind energy resource in China are as following:

a) The coastal area and islands in the southeastern China are the region with the richest wind energy resource. The isoline of the efficient wind energy density larger than 200 W/m^2 is about parallel with the coast. The duration percentage of the efficient wind power reaches 80-90%. The wind speed higher than 3 m/s occurs more than 7000-8000 hours and the one higher than 6 m/s occurs around 4000 hours annually. However, because there are a lot of hills in this region it is quite difficult for the strong cold wind to arrive the southern China in the half year including Winter (October to next March). In the half year including Summer, the wind speed of the typhoon decreases 60-65% within 50 kilometers from the coast. Therefore, there is more wind energy resource only in the areas within tens kilometers from the coast in the southeastern China. In farther areas from the coast, the wind power decreases rapidly. In the areas which are 100 kilometers from the coast, the wind energy density is lower than 50 W/m^2. They become the areas with the lowest wind energy density in China. The wind energy resource on all the islands is quite rich, such as on Taishan and Pingtan in the Fujian Province and Nanlu, Dachen and Chengsi in the Zhejiang Province.

b) Inner Mongolia and northern Gansu Province are the region with the second richest wind energy resource in China. This region is controlled by the west wind within the whole year and it is the region where the cold wind first arrives. The wind energy density is 200-300 W/m^2 and the duration percentage of the efficient wind power is around 70%. The wind speed higher than 3 m/s occurs more than 5000 hours and the one higher than 6 m/s occurs more than 2000 hours annually. All the figures decrease from north to south in the region, but they decrease not as rapidly as in the southeastern China. The area of this region is the largest one in China.

c) Heilongjiang Province and eastern Jilin Province and the coastal areas of Liaoning Peninsula and Shandong Peninsula are the region with richer wind energy resource. The wind energy density is higher than 200 W/m^2. The wind speed higher than 3 m/s occurs 5000-7000 hours and the one higher than 6 m/s occurs around 3000 hours annually.

d) Northern Qinghai-Tibet plateau, north part in the northern China and coastal areas in the southeastern China are the regions with rich wind energy resource. In these three regions, the wind energy density is 150-200 W/m^2, the wind speed higher than 3 m/s occurs 4000-5000 hours and the one higher than 6 m/s occurs more than 3000 hours annually. On the Qinghai-Tibet Plateau, the wind speed higher than 3 m/s occurs 6500 hours annually. But, the sea level elevation there is quite high and the air density is lower so that the wind energy density is not very high. The air density at elevation of 4000 m is 67 % of that at the sea level. It means that the wind energy density at the sea level with the wind speed of 8 m/s is 3136 W/m^2 and the one at 4000 m is only 2000 W/m^2. Therefore, according to the duration of wind speed higher than 3 m/s and 6 m/s, Qinghai-Tibet Plateau is the region with the richest wind energy resource in China. In fact, the wind energy there is much lower than that on islands in the southeastern China.

e) Yunnan, Guizhou, Sichuan, southern Shanxi, Henan, Hubei, western Hunan, mountain areas in Fujian, Guangdong and Guangxi, and the Talimu Basin are the regions with least wind energy resource in China. The wind energy density in these regions is lower than 50 W/m^2 and the usable wind power is less than 20%. The wind speed higher than 3 m/s occurs less than 2000 hours and the one higher than 6 m/s occurs less than 150 hours annually.

f) The other regions instead of those mentioned in terms 4 and 5 are the regions where the wind energy can be utilized in some season(s). For example, it can be utilized in Winter and Spring in some regions or in Summer and Autumn in some other regions. The wind energy density in these regions is 50-150 W/m^2 and the usable wind power is 30-40 %. The wind speed higher than 3 m/s occurs 2000-4000 hours and the one higher than 6 m/s occurs around 1000 hours annually.

3. 2 Development and utilization of the wind energy

a. Survey

China is one of the countries which utilized wind energy in the early years. Nearly 3000 years ago sails were used to power boats. Windmills with canvas blades for pumping water appeared some 1700 years ago. Until the mid of this century, traditional sailing boats and windmills were widely operated. The development of wind turbine generator and new type of wind pump in China started in 1950′ s. Handicapped by the poor and technical conditions at that time, only a few prototype machines got success. Modern wind pumps with metal blades developed in 1960′ s had better performances. 600 units were produced, mainly for farm irrigation. But, later they were replaced by diesel or electric pumps. After the mid of 1970′ s, oil fuel and electric power were in short supply, pollution problems were getting serious, as a clean, renewable energy source, much attention was paid to wind power. A new period for the development of wind energy utilization started in China.

Since 1980′ s the development of mini-wind turbine generators (50-200 W) was a success and has been put into commercial production. Nowadays, more than 130000 units are operating in the Inner Mongolia, Xinjiang and Qinghai pastoral areas, as well as coastal areas without power grid, to meet the demands of lighting and TV reception for herdsmen and fishermen. Wind turbine generators in capacity of 1 KW to 20 KW are under small scale production, 50 KW and 200 KW prototype wind turbines are being tested on site. At the same time, two new model wind pumps (low lifting head-large flow volume and high lifting head-small flow volume) and a 60 ton wind power assisted ship have been certificated. In addition, some progresses have been made in the fields of wind energy resource assessment nationwide; measurement technology of wind turbine performances; basic theoretical research; and the assimilation of foreign wind turbine technology. The operation of wind farm are under way. A small scale wind industry has been established. Recently, the Chinese Government takes the wind energy as one of the energy supply means in the remote areas and pays great attention to the development of the wind energy utilization.

b. Wind pump

Now, there are more than ten types of wind pumping systems being operating in China.

Their rotor diameter ranges from 2 to 7 m; the rated power from 0. 1 to 4 KW and the pumping heads from 0. 5 to 100 m. According to the utilization, the modern Chinese windpumps can be divided into two main categories:

(1) High lifting head-small flow volume wind pump
The windmills for deep well pumping are used to match a single-acting or double-acting piston pump, for drinking water supply in prairie and pastoral areas of China. The lift head ranges from 10 to 146 m and flow volume from 0. 5 to 5 m^3/hour.
(2) Low lifting head-large flow volume wind pump
The low lifting head windpumps adopt steel tube-chain type water-wheels or screw pumps as their lifting tools. They are used to supply water for farmland irrigation, salt making, aquatic products breeding and fish farming. The lift head is between 0. 5 and 3. 5 m, flow volume between 50 and 100 m^3/hour.

In places where both wind energy and water resources are abundant, the development of wind pump is one of the effective ways to ease up the shortage of energy supply in rural areas. To meet the great demands of lifting surface water for salt refining, seafood breeding and farmland irrigation along coastal areas in China, a model FDG-5 wind pump was successfully developed in 1980′s. After several years of test and operation, the results showed that each of this low lifting head (less than 2 m) large flow volume (up to 50 m^3/h) wind pump can satisfy the requirement of sea water lifting for 22 ha of salt field, equivalent to a 5. 5 KW electric pump. 5000 KWh of electricity and RMB 582 Yuan for the electricity expense could be saved annually. 34 more tons salt can be produced in comparison with using electrical pump and it increases income of RMB 2000 Yuan each year. So the cost of the wind pump can be recovered in 4-5 years.

In the northwestern arid region, it needs to lift drinking water from underground for people and livestock. Model FD4-LB60 high lifting head-small flow volume wind pump has been successfully developed, a series of piston pumps can be used to meet the requirements of lifting head and flow volume.

Nowadays, over 2000 wind pumps have been used in China, windpump sites for demonstration and testing totaled up to 50, the production capacity of wind pumps can meet with the markεt demands. In recent years, the windpump technology has been raised to a new level due to adoption of modern science of aerodynamics, structure mechanics and new materials in the research institutions. China is a country where wind pumping is suitable. It is estimated that by the year 2000, about 10000 units will be operating in China.

c. Wind turbine generator

Most of the wind turbine generators developed in China are horizontal axle machines, only a few with vertical axle rotor. Mini machines (up to 1 KW) are matured in technology and have been commercialized, sales volume up to 10000 units each year. Small machines in size of 1 to 10 KW and 20 KW medium machines have been put into small scale production. Prototype wind turbines rated power of 50 KW and 200 KW have been developed and are being tested.

In China the most important application of wind turbine generators currently is to supply electricity to remote areas as a stand-alone power source. The electricity generated from mini or small wind turbines have to be stored in batteries. The electric power will be transmitted from batteries to DC lamps for lighting, or via an inverter to be converted into AC current for TV sets or other household appliances. Over a long period of time, the mini and small wind turbine generators are mainly developed in China. Most of the mini wind turbine generators are operating in the Inner Mongolia Autonomous Region. Subsidized by the local government and improved after-sale service by manufacturers, the installations of mini-windgenerators grew up to 80000 by the end of 1989. More than 25% of the herdsmen's families on prairie are able to use electric light and TV set. In other provinces or autonomous regions, such as Gansu, Qinghai, Xinjiang and Tibet, 10000 mini wind turbines have been installed. For small communities, meteorological stations and sentry posts on maintains or islands, 1 KW to 7.5 KW small wind turbines are used not only for lighting and TV, but also for food processing, heating, medical apparatus and movie showing. People's daily life conditions have been dramatically improved. The specifications of wind turbine generators of 50 and 100 W with batteries which are most widely used and can operate independently are shown in Table Ⅱ-11.

Table Ⅱ-11 Specifications of two wind turbine generators

Type	FD1.6-50W	FD2-100Wyc
Rotor diameter (m)	1.6	2
Starting wind speed (m/s)	3.5	3
Nominal wind speed (m/s)	6	7
Stopping wind speed (m/s)	18	25
Rated power (W)	50	100
Lifetime on duty (years)	15	15
Price (RMB Yuan)	530	760
Price after abandonment (RMB Yuan)	50	80
Type of battery	6-Q-90	6-Q-90
Quantity of batteries	1	2
Efficiency of storing energy (%)	75	75
Lifetime on duty (years)	3	3
Price (RMB Yuan)	190	150
Price for first charging (RMB Yuan)	40	30
Price after abandonment (RMB Yuan)	25	20
Construction fee (RMB Yuan)	30	40
Maintenance (RMB Yuan/year)	26	38

In addition to satisfying the energy demand for daily life, some tests of supplying electricity generated by wind power for other applications are going on. Wind turbines less than 10 KW usually are used to charge batteries, as power source for microwave relays, TV transmission stations, etc. Medium size machine is combined with diesel generator to form a wind/diesel hybrid power system. For instance, within the CHINA-EEC cooperation project, three Danish 55 KW and two Chinese 20 KW wind turbines were installed on Dachen Island, Jiaojiang, Zhejiang Province, connected to an electric grid powered by a 280 KW diesel generator. In CHINA-UK cooperation project, a wind/diesel system which consists of a 60 KW wind turbine and a 60 KW diesel generator was installed on Kongdong Island, Yantai, Shandong Province. Based on the principle of load control, each load can be switched either to wind grid or to diesel grid according to the power generated by the wind turbine. Abundant experiences for operating these systems have been obtained.

In recent years, some grid connection medium and large wind turbine generators have been imported. Three Danish VESTAS 55 KW wind machines were imported in 1986 and installed in Rongcheng, Shandong Province to form the first Chinese wind farm with annual average electricity production up to 330000 KWh. Four HMZ 200 KW large wind turbines donated by Belgian Government were erected on Pingtan Island, Fujian Province. Three wind turbine generators (400 KW in total) were imported from Sweden and installed on Nan'ao Island, Guangdong Province. The biggest wind farm in China at present was built at Daban, Xinjiang Autonomous Region, consisted of thirteen Danish 150 KW wind turbines. In Inner Mongolia, five US 100 KW machines formed an experimental wind farm at Zhurihe. Specifically, under guidance of the Energy Research Committee of CAS and in cooperation with the local government, a wind power station was built in Sijiao, Zhejiang Province in June, 1991 in the CHINA-GFR cooperation project of science and technology. The station consisted of 10 German wind turbine generators of 30 KW each. It was connected with the local grid which includes small heat power plant and a few diesel generators. Electricity of over 800000 KWh can be produced annually. Since then, the station has been operated normally and offers valuable experiences for operating the medium and large wind turbine generators in connection with grid.

Generally speaking, to form the wind farms which consist of tens or more wind turbine generators is still in the stage of feasibility study. Entrusted by the State Planning Commission, more than 20 experts and professors were organized by the Chinese Wind Energy Development Centre to study the planning method of small scale wind farm (1-5 MW), the final report has been completed.

d. Variable speed—constant frequency wind turbine system

Being different to the traditional energy sources, the wind power is only available in certain periords of time and its strength is obviously changed from time to time. So the energy input of a wind machine is not stable. However, the output of a wind turbine is demanded to fulfill some quite high requirements. Following the modern developments of the electric technology, the variable speed-constant frequency wind turbine systems have been utilized more and more. Research in this field started in the Institute of Electrical

Engineering, Chinese Acdemy of Sciences in 1970's. In 1980's, a variable speed-constant frequency wind turbine of 5 KW with modulated megnetic field was developed. Based on this, a variable speed-constant frequency wind turbine which output power is 20 KW at wind speed of 9.2 m/s was developed in 1991. Its efficiency is quite high and its annual electricicty production is 20% higher than the traditional constant speed-constant frequency generators. Starting, speed adjusting and stopping in any case can be operated automatically. Its construction is relatively simple and maintenance is quite convenient. Combined with a diesel generator of similar capacity, it can solve the difficult problem of dynamic stability in a system with randomly variable load and wind speed and ensures the quality and safety of the electricity output.

