Solar Energy Applications in the Western Rural Areas of China

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ABSTRACT

This paper outlines the physical, economic and geographical conditions of the western rural areas of China as they relate to the utilization of solar energy; then it reviews the technical states of solar appliances, such as solar houses, solar cookers, water heaters, that have been developed and popularized in the rural areas of the region; finally, it introduces the major organizations working on solar energy applications in the region.

INTRODUCTION

The western region of China described here includes Shanxi, Gansu, Ningxia, Qinghai, Xinjiang, Tibet, and the western part of Sichuan and Inner Mongolia. The region covers 50 percent of the total land area of China. Most areas of the region are