The populerity rate of electricity supply is not high in China. The diesel generators have to be used in most remote areas. It is quite difficult to change this situation in the near future. So, to develop wind/diesel hybrid power system is important not only for fulfilling the recent requirements but also for the long-term development. Since the mid of 1980's, several wind/diesel hybrid power systems in different types have been imported through the international cooperation projects and become technical modal. But, the prices of these systems are quite high and their maintenances are too difficult under the current conditions in the remote areas in China, so that it is impossible to be used widely in the near future. However, the variable speed-constant frequency wind turbine with modulated megnetic field can solve these problems. At present, a 20 KW wind and 40/12 KW diesel hybrid power system has been developed. Specifically, the technical problems about operation controlling, load matching and distributing, random energy adjusting, etc are being solved in order to obtain a wind/diesel hybrid power system which can be used practically, has stable and very good operation performances, can be operated in relatively simple way and is safe and reliable. It will promote the production in the experimental regions and offer the quantitative basis for the further developments and applications. It will become a satisefactory system.

e. Wind/photovoltaics hybrid power system

Wind/photovoltaics hybrid generation is a better approach to use the renewable energy resource in a complementary way. Now this subject has been investigated in several developed and developing countries over the world. By the end of 1980's, it started to be investigated in China as well. But, only wind/photovoltaics hybrid power systems of hundreds or thousands watts were developed and they are in test or on probation. In 1990's, Chinese Government decides to include this subject in the Eighth Five-Year Plan of Science and Technology Developments. The optimum design, system controlling, efficiency of the system, operation and management of the system, etc have been thoroughly investigated. The system will be widely used and its output power will be increased. The investigation and development of wind/photovoltaics hybrid power system of 30 KW which is pursued in the Institute of Electrical Engineering, Chinese Acdemy of Sciences is the typical one in this field.

3. 3 Several problems in utilizing the wind energy

Now, about two thousand million peasants and herdsmen have not utilized electricity in China. Most regions without electricity supply are located in the poor areas, remote areas and some coastal areas or on some islands. It is quite difficult to supply electricity there by means of grid. The wind generation is a proper way to solve this problem. This is why the mini and small wind turbines have been paid more attention to for a long time in China and the wind turbines of 50 and 100 W for charging batteries are most widely operating in China now. By the end of 1988, over 70000 mini wind turbines were operating in China. The total power of them were 6700 KW and the annual electricicty production was 6300000 KWh. By the end of 1989, over 105000 wind turbines were operating and by the end of 1992, over 125000 wind turbines were operating. They have played very important role in developing economy and production in the remote areas and improving the daily life quality there.

But, several problems restrict the development of wind generation in China and must be solved in the future. In spreading utilization of the mini wind turbines, the main problems are:

a) Purchasing power is low. Generally speaking, the average amount of per capita annual income is quite low in China now. In recent years, economy progress in the pastoral area in the Inner Mongolia progresses is rapid. Nevertheless, the average amount of per capita annual income there is still around RMB 1000 Yuan. The manufacturing cost of a wind turbine of 100 W is over 1000 Yuan. So, only 20% of local population in the pastoral area can buy the mini wind turbine and only less than 12% of families can return all the loan for buying a wind turbine of 100 W in one time from the annual income. The average amount of per capita annual income of peasants and herdsmen in the northwestern China, Henan and other provinces is even lower than that in the Inner Mongolia, so that few families can buy a wind turbine.

b) The lifetime of the wind turbine as a whole machine is not long enough. Although the mini wind turbine manufactured in China are basically usable, their performances are obviously poorer than those of the imported ones in same type. Generally, the regulated lifetime of a Chinese turbine is 10-15 years and the practical lifetime is less than this. The lifetime of the imported ones is 20-25 years. Therefore, the annual depreciation charge of Chinese wind turbine is relatively high.

c) The education level of the users is low. This is a big obstacle for using and maintaining the wind turbine correctly.

There are a lot of advantages to develop wind farms in connection with grid. But, if the induction generator which has relatively simple and reliable construction and lower price is used as the wind turbine, a reactive power which is equivalent to 20-30% of the wind generator power must be supplied by the grid. Furthermore, low economical benefit is another problem.

4. Biological material energy

4.1 Resources

The biological material energy resources in China comprise the following three parts:
(1) The stalk of crops, or straws that can be burnt as fuel,
(2) Wood reasonably cut down from trees in human living area for fuel,
(3) Excrements from man and animals and organic wastes.

Besides burning directly, excrements and organic wastes can be used as energy source by preparing marsh gas from anaerobic fermentation. In areas short of fuel, weed is often collected for burning. But weed should be used as forage for livestock, not as energy source for burning.

In table Ⅱ-12, the amounts of straws calculated from various crops in 1990 are listed. In 1990, the real amount of straws produced is 0.554 billion tons, equivalent to 0.276 billion tons of standard coal, in which the amount of straws used as energy source is 0.295 billions tons (53.3%), equivalent to 0.147 billion tons of standard coal when converted in terms of heat produced.

The reasonable amount of firewood for cutting per year in China is 0.14 billion tons (calculated according to the area of forests of various trees), equivalent to 80 millions tons of standard coal. But the actual amounts of firewood cut every year exceeds greatly the reasonable amount for cutting. In 1990, the amount of firewood for direct burning is about 0.125 billion tons, exceeding the reasonable amount by 75 million tons, which is the major damage to the forest resources and the conservation of water and soil in China.

Table Ⅱ-12 output of straws of main crops in China in 1990

Corp	Output (Million Tons)	Grain Straw Ratio	Amount of Straw (Million Tons)	Heat Procued (Cal/Kg)	Conversion Factor to Coal	Coal Equivalent (Million Tons)
Rice	189.33	1:0.623	117.95	3000	0.429	50.60
Wheat	92.83	1:1.366	134.18	3500	0.50	67.09
Corn	96.82	1:2.0	193.64	3700	0.529	102.44
Photo	27.43	1:05	13.72	3400	0.486	6.68
Kaoliang	5.68	1:1.5	8.52	3700	0.529	4.51
Millet	4.58	1:1	4.58	3500	0.50	2.29
OtherGrains	13.18	1:1	13.18	3400	0.486	6.41
Soynean	11.00	1:1.5	16.50	3800	0.543	8.96
Cotton	4.51	1:3	13.53	3800	0.543	7.35
Oil Crops	16.13	1:3	32.26	3700	0.529	17.07
Sugar Cane	57.62	1:0.1(leaf)	5.76	3300	0.441	2.54
Total			553.82			275.94

The dry excrements from man and animals amount to 0.3 billion tons per year, calculated from population and number of livestock in China. The heat energy produced from it is equivalent to 0.13 tons of standard coal. But at present, only 7 to 8 million tons of dung from livestock are burnt directly in agricultural and pastoral areas, and excrements used for preparing marsh gas is very little. In 1990, only 1 billion cubic meters of marsh gas was produced, which is 1 percent of the total amount of resources.

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In recent years, by the development of economy and the rasing of living standard in rural area, the number of peasant households using coal or gas fuel is increasing rapidly, and so there is a surplus of straws in some areas. In the past, it was presumed that it was due to the shortage of fuel that the straws could not be put back to farmland. Yet now, although there is a surplus of straws, no significant increase of amount of straws being put back to farmland can be seen, especially in northern area, where temperature is low. Because of the cold and dry climate, straws do not decompose in a short time, while the recultivating coefficient of farmland is high. Pulling back straws to farmland not only brings about increase in production, but it may even cause a reduction. Also, the nutritive value of straws is not high when used as forage. As a result, large amount of straws is burnt wastefully. In the countryside of Beijing, one third of the total amount of straws is burnt wastefully. Similar situation can be seen in Shanxi, Liaoning and Jiling.

Firewood forest plays an important role in developing rural energy source. But according to the investigation and analysis by the specialist group of World Bank and China, the economic result of unitary development of firewood forest is beneficial and competitive to coal only in those areas where condition is good and coal is lacking, while in those areas where condition is poor and coal resources is rich, firewood forest cannot compete with coal economically, if the benefit of control of soil erosion is not considered. For example, in Kezou County of Liaoning Province, the cost for firewood production is approximately 80 yuan per ton in 1990, while in some areas the production cost of coal is lower when calculated in terms of heat produced.

4.2 Development of utilization technique

a. Direct burning

The heat utilization efficiency of direct burning of biological material varies greatly. In primitive bonfire burning, the heat utilization efficiency is less than 1 %; when using a most primitive stove by putting up three pieces of stone, the heat utilization efficiency is 3 %; by using conventional Kitchen range in Chinese peasant households, the heat utilization efficiency is below 10 %, and by using Kitchen range with bellow, heat utilization efficiency can reach 13-14 %, In Table Ⅱ-13 the result of a sampling survey of 100 peasant households is in Shanxi Province is shown.

The way of supplying energy by direct burning of immense quantity of biological material causes serious damage to the ecological equilibrium, because the consumption rate of biological material exceeds the growing rate. In a survey of consumption of energy in rural area in China in 1980, it was stated that 47.7 % of peasant households in China were in need of fuel for 3 to 6 months in a year. In order to reduce the amount of biological material utilization efficiency in burning. In 1982, a nationwide meeting was held for comparing and appraising various designs of fuel-saving Kitchen ranges and stoves used in rural area. During the meeting 14 kinds of fuel-saving kitchen ranges and stoves using different biological materials as fuel and suitable for different lifestyles were selected. The heat utilization efficiency of them is between 25 to 30 percent in general, which is 100% to 200% higher than conventional ones (See Table Ⅱ-14). Every fuel saving Kitchen range and stove can sa /e 1 ton of fuel weed (See Table Ⅱ-15). This innovation cannot bring about a radical change to the conventional way of direct burning of biological material, but it is an effective approach to moderate the damage to ecology. Since 1983, 390 counties were arranged as trial counties for spreading the usage of the fuel-saving kitchen ranges and stoves. Up to 1990, the fuel-saving kitchen ranges and stoves had proliferated to one hundred and twenty million peasant households.

Table Ⅱ-13 Statistics of kitchen ranges and stoves in rural area of shanxi province

Elevation	Household Investigated	Item	Type of Kitchen Range or Stove				
>800 m	50	Households	38	2	5	2	3
		Percentage in Total Investigaed Households	76	4	10	4	6
		Average Fuel Consumption per day(kg)	20	11	16	9	7.3
		Heat Efficiency(%)	6.2	7.2	7.8	13.3	17.1
<800 m	50	Households	29	6	10	1	4
		Percentage in Total Investigaed Households	58	12	20	2	8
		Average Fuel Consumption per day(kg)	17	14	14	8	5.3
		Heat Efficiency(%)	6.6	8.3	8.2	13.8	21.1

Table Ⅱ-14 performance of fuel-saving stove in sichuan province

County	Household Using Fuel saving Stoves	Comarison between stoves				Heat Efficiency(%)	
		Conventical(Average)		Fuel saving(Average)			
		Fuel Consumption(kg)	Time (minute)	Fuel Consumption(kg)	Time (minute)	Conventional	Fuel-saving
Jianyan	37	1.3	3.8	0.58	9	10.29	22.98
Xuyung	51	1.5	14.6	0.54	8.15	9.87	23.78
Mabian	20	1.35	16	0.6	11	10.37	22.22
Changshou	7	1.3	17	0.61	9.2	10.26	21.85
Yanting	24	1.25	15	0.6	8.5	10.66	22.22

Note: The figures are for boiling 5 Kg of water.

Table Ⅱ-15 Investigation on the Benefit of Rebuilding Stoves for Saving Fuel

County	Population (Thousand)	Household (Thousand)	Stove Rebuilt (Thousand)	Stalk saved per year (Thousand)	Each Stove	Average Stalk saved (Ton)
Linan, Zhejiang	410.5	111.7	103	92.1	154.3	1.50
Lintao, Gabsu	411.9	83.6	82	98.1	85.0	1.01
Dingxi, Gansu	342.4	66.7	61	97	63.2	1.04
Xinye, Henan	600.0	125.0	121	97.3	10.5	0.87
Dengta, Liaoning	405.7	108.0	99	95	10.0	1.01

But taking a long term view, the fuel saving stove is a backward way of using energy after all. Although the heat utilization efficiency is raise, large amount of biological material is still being burnt up directly, which will affect the ecological circulation in those areas that are poor in biological material resources. In constructing modern villages, this way of using energy cannot meet the requirement of the peasants whose income is increasing, and who are asking for clean and convenient commercialized energy sources such as coal, high quality liquid fuel, gas fuel or electricity.

b. Anaerobic fermentation of organic matters:

Organic matters, under anaerobic condition and through anaerobic decomposition by microbe, can produce marsh gas containing approximately 60% of methane (CH_4), that is combustible.

China started preparing marsh gas by anaerobic fermentation for lighting in the 30's, and is the country that prepared and used marsh gas in this way earliest and most widely in the world. Now there are four million and seven hundred and sixty thousand marsh gas pools for peasant households, with an annual output of one billion cubic meters of marsh gas. In recent years, large and middle scale marsh gas engineering and domestic sewage purification marsh gas tanks in cities and towns are also developing rapidly. More than 1500 marsh gas collecting plants have been built, which can supply marsh gas for sixty four thousand households, and twelve thousand purification tanks have been built, which can dispose excrements and domestic sewage of millions of people.

A study shows that the excrements from a pig of over 50 Kg in weight can provide 0. 2 cubic meters of marsh gas everyday, that is enough for one man' s consumption at low living standard. The excrements from an ox can provide 1 cubic meter of marsh gas everyday, that is enough for a family of five people. The four million and seven hundred and sixty thousand marsh gas tanks in the whole country can provide more than 20 million peasants with marsh gas for eight to ten months in a year, yielding notable benefit in energy supply.

It was once suggested that when excrements is inadequate, stalk can be added to fermentation pool for preparing marsh gas. But as a result of experimental study, the utilization rate of energy in stalk by fermentation to prepare marsh gas is much lower than burning in kitchen range. In Table Ⅱ-16, a comparison is made between preparation of marsh gas by fermentation of pure pig excrements and stalk added pig excrements. The table shows that the energy input of the latter is 4723 thousand Calories more than the former, but the energy contained in the marsh gas produce is only 220 thousand Cal more. In other words, only 4. 7% of the energy of the add in part was converted to energy in marsh gas, and the remainder only increases the energy in the dregsand and the loss. This conversion rate is even lower than conventional kitchen range(10%). Considering the burning efficiency of the marsh gas stove, the energy utilization rate is even lower. Taking the figures in Table Ⅱ-16 for calculation, the energy converted from stalk to marsh gas is only 26. 8%, and considering the combustion efficiency (50-60%) of the marsh gas stove, the energy conversion rate from stalk to heat is only 13. 4-16. 1%, which is only a little higher than conventional stove and lower than fuel-saving stove.

If the only purpose of anaerobic fermentation of organic matters is to provide energy, the economic benefit is low. The return of investment will be long. It is important to carry out multilevel comprehensive utilization of biological material, so that not only the energy utilization efficiency and economic benefit can be raised, also the ecological environment can be improved.

Table Ⅰ-16 A comparison between preparation of marsh gas by pure pig excrements and stalk-added excrements

Item		Material Put into Marsh Gas Pool For Fermentation	
		Pure Oig Excrements	Stalk-added Pig Excrements
Energy Input(Cal)		4547480	9270576
Energy Output (Cal)	Contained in Mash Gas	1034500	1254000
	in Dregs	2801160	6061088
	Total	3834610	7316088
Energy utilzation percentage (%)	Contain in Marsh Gas	22.7%	13.5%
	in Dregs	61.6%	65.4%
	Total	84.3%	73.9%
	Energy Lost	15.7%	21.1%

Note: The ratio of pig excremnets and stalk is 2 to 1.

Table Ⅰ-17 Energy utilization of stalk preparing marsh gas and breed earthworm

Item		Dry Fermentation of Stalk For Preparing Marsh Gas	Marsh Gas Dregs for Breading Earthworm	Earthworm for Feeding Poultry	Total
Energy Input(Cal.)		5846224	3306688	390775	5846224
Energy Output (Cal.)	Contained in Product	1567000	390775	(54678)	1957775
	in Dregs	3306688	2361824	(246673)	2361824
	Total	4873688	2752599	(301351)	4319599
Energy Utilization percentage(%)	Contained in Product	26.8	11.8	14.0	33.5%
	in Dregs	56.6	71.4	63.1	40.5%
	Total	83.4	83.2	77.1	73.9%
	Energy Lost	16.6	16.8	22.9	26.1%

Table Ⅰ-18 Energy utilization by using stalk to grow mushroom to feed pigs and prepare marsh gas by pig excrements

Item		Stalk Powder to grow Mushroom	Mushroom to Feed Pigs	Fermentation of Pig Excrements to Prepare Marsh Gas	Total
Energy Input(Cal.)		12596109	7735039	4147192	12596109
Energy Output (Cal.)	Contained in Product	2729429	2760406	984500	6474335
	in Dregs	7735039	4147192	2581268	2581268
	Total	10464468	6907598	3565760	9055603
Energy Utilization percentage(%)	Contained in Product	21.7	35.7	23.7	51.4
	in Dregs	61.4	53.6	62.2	20.5
	Total	83.1	89.3	85.9	71.9
	Energy Lost	16.9	10.7	14.1	28.1

Table Ⅰ-19 Energy utilization of straw for biogas and of mushrooms, breeding pigs, pig excrements for biogas

Item		Fermentation of Straws to make bio-gas	Planting of Mushrooms by bio-gas digester residues	Breeding of pigs by using Mushrooms	Making bio-gas by fermentation of pig excements	Total
Energy Input(Cal.)		5846224	3306688	2219024	1086367	5846224
Energy Output (Cal.)	Contained in Product	1567000	511376	835170	315885	3229371
	in Dregs	3306688	2219024	1086367	611506	611506
	Total	4873688	2730340	1921537	927391	384087
Energy Utilization percentage (%)	Contained in Product	26.8	15.5	37.6	29.1	55.2
	in Dregs	56.6	67.1	49.0	56.3	10.5
	Total	83.4	82.6	86.6	85.4	65.7
	Energy Lost	16.6	17.4	13.4	14.6	34.3

Biological matter can be utilized in several stages. Edible biomatter can firstly be utilized as raw material for producing foodstuff, such as starch, bean productions, wine, etc. And then, distillers grains, starch grains are further utilized as feed for poultry and livestock. Finally, excrements of human being and livestock are used to produce bio-gas by anaerobic fermentation. The liquids in the bio-gas digester contains abundant microbes after anaerobic fermentation. Such microbes contain high protein and are suitable to cultivate plankton microbes which could be used as baits for fishpond or used as feed for pigs to promote their growth. The residues in bio-gas digester could be used further to breed earthworms. The earthworm is also a high quality feed for poultry, such as chickens and ducks. The residues forced in breeding earthworms are high-quality organic fertilizers. As shown in Table Ⅱ-19, the energy efficiency for planting mushrooms by straw powders, breeding pigs by residues, producing bio-gas by fertilized pig excrements is 51.4 %. The energy efficiency for producing bio- gas fertilized straws, breeding of earthworms by residues and using earthworms as feed, is 33.5 %. The same for production of bio-gas by fertilized straws, planting of mushrooms by residues from bio-gas digester breeding pigs by residues and production of bio-gas by pig excrements, amounts to 55.2 %. The above mentioned utilization of bio-matters resources can not only make the best use of the energy fixed by living beings during photosynthesis but also increase the processed products, expand production and improve the income of farmers. Meanwhile, high quality organic fertilizers are obtained and positive agricultural ecological circulation is archived, which has reasonable advantages for the improving of rural environmental sanitation and the developing of rural economy. An overall approach of solving rural energy consumption for livelihood, fertilizers and feeds simultaneously with increasing rural economic income is shown in Fig. Ⅱ-6.

Ⅱ—6 Biological agricultural circulation centred as biogas

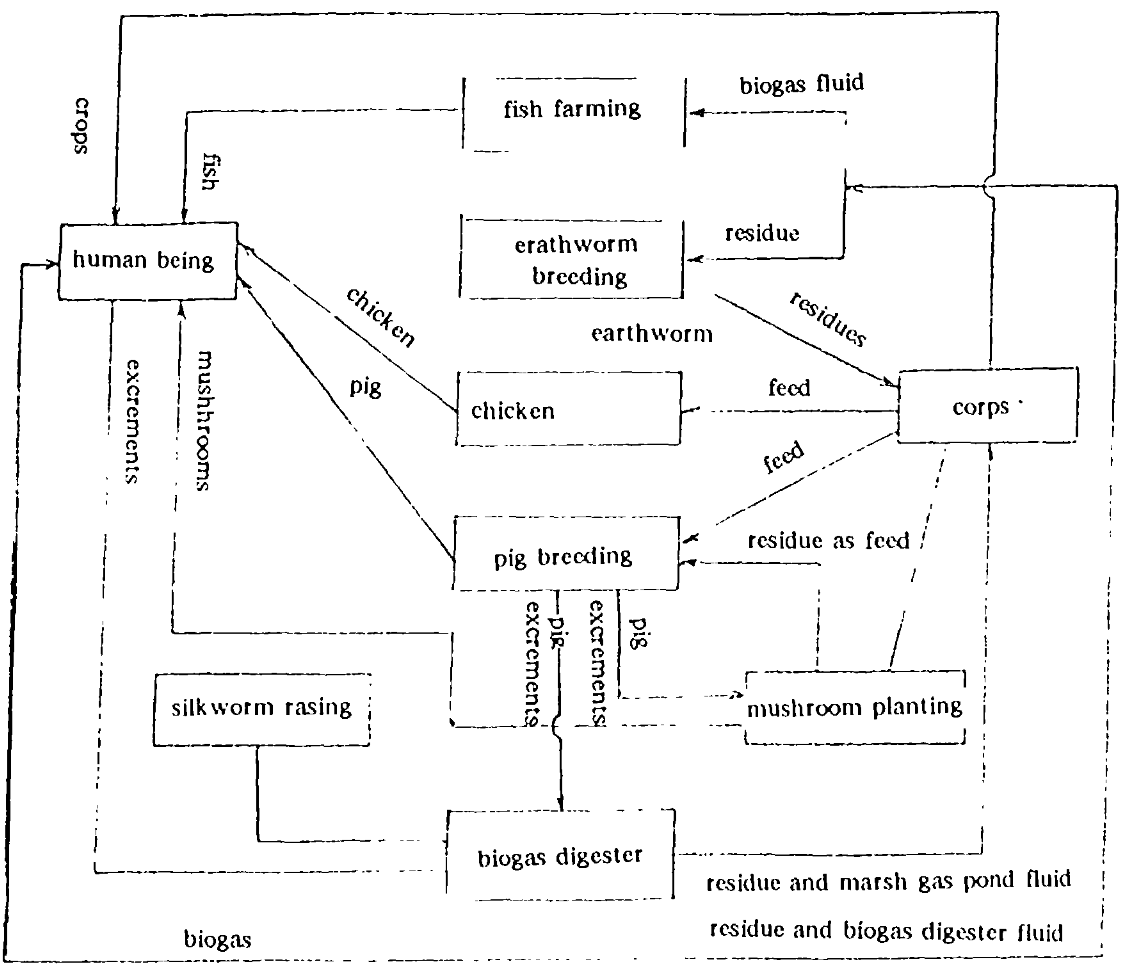

Table Ⅱ-18 points out, the energy transferred to usable products during each transformation of bio-matters amounts to 10-14 %. A certain amount of energy is consumed in the breaths and activities of living beings. Therefore, from the point of view of utilization of energy, the number of transformations should not be too small for the sake of fully utilizing the energy and increasing the economic effect. However, the number of transformations should not be too big. In this case, though bio-matter energy is fully utilized, more energy will be lost and economic effect will be degraded. So, we have to investigate and analyze the various bio- matter utilization models, which are appropriate to different local conditions, so as to make good use of the energy while maintaining good economic effect and ecological environment effect.

In February, 1991, a pig breeding/excrement-processing system was established in Shen Zhen. These are 6500-7000 pigs breeded and an excrements fluid of $200m^3$ is processed. The latter, after anaerobic fermentative, provides bio-gas of 210-320 m^3/day. Furthermore, 10 ton of organic complex chemical fertilizer, vegetable fertilizer, fruit tree fertilizer are produced daily as well. The bio-gas provided heating to the pig-breeding sheds and chicken-breeding sheds as well as provides electricity, which saves 110,000 KWh of power supply and 60 ton of coal. The organic fertilizer production provides an annual income of 240,000 yuan. And, the total investment could be returned in 2-3 years.

The excrement fluid contains BOD of less than 50mg/liter after aerobic fermentation and then oxygen-enriched and physic-chemical treatments. Various models of comprehensive utilization of bio- matter in multiple stages with bio-gas as its core are explored in rural area of China in accordance with the local features of agriculture, animal husbandry and sideline productions as well as agricultural ecology. Such comprehensive models bring in as much energy resources as possible, agricultural and sideline products and economic effect which play an extremely important role in promoting and consolidating bio-gas digester utilization for rural household.

c. Thermo-decomposition and gasification

The upsurge and decline of development process of gasification technology for bio-matter in China closely relate to the status of demand and supply of energy resources. This is similar to the development in various countries worldwide.

Early in the 40′s (in the period of the 2nd world war), when gasoline was short in supply, people in south-west mountainous area of China and inland townships had produced burnable gas from gasified charcoal and hard wood to drive cars for civil transportation. In the year of mid 50's to 60′s, when China petroleum products relied upon imported "foreign gasoline", some urban and natural transportation cars, trucks and electric power stations utilized gasified wooden fuel to drive internal combustion engines, called gas engines.

Up to now, air is used as gasification media in all practical bio-matter gasification devices. The product is also called air gas. Such gasification furnace is simple in construction and easy is to operate, despite its low heat values. As up suction type gasification was used, then, the tar and water contents are quite big in the gas when wooden fuel is used. This would block up the pipes. And, it has strict limitations to the fuel materials. Gasification efficiencies are low for such arrangements. So, in the late 60′s, they were replaced by diesel engines and electric motors.

Along with the increase of the energy demand, and the continuously increasing wasters from agriculture, forestry and inducting productions, new bio-matter utilization approaches and new ecological environment protection have to be exphoned. So, new meanings have been attached to the development of new generation gasification technology.

In the early 80′s, China began to develop gasification devices for bio-matter, corresponding to diversified fuel resources. The features of such new generation gasification devices are compact size, practical, simple, durable, reliable and adaptable to township enterprize. The features in comprehensive technical performance are:

(1) adaptability to multiple functioning operations, including utilizations, such as stoving, heating and generation of electricity.
(2) adaptability to diversified fuel resources, including fuel of crashed, soft, and dispensed materials such as sawdust, nice husks. the range of energy output is $20 \times e^4$ KWh; gasification efficiencyis 75 %.
(3) Utilization of fixed bed type in construction which is simplicity in structure; emphasis is put on practicability, reliability and durability; possible of operation by unexperienced worker.
(4) Setting up of mathematical models for energy equilibrium of gasification mechanism. Temperature distribution graphs for gasification precesses is made possible by micro-computer data acquisition and manipulation.

Gasification technology for bio-matter in China has been developed for more then 10 years as supported by the government authorities. The important point in the future is to step forward from the research and development of photo type machines, to enter into the market and to establishes sizeable enterprise with the market demands as internal primitive power for development. In 1988, a kind of down -suction gasification range was put into small-batch production. Such range have 500-650 kilo-joules per hour of energy output and 600 mm of range-chamber diameter. They have been sold out and are welcome by customers for the stoving of wood plates using residues of wood furniture factories.

The utilization of gasification of bio-matter for power supply is at present still in the period of test stage. The institution under the Ministry of Commence of China participated the technical conference for the utilization of rice husks in Asian-Pacific countries organized by FAO in 1982 in Bangkok and, furthermore, took part in the design of a 60 KW generators sponsored by FAO. Before that, a gasification electric power station was developed by using of rice husks in rice milling factories in Wu County of Jiangsu province. The power rating reached 140-160 KW. It was a single unit and was not yet manufactured in batch and sold.

The gasification ranges developed in China are classified into two types from the point of view of gasification: upsuction type and downsuction type.

The features of upsuction gasification stoves are: simple in construction, distinct layers of gasification reaction and completeness of gasification. The disadvantages are big amount of tar and water in gas and low quality of gas. The measure of increasing reaction temperatures was adopted in design. Conducting the water and tar to the gas inlet system to take part in burning reaction is a new measure to lower the tar and water content. On the opposite, downsuction gasification ranges provide clear gas with high contents of H_2 and CH_4, high heat values and good quality of gas. They are adaptable to drive internal combustion engine and to achieve high level thermal energy utilization. The type ND-600 gasification range has a gasification temperatures of 1200-1300 C, and content of H2 13.84%, a content of $CH_4+C_nH_m$ of 5% and a gas heat value of 6.28 Mj/m^3. The disadvantages are lack of distinct reaction boundaries, difficulty in controlling of reaction layer and bigger residual carbon content than upsuction type rangers. Furthermore, reaction temperatures are too high with too high heat loading in the range. In order to improve gas quality in such gasification ranges, short flame columns are used, and special inlet system is used to lower down the thermal load of the range chamber.

The rapid development of China township enterprise results in great energy demand. Along with the shortage of oil and electricity and the price rises of coal, the gasification technology of biological matters has obtained more places in the market. Comparing the above products with other well developed products, one could see that only ND-600 type gasification range has its product manufactural in small quantities and been sold to market. Only a single model is developed, and, only a single function is available. No professional factory with reliable manufacturing technology is formed. Nor are there channels for product circulation. Technical training and complementary services are still under Explanation. Research and pilot experiments are also underdeveloped. The institutions which are engaged in this development and have contain research bases and conditions, are the China Agricultural Mechanical Research Academy (downsuction type) in the north and the Guangzhou Energy Resources Institute(upsuction type)in the north. On conclusion, continuous efforts are required as to form sizable enterprises for biological matter gasification technology.

d. Production of alcohol from biological matter

In order to solve the shortage of liquid fuels, China has developed a series of research on production of alcohol using biological matters. The most successful example is the experimental research of making alcohol from sweat sorghum (kaoliang) by Shenyang agriculture university. The university has developed by selection a breed of sweat gao liang with multiple functions and adaptable to both oil and grain, model "Shen-Tian-za-No. 2". For the fermentation process, a technology of fixed proliferation cells and a corresponding fermentation equipment with three stage cone-type fluid-beds are utilized. A pilot test with a capacity of 412-liter has been successfully completed. An industrialized manufacturing equipment, having annual production of 3000 tons, is under construction.

Although China has matured technology and experience in making alcohol from starch and sugar, the energy input often could not be in equilibrium with energy output. China has successfully developed a technology of "one-step fermentation" and low-temperature distillation which will gradually change the above mentioned situations.

The research on making alcohol with cellulose as raw material is now in the initial stage of exploration. Many research projects have been carried out in the breeding of high efficiency cellulose- decomposing enzymes and the cultivation of multiple-functioning new bacteria by gene engineering.

e. Research on energy crops

China is very rich in energy crops. The research mainly includes the selection of perfect wild plants and cultivation of perfect energy crops. Furthermore, experimental research is also conducted in producing biological diesel oil by utilization of the catalytic reaction of cotton seed oil with tung seed, shiny-leaved yellow horn and oil-sand bean.

4.3 Analysis on economics of the technology

As same with other applied technologies the spread and application of bio-matter energy technology are quite dependent on its economics effect and environmental effect. For example, the utilization of alcohol technology could reduce import of the crude oil. The development of bio-gas could reduce pollution and protect ecological environment. On this basis, the relevant authorities have adopted some favorable policies, such as deduction of taxation and loans with paid interests.

Generally speaking, it will cost 30-50 yuan of RMB to change on old-firewood range to a firewood-saving one. In the under development areas, the cost will be lowered by using cheap materials. In developed areas, it costs higher, if ceramic files are used. Theoretically speaking, the save in firewood is about one ton per year, which costs 50-100 yuan, if calculated at country- fair prices. The cost saved in less than one year will be equivalent to the investment for the range reform. But, most farmers do not buy firewood, as they are not able to get actual monetary income by using firewood-saving ranges. Therefore, they are not so interested in range reform, except those farmers who do buy firewood. It is a common practice that governments at various levels, aiming at improving ecological effect, promote the range reforms by offering certain subsides and technical support. The economic evaluation of family bio-gas digesters has the same situation. Theoretically calculating, it costs roughly 300 yuan of investment to set up a 8 m bio-gas digester, with an annual maintenance fee of 10 yuan. If the digester has an average operation period of 8 months in one year, the firewood saved from the bio-gas in cooking, amounts to 1300 Kg, which costs 78 yuan at a price of 0.06 yuan per kg. If used in lighting, 4 yuan of kerosene will be saved, which provides totally a 82 yuan profit. As analyzed in Table Ⅱ-20, the investment and its interest could be returned in less than 7 year. But practically, farmers do not buy firewood. When they use residues to the lands, chemical fertilizers are saved. Thus, farmers do not actually recognize the increase monetary income. So, despite the tremendous social effect and ecological effect of bio-gas, direct economic effect confirmed by the farmers remains not obvious.

Table I-20 Economic analysis of family bio-gas digesters

unit: yuan(RMB)

Year	Remainder from last year	Interest to pay in the year(%)	Annual maintenance fee	Annual income	Fee to pack back in next year
1	300	18	10	82	246
2	246	14.8	10	82	188.8
3	188.8	11.3	10	82	210.1
4	210.1	12.6	10	82	150.7
5	150.7	9.0	10	82	87.7
6	87.7	5.3	10	82	21.0
7	21.0	1.3	10	82	49.7

Regarding big bio-gas engineering projects with central supply, the economic effect mainly depends on the prices of alternative energies. For example, the Chong Ming Dao Progress Farm has established 65 digesters of 50 m^3 each, supplying 720 customers. The investment was 547,000 yuan at an interest of 6%. The maintenance fee of bio-gas digesters and their supply systems was 6600 yuan. If the coal saved would be worth 40,000 yuan, the investment is very difficult to return. if the bio-gas is priced 0.3 yuan per m^3, and total annual production is 288,000 m^3, it only take one year to return the investment and the interest. furthermore, the bio-gas project in ShenZhen produces organic fertilizer besides bio-gas, the total investment could be returned in 2-3 year. If the investment will be shared by the environmental project, the net investment for the bio-gas itself could be returned within a shorter period.

The investment needed for a rice husk gasification electric generation system of 160 KW is 800,000 yuan. The annual interest is 64,000 yuan at 8 %. The annual depreciation (15 year) and operation cost (5 %) amounts to 930,000 yuan. The annual salary expense is 10,000 for 5 persons. The total expenses amount to 163,600 yuan. The power generated each year is 160 Kw X 6000 Hr = 960,000 KWh; The price of electric power generated is only 96,00 yuan at 0.1 yuan per KWh for present industry power rating. Such an income could not balance the expense. If the power is at negotiated prices as available at many places, say 0.25 yuan per KWh, the income from power generations is 240,000 yuan, which will return the investment and its interest within 5 years. If the rice-husk ash could be sold, the recoupment period will be shortened.

According to a Brazil analysis of economic effect of bio-matter, the recoupment period is reasonable only if the oil is priced at U.S. $ 45 per barrel. Otherwise, the government has to adopt favorable policies for the spread and application.

5. Hydroelectric power

5. 1 Hydropower resources

China is rich in hydropower resources with numerous rivers on its vast territory. Based on the results of the 5 th national investigation on hydropower resources done during the period from 1977 to 1980, the theoretical hydropower potential in China is estimated to be 676 GW with an annual power production of 5920 TWh. Among those the installed capacity feasible for development is 378 GW with an annual power production of 1920 TWh which accounts for 16. 7 % of the world total feasible resources and ranks first in the world (Table Ⅱ —21).

In terms of per land area and per capita hydropower resources, China' s occupancy, however, is not the biggest. Per land area hydropower resources in China are only 39. 4 KW per square kilometer, ranking 11th in the world. While in Switzerland, Austria and Japan , which are the countries richest for per land area hydropower resources, the figures are 268, 220. 5 and 133. 3 KW per square kilometer respectively. Per capita hydropower resources in China are 0. 338 KW with an annual power production of 1719 TWh, which ranks 17th in the world and is lower than the average world level of 0. 435 KW with an annual power production of 1885 TWh.

Table Ⅱ-21 Hydropower resources in China and other continents of the world

continent or country	feasible installed capacity		hydropower resources feasible for development	
	GW	%	TWh	%
world total	2261	100	9800	100
Asia	684	30. 3	2640	26. 9
Africa	437	19. 3	2010	20. 6
North America & Central America	331	14. 6	1490	15. 2
South America	288	12. 7	1640	16. 7
former USSR	269	11. 9	1090	11. 1
Europe	215	9. 6	720	7. 4
Austratria	37	1. 6	200	2. 0
China	378	16. 7	1920	19. 6

Information sources:

1. Except Chinese information, others are quoted from "Energy Resources Investigation", Conference on World Energy.
2. Chinese information is quoted from "Results of Investigation on Chinese Hydropower Resources", 1981.

Though China's hydropower resources are abundant, their distribution is extremely uneven and location is far away from the east coast region where economy is fairly developed. Hydropower potential is decided by both the head and the runoff of rivers. The topography of China features that the ground surface is higher in the west than in the east and the ground slopes down from the Qinghai-Xizang plateau in the southwest and the Pamirs in the west gradually to the east, while the precipitation decreases gradually from the southeast to the north west. As a result the head of rivers is higher in the western part and the runoff is richer in the southern, the distribution of hydropower resources in regions is inhomogenous. 70% of the national hydropower resources concentrates in the southeast region. The second place in the hydropower resources possessions is held by the mid-south and the north east regions where the proportions are 15.5% and 9.9% respectively. While in economy developed regions, such as East China, Northeast China and North China, the proportion altogether only accounts for 6.8% of national hydropower resources (see Tab. Ⅱ-22). The distribution of hydropower resources in river systems , shown in Tab. Ⅱ-23, ranks Changjiang river first, the proportion of which is 53.4% of national hydropower resources.

Table Ⅱ-22 Distribution of hydropower resources in regions

Region	Theoretical potential GW	Feasible for development		Share in national feasible hydropower production %
		installed capacity GW	annual output TWh	
North China	12.30	6.92	23.23	1.2
Northeast China	12.12	11.99	38.39	2.0
East China	30.05	17.90	68.79	3.6
Mid-south China	64.08	67.43	297.37	15.5
Southwest China	473.31	232.34	1305.04	67.8
Northwest China	84.18	41.94	190.50	9.9
Whole country	676.04	378.53	1923.30	100.0

Note: The figures in Taiwan are excluded.

Table Ⅱ-23 Distribution of hydropower resources in river systems

Region	Theoretical potential GW	Feasible for development		Share in national feasible hydropower production %
		installed capacity GW	annual output TWh	
Changjiang River	268.02	197.24	1027.50	53.4
Huanghe River	40.55	28.00	116.99	6.1
Zhujiang River	33.48	24.85	112.48	5.8
Haihe & Luanhe River	2.94	2.13	5.17	0.3
Huaihe River	1.44	0.66	1.89	0.1
Rivers in Northeast China	15.31	13.70	43.94	2.3
Rivers in Southeast coast region	20.67	13.90	54.74	2.9
International rivers in southwest region	95.90	37.68	209.87	10.9
Yaluzangbu River & other rivers in Tibet	159.74	50.38	296.86	15.4
Rivers in north interior & Xinjiang	34.99	9.97	53.87	2.8
Whole country	676.04	378.53	1923.30	100.0

Note: The figures in Taiwan are excluded

5.2 Hydropower Development

Since the founding of the People's Republic of China, rapid advances have been made in hydropower development. In the past forty years, the installed capacity has increased by 25 times, up from 0.16 GW in 1949 to 36 GW in 1990 and the annual hydropower production has increased by 180 times, up from 0.7 TWh in 1949 to 126.4 TWh in 1990. The proportion of hydropower installed capacity in the total installed power capacity has been raised from 9% in 1949 to 26% in 1990. As to the proportion of hydropower production, converting into standard coal, in the total national output of unrenewable energy, the percentage reached 4.8 in 1990 as against 3 in 1949. All these figures indicate the relatively rapid growth of China's hydropower development. In comparison with industrial developed countries and developing countries rich in hydropower resources, the growth rate of China's hydropower development, however, is still slow and a full play has not given to the superior hydropower resources yet. The data in the Tables Ⅱ-24 and Ⅱ-25 reflect the proportion of hydropower production in the national total power production and the developed level of hydropower resources in some countries of the world by the end of 1988 respectively.

Table Ⅰ-24 The proportion of hydropower production in the national total power production in some countries of the world

unit: %

Country	years							
	1935	1940	1945	1950	1960	1970	1980	1988
World				35.6	29.6	23.5	21.3	18.9
Canada	98.3	98.1	97.5	96.3	92.3	76.6	68.4	60.8
Italy	97.3	92.1	97.1	92.7	85.7	37.5	26.7	20.3
Japan	76.8	70.5	89.1	85.2	53.0	22.8	16.0	12.7
France	52.2	63.6	55.7	48.7	55.9	40.2	28.4	20.1
USA	35.5	28.7	31.2	25.9	17.7	15.3	12.0	8.0
Norway				99.7	99.3	99.4	99.8	99.6
Sweden				95.4	89.5	68.5	64.3	48.1
Brazil				91.4	80.4	87.7	87.0	93.0
India				36.7	39.0	41.3	37.5	21.8
Former USSR	14.0	10.6	11.2	13.9	17.4	16.8	12.7	12.5
China				17.4	12.5	17.7	19.4	20.0

Table Ⅰ-25 The developed level of hydropower resources in some countries of the world

country	hydropower resources feasible for development		hydropower production in 1988		
	TWh	%	TWh	share in the world (%)	developed level (%)
World	9700.0	100	2086.6	100	21.5
Norway	121.0	1.25	108.9	5.2	90.1
Italy	50.6	0.52	40.7	2.0	80.4
Sweden	100.3	1.03	70.4	3.4	70.2
Japan	130.0	1.34	95.9	4.6	73.8
Canada	535.2	5.83	306.5	14.7	57.3
USA	793.1	8.17	229.1	11.0	28.9
Former USSR	1095.0	11.3	229.1	11.0	20.9
Brazil	968.0	9.98	199.1	9.5	20.6
India	280.0	2.89	51.9	2.5	18.5
China	1923.3	19.79	109.1	5.2	5.7

After China's reform and opening to the outside world, the shortages of electric power which have been one of the factors restricting the economy and social development for many years become more serious, therefore, the development of China's hydropower resources is pushed forward further and a detailed project of hydropower construction has been set up by the State. The goal of national total installed capacity by the end of 2000 is 220-240 GW with an annual power production of 1100-1200 TWh. At that time, the hydropower installed capacity will be over 50-60 GW, accounting for about 20% of national installed capacity and the energy of hydropower production is equivalent to the energy of 150 million tons coal, nearly 10% of hydropower resources will be developed.

In order to meet the demands of development and utilization of hydropower resources after 2000, the goverment departments concerned drafted a national plan for developing 12 large hydropower bases and 30 large hydropower stations in 1989. These hydropower construction projects amount to half of our country' s hydropower resources feasible for development. Summarized technical and economic specifications are listed in Tables Ⅱ-26 and Ⅱ-27. The amount of invested capital shown in tables is that of static invested capital in terms of a 1988 constant price. It can be seen from Table Ⅱ-26, the Table of Technical and Economic Specifications of 12 Large Hydropower Bases, the invested capital per KW is 1528 yuans which is close to the one of thermal power plant at the same year. From the sepecifications of 30 large hydropower stations, the invested capital per KW is 1845 yuans for the total installed capacity of hydropower projects, 83 GW, including the Three Gorges Project. While for the total installed capacity excluding the Three Gorges Project, 66 GW, the invested capital per KW is 1812 yuans which exceeds that of thermal power plant at the same period by more than 10 %. It shows there is a potential in China to develop hydropower with relatively good technical and economic specifications.

Along with the further deepening our country' s reform and opening to the outside world, the development of national economy will be accelerated. Modernization of industrial production and people' s life demands that the proportion of electricity consumption in whole energy consumption continuously increases. The tight supply of mineral energy, the raise in price of fossil fuel and the restriction of using mineral energy in large scale imposed by the requirement of environmental protection give obvious benefit to the development and utilization of hydropower resources. From those and the successful experiences of developed countries in developing and utilizing hydropower resources at an early date additionally, it can be predicted the priority of development must be given to the hydropower resources. The project of 12 large hydropower bases will be constructed and completed around the year of 2020. At that time, if the international enviroment is peaceful, it is possible to reach hydropower installed capacity of 200 GW, i. e. nearly a half of hydropower resources feasible for development will be utilized.

In the last 20 years, the installed capacity of small hydropower stations with capacity is less than 1 MW increased with a yearly growth rate of 7-13%. By the end of 1989, the amount of small hydropower stations in operation was 61593, the total installed capacity was 12. 4 GW , accounting for 11% of the total national electric industry, and the small hydropower production was 34. 3 TWh, accounting for about 6% of the national total power production. As one of the most practical and efficient rural energy, small hydropower has been playing an important role in the process to realize electrification of Chinese countryside. Nowadays, 1/5 - 1/4 of electricity consumed in countryside is provided by small hydropower. Of the 2300 counties in China, 800 counties depend mainly on small hydropower stations for electricity. Judging by the requirement and possibility of engineering equipment and equipment supplies, the total national installed capacity of small hrdropower will hit over 20 GW, that means 10 GW installed capacity will be added during the next few years.

5. 3 Changjiang Three Gorges Project

In April 3d, 1992, the 5th session of the 7th National People' s Congress approved listing the construction of the Three Gorges Project in the country' s 10-year programme for economic and social development and authorized the State Council to choose an appropriate time in the light of the reality of the national economic development and the nation' s material and economic resources for organizing the implementation of the Project. This is a key project, which would accelerate the process of our country' s four modernization, enhance the national overall strength and increase the staying power for China' s development during the 21 century.

The earlier stage work of the Changjiang Three Gorges Project has started since the beginning of the 50s, thanks to the concern of our top leaders of older generation, Mao Zedong, Zhou Enlai and others. In the last 40 years, the departments related and a large number of scientists and engineers have done a lot of prospecting, research, design and experiments on the Project. Especially since 1984, some lingering questions, such as resettlement of million displaced people from reservoir area, ecological and environmental protection, siltation in the upper reach as well as collection and recovery of colossal fund etc. , have been reviewed and justified. So far, the key problems which need to be studied and solved are basically clear and a solution for problems has been worked out. The construction programme is being perfected , since the valuable opinions and suggestions from various social circles have been considered and incorporated.

After several years' research and justification, the Sandouping township, Yichang city, Hubei Province, was selected as the Three Gorges' dam site. Whole construction will mainly consist of dam, hydropower plant and navigable buildings. A concrete gravity dam will be adopted, the total length of dam is 1983 meters, the elevation of dam top 185 meters, the maximum dam elevation 175 meters, the normal water storage level of reservoir 175 meters and the total storage capacity of reservoir 39. 3 billion cubic meters. 26 units will be installed in the hydropower plant, the capacity per unit is 680 MW, the total installed capacity is 17680 MW and the annual power production averaged in terms of many years is 84 TWh, accounting nearly 1/8 of the present power production in our country. The total invested capital for the Project is 57 billion yuans in terms of a 1990 constant price, of which 29. 8 billion yuans for key water control construction, 18. 5 billion yuans for resettlement of displaced people and 8. 7 billion yuans for transmission and transformation construction. Three years more are needed for preparation of the Projcet' s construction. The main part of construction will totally take 15 years to complete and in the 9th year the first units will start generating electricity.

In addition to the significant role played in the flood control and the improvement of navigable ability of the Changjiang river, the Project also contributs a large comprehensive benefit of water generation, irrigation, water supply and economic development of reservoir area to the economy and society.

The scale of the Three Gorges Project is colossal, the technique is advanced and the technical level of some electric- machinery equipment is equal to or close to the world level. The construction of the Three Gorges Project will inevitably promote the development of water conservancy and hydropower science and technology further in our country and raise those construction to a higher new level.

Table I -26 Technical and Economic Specifications of 12 Large Hydropower Bases

Name of base	total scale		average inundated field per KW (mu/KW)	average displaced population per KW (head/KW)	average invested capital per KW (yuan/KW)	installed capacity covered by investment (GW)
	installed capacity (GW)	annual output (TWh)				
total	210.47			1528	158.34	
1. Jinshajiang River	47.89	261.08	0.008195	0.005998	1203	15.00
2. Yalong River	19.40	118.14	0.003445	0.003029	1265	11.20
3. Daduhe River	18.51	100.96	0.005060	0.008296	1627	18.05
4. Wujiang River	8.68	41.84	0.017394	0.017155	1584	8.67
5. Upper reach of the changjiang River	28.32	135.99	0.020234	0.041063	1828	24.29
6. Nanpanjiang River Hongshuihe River	13.12	53.29	0.015533	0.016365	1246	13.12
7. Main stream of the lanchangjiang River	21.37	109.40	0.013010	0.004130	1147	14.31
8. Upper reach of Huanghe River	14.16	50.79	0.025783	0.016079	1238	14.15
9. North main stream of the Huanghe middle reach	6.09	19.29	0.018377	0.011471	1873	6.09
10. Western Hunan Province	7.92	31.69	0.013263	0.011780	3252	6.57
11. Fujian Zhejiang & Jiangxi Provinces	14.17	41.17958	0.226321	1496	14.04	
12. Northeast China	11.32	30.87	0.059042	0.015088	1409	12.85

Table Ⅰ-27 Main technical and economic specifications of 30 large hydropower stations

No.	Name of power station	location in river	capacity (GW)	output (TWh)	losses for inundation		static total invested capital (billion yuan	remarks
					* (head)	** (mu)		
1	Laxiwa	Huanghe	3.72	9.74	173	186	5.14	
2	Gongboxia Gongbo Gorge	Huanghe	1.50	4.96	2990	6049	2.54	
3	Xiaoguanyin or Daliushu	Huanghe	1.40	4.60	55329	46112	3.03	
4	Wanjiazai	Huanghe	1.02	2.63	2429	4251	1.54	total capital invested only for power plant
5	Qikuo	Huanghe	1.80	5.15	53700	78300	2.40	
6	Longkuo	Huanghe	2.10	7.95	4351	19355	3.66	total capital invested only for power plant
7	Xiaolongdi	Huanghe	1.56	5.10	135700	170100	5.20	
8	first cascade of Tianshengqiao	Nanpan-jiang	1.20	5.23	38892	35819	2.58	
9	Longtan	Hongshui-he	4.20	15.67	72104	50178	6.05	32879.5 mu resting in turn field inundated in addition
10	Datengxia (Dateng Gorge)	Hongshui-he	1.20	6.43	23138	37400	3.69	
11	Xiluodu	Jinshai-jiang	10.00	54.00	29700	35400	13.39	inundation losses only for power production
12	Xiangjiaba	Jinshai-jiang	5.00	28.20	57000	31000	8.84	
13	first cascade of Jinping	Yalong-jiang	3.00	18.20	2000	2500	6.25	
14	second cascade of Jinping	Yalong-jiang	1.5/3.0	1.4/21	a few	a few	5.20	first phase/ second phase
15	Pubugou	Daduhe	3.30	14.43	62000	38000	4.82	
16	Gongzui (heightening)	Daduhe	2.06/0.7	10.1/3.4	/	/	2.71	after heightening/present
17	Zipingpu	Minjiang	0.65	3.17	19672	9227	1.61	
18	Hongjialiu	Wujiang	0.54	1.57	32764	21700	1.35	
19	Guopitan	Wujiang	2.00	3.89	19728	26877	3.94	
20	Silin	Wujiang	0.84	4.11	7865	9045	1.61	

21	Pengshui	Wujiang	1.08	5.77	14329	13421	2.34	figure of displaced population planned for the year of 2008
22	Three Gorges	Chang-jiang	17.86	84.00	1130000	431300	34.79	
23	Buwan	Lancang jiang	4.20	18.78	28700	34900	6.79	
24	Dachaoshan	Lancang jiang	1.26	5.52	5970	9840	1.81	
25	Nuozadu	Lancang jiang	4.50	23.11	14800	36000	6.65	
26	Sanbanxi	Qingshui jiang	0.68	2.26	17200	4100	1.91	
27	Shiti	Xishui	0.90	1.37	38300	42100	1.66	
28	Pankou	Duhe	0.51	1.37	38300	42100	1.66	
29	Shuibuya	Qing jiang	1.49	0.98	21838	35272	0.83	
30	Yongding (Mainhuatan)	Ting jiang	0.60	1.51	34622	38160	0.99	
31	Mohe	Heilong jiang	2.00/2	5.85/2	200	2000	2.37	/2 means each half for former USSR and China, both inundation and investment only for Chinese side
32	Lianhe	Heilong jiang	1.00/2	3.13/2	5400	21100	1.65	
33	Taipingguo	Heilong jiang	2.00/2	7.77/2	/	/	2.93	
total (Three Gorges included)			83.28	373.96	1940694	1300392	153.69	
(Three Gorges excluded)			65.61	289.96	810694	869092	118.90	

* - displaced population
* * - inundated field

6. Geothermal energy

6.1 Resources

The distribution of geothermal resource depends on the geotectonics, especially the volcanic activities and earthquakes in China, there are 5,500 geothermal outcrops identified, including some 3,000 hot springs and 2,500 wells. The high-temperature geothermal resources are centered mainly in southern Tibet, western Yunnan and eastern Taiwan. They are so called Yunnan-Tibet High Temperature Geothermal Zone and East Taiwan High Temperature Geothermal Zone respectively, and also they belong to Mediteranean-Himalaya Geothermal Zone and Surrounding Pacific Geothermal Zone respectively in the global point of view. According to the preliminary survey, there are over 120 of high temperature geothermal reservois within these two zones. The high temperature geothermal fields which were/are being explored are: Yangbajing, Naqu, Ali Yangyinxiang geothermal fields in Tibet; Ruidiań, Rehai geothermal fields in Yunnan; Tuchang, Qingshui, Datun, Lushan geothermal fields in Taiwan.

Yangbajing Geothermal Field is of steam-water type, which has been exploited first in mainland since 1970s. The well temperatures of the shallow geothermal reservoir at this field reach 145 ~172 ℃ and the pressures at the well head are 3~5kg/cm^2. A water temperature of 202 ℃ at 1000 m deep was measured in 1988. It may indicate a great potential for expanding the electrical power in this field.

The Ruidian and Rehai fields in western Yunnan have long been the focus of geothermists' attention at home and abroad due to their strong geothermal manifests there. With the temperature of geothermal reservoir over 200℃ calculated by geothermal thermometer, these fields have large potential for power generation.

The low-moderate temperature geothermal resources are widely spread throughout China mainly existing beneath deep fault basins and subsidences basins in different sizes. There are 37 basins with each area of 10,000 km such as North China Basin, Songliao Basin, etc. Five hundred artesian geothermal wells have been drilled along with oil exploration at North China Basin, for instance, over 20 wells of 70~98℃ and about 2,000 t/day at Gudao, Hekou of Shengli oil field; hot water or salt water of 80~90℃ from Sichuan Basin and Jianghan Basin at depths of 2,000 to 3,000 m; one well of 73 ℃ and 300t/day at Daxing County of Beijing; as well as 20 wells at Dagang oil field with temperatures ranging from 70~97.5℃ and maxium flow rate over 5000 t/day. In addition, the distribution of geothermal resources along the eastern coast with characters of shallow bed and in good quality are related to the active geothermal structure. Most of them are located at populous areas, thus the uses of geothermal resources there appear worthwhile.

According to the rough statistics, the natural heat discharge of hot springs is 11.1×10^4Tj/yr, and the total geothermal resource estimated to about 32×10^5 MW, in which, the electrical power potential is estimated over 1000 MW.

6. 2 Electrical use

Since the construction of the first geothermal power plant at Fongshun, Guang dong Province, eight geothermal experimental power plants have been under development at Yichun of Jiangxi Province, Huailai of Hebei Province, Huitang of Hunan Province, Yangbajing and Ali of Tibet, etc.. Most of the power plants are operated by water energy conversion under the temperature below 100℃, except Yangbajing (145~172℃) and Ali (about 110℃). However, those power plants do not run in a cost effective way. At present, only Alee, Fongshun, and Huitang power plants work intermittently. The total electrical capacity in China is 20. 88MW at the end of 1989.

Yangbajing Geothermal Power Plant was constructed in 1977. At the end of 1989, the capacity reached 19. 18Mw and now it plays a key role of power supply in Lhasa area. Its deep reservoir has been explored and a deep well of 202℃ was drilled out in 1988. It would show the bright future for expanding the electrical capacity in this area.

6. 3 Direct uses

Since 1970's, China has widely utilized the low- moderate temperature geothermal energy for industrial processing, greenhouse, fish farming, bath, spa and space heating, etc. According to the rough statistics, the total energy consumption of direct uses is 41,222 TJ/yr while the beneficial heat is only 7,198 TJ/yr, figuring 17. 5%. The greatest energy consumption is for fish farming, 46. 8% of the total. As an alternative energy source, geothermal energy has been recognized and accepted by local people and makes contribution in national economy.

a. Industrial use

The industrial uses of geothermal energy cover the following major fields: tannin extraction, hide processing, drying, paper making, dyeing, cooling, preheated boiler water, etc. , and have got socio-economical effects. For examples, the tannin extract industry in Yinshan County, Hubei Province, utilizing geothermal water (42~50℃) has saved 12, 800 tons coal per well within 12 years; geothermal water served for hide processing (66 ℃) in Xiongxian County, Hebei Province is equivalent to replace 5,000 tons of coal every year with a payback time of less than two years; people in Tengchong County, western Yunnan, utilize 92 ℃ water for soaking pulp and drying papers which are produced for export trade. The first absorption cooling equipment powered by geothermal hot water (92℃) was built in Fuzhou, prodcing 6 tons of ice bar every day for 173 m^3 of cold storage and 154 m^3 of vegetables storage houses.

At present, there are 49 geothermal projects for industrial application in China. Tianjin is the largest user mainly in dyeing industry and gets the benefits due to improving products quality and reducing cost comparison with using cold tap water.

b. Greenhouse

There are greenhouses using geothermal water with total area of 1. 16 km^2 in 17 provinces and autonomous regions, according to the report made at the end of 1989, in which, 0. 32 km^2 locating in Hebei Province. The total energy consumption is 512 TJ/yr.

Xiaotangshan greenhouse locates in the suburb of Beijing. It has an area of 43,290 m^2 heated by 48~52 ℃ geothermal water at three sites. It is famous for supplying dozens varieties of special vegetable to hotels and restaurants.

Forming an artifical micro climate using geothermal water in greenhouse, scientists of The Inst. of Geothermal Water for Agriculture Use of Fujian Provincial Academy have successfully done a series of experiments on flower transplant, variety germination etc. Using the drainage from power generation, Yangbajing Power Plant has built greenhouses of 50,000 m^2 for growing fresh green vegetables. It is the first time for the plateau people to enjoy the fresh vegetable during winter time.

c. Fish farming

The fish farming is a fast growing application in China. In the early stage, it was only used for aquatic products, such as african fish, eel, shrimp, turtle, … etc. , now it is expanded to breed poisonous snake and snail which can provide more economic benefits. There are 72 locations covering 17 provinces using geothermal water for aquacultural use. The total fishing area is 1. 6 km^2 and the annual heat consumption equivalent to 46. 4% of the total. Fujian Province is the largest fish breeder.

d. Space heating

There is 19 application projects for space heating in China with an annual energy consumption of 1,203 TJ. Tianjin and Beijing have got a floor area of 1. 1 km^2 heated by geothermal water, accounted 84. 5% of the total. Space heating project in Tianjin mainly centered in Tanggu, Hangu and Dagang districts. The total heated area reaches 805,000 m^2. Based on recent exploration, there are higher temperature geothermal water (70~92 ℃) at the depths of 2,000 or more. It could provide more space heating areas in Tianjin.

e. Public bath and spa

The uses of geothermal water for public bath and spa are not only earliest applications but also the fast developing utilizations in China. At present, there are 594 baths, 23 swimming pools, and 179 spas. People taking such bath and spa have got excellent medical effects in particular for skin disease, nerve system disease etc. . Fuzhou is called hot spring city by its abundant hot springs. There are 135 users over there, in which, 68 hot spring hotels, 2 geothermal water swimming pools and 1 hot spring park as well as 1 spa. It becomes an enjoyment for the local people and visitors.

f. Others

In addition to the uses mentioned above, the geothermal resources are also used for hatching, irrigation and extracting minerals, etc. Geothermal resources in Tibet contain some valuable mineral resources like B, Li, Ga, Sr, etc. , however, they have not been extracted yet.

China is rich in geothermal resources. Among 5,500 locations, less than 1, 000 are utilized for various applications. Most of the applications are of direct use and the thermal efficency is very low. Thus China still needs many efforts in this field to follow up and adopt the modern technology applied in developed countries.

6. 4 Development and utilization of geothermal resources in tibet

On the great Tibet Plateau there is more than 1. 2 million km^2 with abundant geothermal resources. In the middle of 1970's comprehensive and systematical investigations to hydrothermal activities in Tibet started. Based on this arduous effort, records of the hydrothermal activities in Tibet have been renewed: the total number of hydrothermal areas increased sharply from 46 to more than 600, geothermal manifestations have been found nearby almost every county's township, and various impressive hydrothermal manifestations, such as hydrothermal explosion, geysers, furnaroles, boiling springs and spouters have been observed. These intensive hydrothermal activities is centered in southern Tibet between the Himalayas and Gangdise-Nianqingtanggulas, where is named the Himalayan Geothermal Belt because it was formed as consequence of the Himalayan oregenic movement since the Cenozonic era.

Tibet is critically short of such fossil fuels as coal and oil, and abundant hydropower resources will not be intensively exploitated in the near future. Howcver, numerous hydrothermal areas could supply the Tibetan people with rich geothermal power. After the development of Yangbajing geothermal field, explorative activities have been carried out in several other areas: Yangyixiang, Naqu and Langjiu. The preliminary results indicate an optimistic future in these areas. In order to accelerate the development of energy industry of Tibet, the exploration strategy of geothermal resources is focused on the deep reservoir searching out high quality geofluid and upgrading the capacity of geothermal power plant.

Beside geothermal field being explored, numerous other hydrothermal areas with electrical potential could be developed as energy bases for dispersed towns and industries in Tibet. More than 20~30 hygrothermal areas are situated near a county's suburbs within 20~30 km, such as Ga'er, Geji, Jilong, Dingri, Lazi,Sajia, Xietongmen, Nielamu, Dangxiong, Cuomei, Anduo, Nierong, Angri, Baqing, and Chayu, etc. , where small geothermal power plants could be developed.

Yangbajing is the largest geothermal power plant in China's mainland, which not only plays an important role in meeting the electrical demands of Lhasa, but also provides important information for disclosing the mysteries of this unique and youngest plateau in the world. Some 90 km from northwest Lhasa, Yangbajing geothermal field is situated in the southern part of the 4300 m high-altitude Yangbajing Basin, flanked by mountainranges of 5000～6000 m altitude on both sides—Mt. Nianqingtanggulas on the northwest and Mt. Tang on the southeast respectively. The Zhanbu River flows through from SW to NE and converges into the Yangbajing River. The Qinghai-Tibet and China-Nepel highways pass through east and north side of the field. The Yangbajing geothermal field has an area of 14.6 km^2. Drilling started in July, 1975. Sixty-one wells had been drilled with the depths of 42.6～1726.4 m(including shallow-explorative wells)by the end of 1988, and 10 of them serve as production wells at present. A downhole temperature of 202.2 ℃ was recorded, while the maximum temperature in production wells is 172 ℃.

Yangyii geothermal field is located on the border of Dangxiong County and Nimu County, about 60 km away from Yangbajing. Hydrothermal manifestations scatter along piedmont valleies of the Mt. Nianqingtanggulas. More than 40 boiling springs spread over a distance of 500 m in one of the valleies. After the exploration of Yangbajing, Tibet geothermal geological team started a systematical survey and drilling in 1985 there. A temperature of 201.8℃ was measured at 386 m depth in well ZK 203 in this field, which is the first record of downhole temperature over 200℃ on the China's mainland. Geofluid of 24 % dryness discharged from the well at a wellhead pressure of 890 kPa with the total flow of 237 t/h. The electricity generation potential of this well is estimated about 5 MW.

Naqu is respected as the gateway of northern Tibet, where a geothermal field is situated near the town Naqu geothermal field has been explored from 1984, four production wells in the centre of the field have been completed. Single well tests, interference tests were carried out in 1988. At wellhead, temperature is 105 ～110 ℃ and pressure is 1.96～2.45$\times 10^5$ Pa. The Government of Tibet Autonomous Region is planning to build a MW grade pilot geothermal power plant of twin cycle system at Naqu with foreign aids. The implementation of this project will not only meet the electricity needs of Naqu, but also serves as a demonstration for the approach to supply electricity to numerous townships scattering on the great Tibet Plateau with low-medium enthalpy geothermal resources.

Shiquanhe is a town of strategic importance in western Tibet. The people there has suffered from short of electricity till today and lighted with butters lamp and candle. Fortunately, some 30 km from the town lies in the Langjiu geothermal field, where drilling and construction of a geothermal power plant started in 1984, but the plant has not been put into commerical operation because of lacking necessary geothermal, geological, geochemical and geophysical surveys. However, based on the gathered geoscientific data, this field is believed to have the electricity generation potential of a few MWs and the capability to supply residents in Shiquanhe with electricity for daily life.

In addition to electricity generation, geothermal resources can be directly used for many purposes. The water from the Qiaga hot spring, for example, is channeled for use in greenhouse, a bathing room and a swimming pool at 8 km northwest of Xietongmen. The geothermal greenhouse covers more than 600 m^2 and is heated by a stream hot water. Consequently, spring-like growth occurs all-year round on the 4000 m high plateau.

The Cuona spring water runs beneath building foundations in the central town and flows through countless labyrinths—like channels under houses. Althrough heavy snow blocks the doors, spring warmth exists inside. Buckets of hot water 40~50°C in temperature can be hoisted from the underground springs.

With the developmnet of Yangbajing geothermal field, the comprehensive utilization of geothermal resources has been forged rapidly ahead. In the Yangbajing Basin, geothermal greenhouse stand one by another, covering an area of 40000 m^2, a district heating system will be completed recently for the living area of the power plant, and the "year round operating" bathrooms can be found all over the field.

The abundant geothermal, solar and wind resources in Tibet presents a challange to the Tibetan people. In the near future, many geothermal power plants, greenhouses and comprehensive new energy development centres will bring the "roof of the world" more light, more warmth and more vitality.

7. Ocean energy and hydrogen energy

7.1 Ocean energy

China has a vast territory with a sea area of more than 3 million km^2 forming a long coastal line of 32,000 km as well as with over 6,000 offshore isles. It is considered that China is rich in ocean energy resources with a potential of 400~500 million kW capacity. From geographical point of view, the eastern coastal area is suitable for developing tidal energy, the offshore isles for wave energy and tide-current energy exploitation, the South China Sea and coastal area of Taiwan Island for OTEC development, and the river coastal terminal for energy conversion from ocean salinity differenes.

a. Tidal electricity power conversion

In China, the utilization of tidal energy with modern technologies started in the year of 1956. Several tidal power stations were built in Fujian and Guangdong Provinces for pumping water for irrigation. After then, it entered the phase of tidal electricity. The development could be concluded in there different stages. The first stage could be dated back to 1958. At that time, 40 small tidal power stations with the capacity of dozen kilowatt were built. Another dozens of tidal power station with larger capacity were built in the second stage around the year of 1970, among them, Jiangxia tidal power plant and Baishakou power plant were the largest ones with the capacity of 3,000 kW and 960 kW respectively. Unfortunately, most of the tidal power stations built in those two stages were out of service due to wrong siting, backward technology and conflict service batween irrigation and navigation purpose, and inconvenience in use etc. At present, there are seven tidal power stations and one tideflood power station in operation with a total capacity of 11 MW. The third stage has started since the end of 1970's. The emphasis is put on the further improvement and scientific management on the existing stations, optimizing their economical and social benefits, inviting experts for site investigation for a 10 MW tidal power station and conducting experiments on comprehensive utilization on new and renewable energy resources in Pingtan Island of Fujian Province and Dachen Island of Zhejiang Province. The Xingfuyang tidal power plant in Pingtan Island built in 1985 with a total installed capacity of 1. 28 MW, was put into operation in May, 1989. The feasibility study of a 10 MW level intermediate experimental tidal power station in Jiantiao Port of Zhejiang Province and Daguanban Port of Fujian Province has been worked out. The planning of the Maluanwan tidal power plant is under way.

b. Wave energy power generation

Since the middle of 1970s, the wave energy power conversion research projects have progressively carried out in Shanghai, Guangzhou, Dalian, Qingdao, Beijing and Tianjin. In 1975, Shanghai Boiler Works developed a prototype of floating wave energy power generating device and tested it on sea site. Later on, Shanghai Research Institute of Hydrographic Bureau developed a four valuewave energy power conversion device for installing beacon light power supply and produced 10 sets in 1985 for demonstration. In the same year, Guangzhou Research Institutte of Energy Conversion of Chinese Academy of Sciences developed a prototype of BD-102 type wave energy conversion device with symmetrical wing air turbine for beacon light power which was filed a patent in National Patent Bureau and put fifty units of such new design into trial production in 1987 and distributed to the Hydrographic Departments in Guangzhou, Shanghai and Tianjin. Besides, the feasibility study and pilot study of the various kinds of coastal wave power experimental station for different coastal sites are under way. Among them, the Daiwanshan wave power pilot station with a capacity of 8 kW has been ready for its first generator of 3 kW. The feasibility study of Lanyu wave force power station has been completed by Taiwan Electric Power Company in March, 1989.

c. Tidal current power generation

For tidal current power generation, an experimental work was carried out in 1978 in Zhou Shan sea area for fundamental study. Two sets of electricity generation device with propeller hydraulic drive were installed, their power output reached 5. 7 kW under the maximum current flow rate of 3 m/s. Recently, some other novel tidal current power conversion systems are under further research and development in Qingdao and Harbin.

d. Oceanic thermal energy conversion

For OTEC, two projects of "Lifting Cycle by Fog Drops" and "Open Cycle of Oceanic Thermal Energy Conversion" are conducted in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences. An open cycle experimental OTEC system was built in 1986 with a temperature difference of 20℃ and using water as working medium.

Further development of ocean energy conversion in China should be carried out with following strategy in accordance with the China's concrete conditions:

a) The location of the installation should be carefully sited in those areas where the con-

ventional energy is not available.
b) In order to make tidal or ocean energy conversion becoming vital, the design of ocean energy conversion systems should be diversified for meeting different uses and demands, and the economics consideration should be seriously taken.

c) In recent decades, it is not possible to build commerical ocean power generstion systems. However, further demonstration in small and medium scale in coastal areas where the electricity grid does not reach seems feasible.

7. 2 Hydrogen energy

The history of research and development for hydrogen energy system in China can be traced back to early sixties. Chinese scientists have contributed a lot for the development of China's aerospace industries, such as liquid hydrogen production as the rocket fuel and the fuel cell application.

The era of hydrogen as an energy system and subsequent attempt for large amount of hydrogen use in transportation vehicles as a liquid and gas fuel alternatives have not yet attracted the scientific people's attention until the end of seventies. Owing to greenhouse effect and environmental and ecological impacts in the biosphere of the earth, hydrogen energy system becomes recognized as the potential candidate for future substitute of fossil fuel. Some universities and research institutes conducting the research of solar catalytic conversion of water to hydrogen (including photochemical and photoelectrochemical methods). Research of metal hydride hydrogen storage material and its practical application has been found wide field of investigation during the last decade. The majority of these achievements have been presented in the Proceedings of the International Symposium on Hydrogen System, 7～11 May 1985 Beijing, China.

In Sptember 1986, China Association for Hydrogen Energy was established in affiliation to the China Energy Research Society with the aim of dissemination mainly on an inexhaustible source of clean energy system—HYDROGEN.

A forum proposal was then made and signed by more than 30 Chinese prominent scientists and engineers with the primary view of alleviating the environment impacts and coal combustion and long term ecological influence including ozone depletion in the stratosphere etc. and emphasizing the necessity and urgent importance of strengthening research and development of hydrogen energy in China.

a. About the investigation of production processes

It is reported that a new hybrid thermochemical cycle in connection with the anodic oxidation of iodide in concentrated iodine-iodide solution, using rotary disc electrode technique is developed in the Research Institute of Resources Exploitation and Applied Technology, Wuhan University. The project has obtained a limited financial support from "The National Natural Science Foundation".

Shangdong University in cooperation with the University of Vienna, Austria, has produced a stable multilayer n-type silicon photoanode, modified by a thin Ni-film. Under irradiation with intense light at a constant potenial, during a period of 100 hours no appreciable decrease of photocurrent was observed. After long term anodic polarization under illumination the Ni_2Si layer is transformed into an NiO(OH) - amorphous film with rather high corrosion resistance and photoefficiency. The same university on the other hand by using MOCVD (Metall Organic Chemical Vapour Deposition) method studied the effect of TiO_2 and Fe_2O_3 thin film (in the form of $(C_4H_9O)_4Ti$ and $Fe(C_5H_5)_2$) coated on the surface of Pt/P moncrystalline silicon as a sort of surface modification. It is found that thin film can improve the stability of semi-conductor silicon in aqueous solution and imparts a catalytic property to the electrode in favour of hydrogen evolution.

In Xi'an Jiaotong University two experimental projects are in progressing—production of hydrogen both by utilization of solar energy and by electrolysis of water in electrolyte solution. A group of researchers in Beijing Petroleum University are devoting themselves to the development of a new electrolytic catalytic process for the production of hydrogen and organic compounds through oxidation of solid fossil fuels.

The Lanzhou Research Institute of Chemical Physics, Academia Sinica has been conducting the sacrificial system research, i. e. by photolysis of hydrogen sulfide and ROH in presence of Rh_2O_3/CdS, of which the preliminary result is considered encouraging, capable of improving the evolution rate photolysis and prolonging the life of catalyst.

The Beijing General Research Institute of Non-ferrous Metallurgy has beenexploring a simple method for the instanttaneous evolution of hydrogen by treating pulverized Al-alloy with dilute sodium alkali solution, the primary result being 1 m^3/kg alloy.

Investigation of hydrogen production through fermentation process has been undertaken in both the Research Institute of Microorganism, Academia Sinica and Food and Fermentation Research Institute of the Ministry of Light Industry on the basis of biological work for the production of methane.

b. About the new technology storage-research and development on metallic hydrides

Nankai University in Tianjin has chemically synthesized a series of Mg-base Hydrogen storage alloys possessing excellent surface properties and higher hydrogen storage capability than those prepared by direct metal-melting methods, e. g. easily activated, higher specific surfaces and lower temperatures for hydrogen absorption and desorption. A new type of storage battery with high energy density and capable of being used repeatedly about one thousand times is reported under exploitation. A new type H_2-air fuel cell is arranged in their research project.

The Beijing General Research Institute of Nonferrous Metallurgy has worked on the rare earth hydrogen storage materials and Ti-Fe alloy. It is noticeably mentioned that having solved the difficulties in the activation at room temperature was solved. Hydrogen vessels containing Ti-Fe alloy of various sizesm e. g. 0. 5, 1. 5, 2. 5, 3. 2, $10Nm^3$ have been made for sale, mainly used in the semi- conductor material production with high purity of 99. 9999%, in the atomic clock, in gas-chromatograohic carrier-gas supply and also in hydrogen-combustor trucks.

Shanghai Metallurgical Research Institute has investgated a Fe-Ti-Mn series of alloys for storing hydrogen and is able to supply the metallic hydride containers, from which high purity hydrogen, 99. 9999% is available. A continuous supply system of high quality hydrogen is now under investigation in the institute.

The Department of Material Science, Zhejiang University, Hangzhou has worked on the storing hydrogen materials mainly along the line of mixed rare earth elements (La, Ce, Pr, Nd)relatively rich in lanthanum. They are now trying to install a hydrogen compressor, characterized by having no moving parts. A metallic hydride system for the recovery of hydrogen in exhausted gas of synthetic ammonia plant is developed.

Research work on $Ti\text{-}Fe_xCr_y$ has been conducted in Shanghai University of Technology with respect to the interfacial changes of phase-matrix during hydrogen absorption-desorption cycles.

Metal hydride has widely been used in making heat pump, such as low-level heat sources upgrading heat pump and air conditioning and refrigerator without use of freon, while these kinds of hydride technology investigation have been carried out in some of the universities and institutes in China.

TiFe storage tank for hydrogen is now used in wind and solar energy storing, it is still in preliminary stage.

c. Industrial appliances of hydrogen

In Xi'an Jiaotong University, several research subjects are carried on in the field of hydrogen utilization, such as "Study on Hydrogen Combustion Power Cycle", "Utilization of Hydrogen in Space Technology", "Study on Hydrogen Combustion Flow Field and Performance Evaluation of Hydrogen Flame". A catalytic hydrogen combustion appliance is arranged in design offices, intended to assure itself of practical application for civil use in near future.

Hebei College of Technology, Tianjin has devoted his study to different kinds of theoretical cycle system using hydrogen gas combustion turbine in combination with the steam turbine. Because of its full utilization of low temperature energy in liquid hydrogen, the efficiency of the combined cycle and its power output are significantly enhanced.

A practical running test on bus by injecting 5% (by weight) of hydrogen to gasoline combustor was carried out in Tianjin University under the instruction of professors Shi Shaoxi and Li Housheng with little alteration of the original gasoline engine. The primary result revealed a saving of about 34% of gasoline fuel and of overall heat efficiency by approximately 15%. It is planned to use the by- product hydrogen from a water electrolysis plant as the substitute of gasoline to run the bus route from Tianjin to Tanggu where the exhaust hydrogen is available.

Ⅲ. Perspective and Suggestions in the Next Decade

1. A fast developing period of solar energy utilization

Due to worldwide shortage in energy resources, people naturally begin to realize that normal energy will not meet the people's demand in future. Mankind should rely on renewable energies such as water power, wind power and solar energy, etc. A great many experts have predicted the tremendous changes in the energy structure all over the world in the middle of the next century (2050). The situation is caused not only by the limitation in storage of fossil resources, but also by human being's concern about their own living environment. Now people have shared the common knowledge: a sustaining society should be one which can both meet the ever growing social demands at present and do no harm to their offsprings in future. It has been shown that remaining to depend on the fossil fuels will result in global catastrophic changes in climate. Therefore, we have to reduce the total discharge of carbon to two billion tons, namely 1/3 of the present amount to stabilize the global change. If we fail to realize this goal in the next 40—50 years, the deterioration of environment and depression of economics will render mankind's society falling into abyss of disintegration. Hence, to substitute mineral fuels by other energy resources as soon as possible is a task of top priority of the moment.

Emphasis on the development of new types of and renewable energy resources is a common policy of China and other countries the world over. According to the spirits of the UN International Environment and Development Congress held in Brazil in June, 1992, at which the premier of the Chinese government was present, the State Council has put forward ten measures, in which the term "raise the efficiency of energy utilization and improve the structure of energy resources" definitely indicates that we must speed up the development and popularization of clean energy resources such as solar energy, water power, wind power, earth thermal energy, tide energy and organic materials in line of the local conditions to cope with the problems of environment and development.

Not long ago, the State Economic Planning Committee financially aided by the World Bank has organized the experts in energy resources to conduct an investigation on "strategies looking for substitutes of fuels containing high carbon" and suggested some possible schemes to replace coal by clean energies directly till 2000, 2010 and 2050, respectively. The prediction of the study for 2000 is listed in Tab. Ⅲ-1 — Ⅲ-4.

In view of potential great advances in techniques in utilizing new types of and renewable energy resources, the merchandization of some more mature ones will be speeded up. They will be commonly accepted by comprehensive consideration of both economic and environmental benefits. It is estimated that the utilization of solar energy will develop more swiftly in the next decade.

Table Ⅲ—1

ALTERNATIVE ENERGY SUPPLY OPTIONS IN 2000 DIRECT SUBSTITUTION FOR COAL -BUSSINESS AS USUAL(IN 1990 YUAN)

	UNIT	TOTAL	COAL	OIL	GAS	BIO-MASS	NEW-BIOMASS	BIOGAS	SOLAR THERMAL	SOLAR HOUSE	SOLAR COOKING	GEO THERMAL
TOTAL	mtce	953	465.14	236	23	220	0	1	0.27	0.02	0.07	7.5
Cooking & heating in household:	mtce				3	220						6
Heating in commercial & industry:	mtce				12							1.5
existed in 1990	mtce		407	164	20	266		0.9	0.25	0.005	0	2.45
net increase	mtce		58.14	72	3	-46	0	0.1	0.02	0.015	0.07	5.05
Investment/unit	Yuan/tce		400		1550	0	700	4000	6542	1500	526	600
CO2 emission coef.	t/tce		0.735	0.538	0.409							
Total emission	million ton	478.2529	341.877	126.9	9.407							
Total investment	billion yuan		23.256	0	4.65	0	0	0.4	0.13084	0.022	0.03682	3.03
Period of construction	year		3		2	0	0	1	1	1	1	2
Annualized investment cost	billion yuan		0.74418		0.206			0.032	0.01072	0.001	0.00301	0.1344
Interest	% annual		8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Life time	year		25		25			20	15	30	3	50
Depreciation	% annual		3.8		3.6			4.5	6	3.3	33	[illegible]
Discard value	%		5		10			10	10	1	[illegible]	10
Maintenance	% annual		10		1			1.5	2	0.5	[illegible]	1.65
Labour	million yuan		1773.27		0.023			0.004	0.00130	0.000	0.00036	5
Fuel	million yuan		4244.22		1575			0	0	0	0	0
TOTAL ANNUAL COST	billion yuan	12.30713	9.97100	0	1.995	0	0	0.056	0.02119	0.002	0.01627	0.2439
LEVELIZED COST	yuan/tce		171.499	0	665.0	0		568.0	1059.86	180.0	232.497	48.307

Table Ⅲ—2

ALTERNATIVE ENERGY SUPPLY OPTIONS IN 2000 DIRECT SUBSTITUTION FOR COAL -SCENARIO MEDIUM (IN 1990 YUAN)

	UNIT	TOTAL	COAL	OIL	GAS	BIOMASS	NEW-BIOMASS	BIOGAS	SOLAR THERMAL	SOLAR HOUSE	SOLAR COOKING	GEO-THERMAL
TOTAL	mtce	953	411.525	236	50	220	22	3	0.37	0.025	0.08	10
Cooking & heating in household:	mtce				10	220						8
Heating in commercial & industry:	mtce				40							2
existed in 1990	mtce	860.605	407	164	20	266		0.9	0.25	0.005	0	2.45
net increase	mtce	92.395	4.525	72	30	-46	22	2.1	0.12	0.02	0.08	7.55
Investment/unit	Yuan/tce		400		1550	0	700	4000	6542	1500	526	600
CO2 emission coef.	t/tce		0.735	0.538	0.409							
Total emission	million ton	449.8888	302.470	126.9	20.45							
Emission change	million ton	-27.4791	-38.529	0	11.05							
Total investment	billion yuan		1.81	0	46.5	0	15.4	8.4	0.78504	0.03	0.04208	4.53
Period of construction	year		3		2	0	0	1	1	1	1	2
Annualized investment cost	billion yuan		0.05791		2.062			0.638	0.06437	0.002	0.00345	0.2009
Interest	% annual		8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Life time	year		25		25			20	15	30	3	50
Depreciation	% annual		3.8		3.6			4.5	6	3.3	33	1.8
Discard value	%		5		10			10	10	1	1	10
Maintenance	% annual		10		1			1.5	2	0.5	3	1.5
Labour	million yuan		138.012		0.232			0.084	0.00785	0.000	0.00042	5.4
Fuel	million yuan		330.325		15750			0	0	0	0	0
TOTAL ANNUAL COST	billion yuan	22.42622	0.77603	0	19.95	0	0	1.192	0.12718	0.003	0.01859	0.3558
LEVELIZED COST	yuan/tce		171.499	0	665.0	0	0	568.0	1059.86	180.0	232.497	47.132
TOTAL COST PER CO2(TON CARBON) REDUCED	yuan/t.carbon	379.4233										

Table Ⅱ—3

ALTERNATIVE ENERGY SUPPLY OPTIONS IN 2000 ELECTRICITY GENERATION

-BUSSINESS AS USUAL (IN 1990 YUAN)

	Unit	TOTAL	COAL	HYDRO	MINI-HYDRO	NU-CLEAR	SOLAR PV	MINI-PV	WIND	MINI-WIND	SOLAR THERMAL	GAS-BASED	BIOGAS	GEO-THERMAL
electricity demand	billion kwh	1350	988.256	247.5	87.5	19.8	0.002	0.173	0.375	0.093	0	6	0.1	0.2
peak load demand	million kw	265.6727	197.651	55	6.5	3.3	0	0.079	0.022	0.03	0	3	0.05	0.04
grid support	million kw	19.7875	0	0	19.5	0	0.16	0	0.127	0	0	0	0	0
capacity required	million kw	282.3012	197.651	55	25	3.3	0.001	0.079	0.15	0.03	0	1	0.05	0.04
existed capacity in 1992	million kw	165.74	125	24	16	0.3	0	0.001	0.004	0	0	0.4	0.006	0.028
capacity increased	million kw	116.5612	72.6512	31	9	3	0.001	0.077	0.145	0.03	0	0.6	0.044	0.012
operation hours	hours/year		5000	4500	3500	6000	2200	2200	2500	3100	2500	6000	2000	5000
investment/unit	yuan/kw		4950	6360	4500	10500	28400	39400	7100	10000	10640	7900	5000	7000
TCE of coef.	g/kwh		350	350	350	350	350	350	350	350	350	350	350	350
Mtce coal	Mtce	472.5	345.889	86.62	30.62	6.93	0.000	0.060	0.131	0.032	0	2.1	0.035	0.07
CO2 emission coef.	ton carbon/Mtce		0.735									0.409		
total emission	m.ton carbon	255.0877	254.228									.858		
total investment change/coal	billion yuan	173.1795	0	77.55	80.32	18.31	0.028	2.721	0.953	0.151	0	-6.95	0.002	0.082
Total investment for capacity increased	billion yuan	638.2423	359.623	197.1	40.5	31.5	0.028	3.053	1.033	0.3	0	4.74	0.22	0.084
Period of construction	year		3	6	3	9	1	1	1	1	3	1	1	3
Annualized investment cost	billion yuan		11.5078	3.995	1.295	0.539	0.002	0.250	0.084	0.024	0	0.383	0.018	0.0026
Interest	% annual		8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Life time	year		25	50	30	30	30	30	20	7	20	25	30	30
Depreciation	% annual		3.6	1.96	3.266	3.333	3.333	3.333	4.5	14.28	4.85	3.6	3	3
Discard value	%		10	2	2	0	0	0	10	0	3	10	10	10
Maintenance	% annual		3.5	2	2	2.3	0.7	0.7	1.5	3	2	2.700	3.75	7.4
Labour	million yuan		2125.04	906.7	263.2	31.5	0.019	2.23	5.165	0	1	84	2.5	3.2
Fuel	million yuan		25427.9	0	0	945	0	0	0	0	0	1050	0	0
TOTAL ANNUAL COST	billion yuan	86.76661	64.5941	12.71	3.692	3.290	0.003	0.375	0.151	0.076	0.001	1.821	0.035	0.0146
LEVELIZED COST	yuan/kwh		0.17781	0.091	0.117	0.182	1.588	2.203	0.417	0.822		0.505	0.402	0.2437

Table Ⅲ—4

ALTERNATIVE ENERGY SUPPLY OPTIONS IN 2000 ELECTRICITY GENERATION

-SCENARIO MEDIUM (IN 1990 YUAN)

	Unit	TOTAL	COAL	HYDRO	MINI-HYDRO	NU-CLEAR	SOLAR PV	MINI-PV	WIND	MINI-WIND	SOLAR THERMAL	GAS-BASED	BIOGAS	GEO-THERMAL
electricity demand	billion kwh	1350	931.972	270	94.5	31.8	0.006	0.235	2.5	0.156	0.2	18	0.3	0.3
peak load demand	million kw	261.9714	186.394	60	6.75	5.3	0	0.107	0.15	0.06	0	3	0.15	0.06
grid support	million kw	21.34	0	0	20.25	0	0.16	0	0.85	0	0.08	0	0	0
capacity required	million kw	283.1544	186.394	60	27	5.3	0.003	0.107	1	0.06	0.08	3	0.15	0.06
existed capacity in 1992	million kw	165.34	125	24	16	0.3	0	0.001	0.004	0	0	0	0.006	0.028
capacity increased	million kw	117.8144	61.3944	36	11	5	0.003	0.105	0.995	0.06	0.08	3	0.144	0.032
operation hours	hours/year		5000	4500	3500	6000	2200	2200	2500	3100	2500	6000	2000	5000
investment/unit	yuan/kw		4950	6360	4500	10500	23800	34900	7160	10000	15200	7900	5000	7000
TCE of coef.	g/kwh		350	350	350	350	350	350	350	350	350	350	350	350
Mtce coal	Mtce	472.5	326.190	94.5	33.07	11.13	0.002	0.082	0.875	0.065	0.07	6.3	0.105	0.105
CO2 emission coef.	ton carbon/Mtce		0.735									0.409		
total emission	m.ton carbon	242.3264	239.749									2.576		
total investment change/coal	billion yuan	222.2955	0	84.6	88.08	29.41	0.071	3.204	6.417	0.303	1.216	8.85	0.[illegible]	[illegible].123
CO2 emission change	m.ton carbon	-12.6735	-14.250									1.576		
Total investment for capacity increased	billion yuan	672.2034	303.902	228.9	49.5	52.5	0.071	3.681	7.127	0.6	1.216	23.7	[illegible].72	0.224
Period of cons-truction	year		3	6	3	[illegible]	1	1	1	1	3	1	1	3
Annualized invest-ment cost	billion yuan		9.72480	4.640	1.583	0.898	0.005	0.301	0.584	0.049	0.03891	1.943	0.059	0.0071
Interest	% annual		8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Life time	year		25	50	30	30	30	30	20	7	20	25	30	30
Depreciation	% annual		3.6	1.96	3.266	3.333	3.333	3.333	4.5	14.28	4.85	3.6	3	3
Discard value	%		10	2	2	0	0	0	10	0	3	10	10	10
Maintenance	% annual		3.5	2	2	2.3	1	1	1.5	3	2	1.620	11.25	7.4
Labour	million yuan		1795.78	1053	321.7	52.5	0.044	2.41	35.63	0	1	252	7.5	4.6
Fuel	million yuan		21488.0	0	0	1575	0	0	0	0	0	3150	0	0
TOTAL ANNUAL COST	billion yuan	87.92583	54.5856	14.76	4.512	5.483	0.008	0.463	1.047	0.152	0.12320	6.582	0.169	0.0350
LEVELIZED COST	yuan/kwh		0.17781	0.091	0.117	0.182	1.362	1.998	0.421	0.822	0.61603	0.365	0.587	0.2191
TOTAL COST PER CO2(TON CARBON) REDUCED	yuan/t.carbon	73.05265												

2. Potential applications of solar energy in China.

The 8th Five Year National Economic Plan (1991—1995) is being implemented in China now. According to the present situation to what degree we have made use of renewable energy resources, the guideline in the period of Eighth five year plan is to carry out the policy "suit measures to local conditions, make use of various energy resources comprehensively, find out other usages of fuels and lay more emphasis on efficiency". We in particular stress on the development of solar and wind energy so as to meet the demand of electricity in frontier, poor farming and pastoral areas far from coastline and islands where normal energy resources is hard to develop. As for investment, we advocate collecting money by local people, local and central government jointly. Our plan is as follows:

a) In wind power, main direction remains the popularization of mini—wind generator for household use. 20 thousand of them are to be added annually. Thus, 100 thousand in five years amount to the total energy of 15 MW. If conditions permitted, we plan to build a certain amounts of wind power stations equipped with generator sets. It is estimated that wind power capacity newly increased is 21.5 MW and ultimately reaches 33.5 MW by the end of Eighth five year plan. The plan of China's wind power in 1991—95 is listed in Tab. Ⅲ-3—Ⅲ-5.

Tab. Ⅲ—5 Plan for wind power in 1991—95

item	power MW			attrib.	invest.
	total	available	added		10 thous.
Zhurihe	2.5	0.5	2.0	ext.	1,000
Nanao	3.39	0.39	3.0	ext	1,500
Pintan	1.56	1.06	0.5	ext.	250
Daban	2.05	2.05			
Rongchen	0.17	0.17			
Dachen	0.17	0.17			
Daju	0.5	0.5		new	250
Dalian	0.5	0.5		new	250
minigenerator	23.0	8.0	15.0	new	15,000
Badalin	23.0	23.0	15.0	new	205
total	33.84	12.34	21.5		18,455

b) Household photovoltaic cells will be greatly developed. If we can install 20 thousand sets of 25 Watt on average each year, then, total capacity will be 2.5 MW for 100 thousand sets in five years to solve people's daily use of electricity for illumination and watching TV. At the same time, 15—30 kw independent photovoltaic power station are to be built in 9 nonelectricity counties for residents' living, water pumping and small motors. The total photovoltaic power capacity 2.3 MW newly installed are planed to be applied in traffic, communication, meteorology satations, cathode protection etc. They will finally increase to around 6 MW by the end of 1995. The plan for developing photovoltaic power stations from 1991—95 in China is provided in Tab. Ⅲ-6.

Tab. Ⅲ—6 **Plan for photovoltaic power generator in 1991—95**

item		power MW		attrib.
	total	available	added	
Madou, Qinhai	0.02	0.02		new
Gaize, Tibet	0.02	0.02		new
Chuqin, Tibet	0.02	0.02		new
Andou, Tibet	0.03	0.03		new
Senza, Tibet	0.015	0.015		new
Bange, Tibet	0.015	0.015		new
Wenbu, Tibet	0.015	0.015		new
Suanghu, Tibet	0.02	0.02		new
Gegi, Tibet	0.025	0.01	0.015	ext.
agri. traff. comm.	2.955	0.60	3.555	ext.
frontier, islands				
household	use	2.90	0.40	2.50
ext.	total	6.01	1.010	5.0

c) Earththermal power. Two earththermal stations with installed capacity of 4—6 MW are to be built in Naqu, Tibet (3 MW) and Hueitang, Hunan province(1—3 MW) (see Tab. Ⅲ-7)

Tab. Ⅲ—7 **Plan for earth thermal energy in 1991—95**

item		power MW		attrib.
	total	available	added	
Naqu, Tibet	3.0	3.0		new
Hueitang, Hunan	3.3	0.3	1—3	ext.
Dengu, Guangtong	0.3	0.3		new

d) Tide power station, no new project is under consideration during Eighth five year plan. We' ll continue to complete two tide power stations in Daguanban, Lianjian, Fujian province with installed capacity 4 3 MW) and in Jiansha, Zhejian province with installed capacity 1 0.8 MW. For details, see Tab. Ⅲ-8.

Tab. Ⅲ—8 **Plan or tide energy in 1991—95**

item		power MW		attrib.
	total	available	added	
Jiansha, Zejian	4.0	3.2	0.8	ext.
Pintan, Fujian	1.28	1.28		ext.
Baisakou, Sandong	0.96	0.96		ext.
Yupu, Zejian	0.3	0.3		ext.
Haisai, Zejian	0.15	0.15		ext.
Liuhe, Jiansu	0.15	0.15		ext.
Shasan, Zejian	0.04	0.04		ext.
Guozisan, Guangxi	0.04	0.04		ext.
Ganzutan, Guangtong	5.0	5.0		ext.
Daguanban, Fujian	12.0	12.0		con.
Total	23.92	11.12	12.8	

Based on the achievements in 1986—90, we are going to set up 100 more example counties for multiple—energy utilization in Eighth five year plan to accumulate experiences in popularization of various new type of and renewable energy resources to release the shortage in energy ,improve ecological environment, enhance the production of agriculture and husbandry.

Now that the policies of economic reform and open to the world are being carried out, especially the policy to built up social market economic system was decided by the 14th National Plenary Congress of CCP, the development of new types and renewable energy resources will be further promoted to a higher level. Wider applications of solar energy in many areas in the last 5 years of this century are very likely expected; for instance, after 1995 China is to establish a photovoltaic power station network of large scale; the total capacity of nationwide wind power stations will be increased to more than 1000 MW; the fuels of organic materials utilized in 2000 will be equivalent to 239 MT of standard coal, i. e. 10 percent less than that in 1990. However, increased portion of high quality energy due to organic materials and the change of their utilization manner will lead to people' s concern switching from rural areas to towns and cities.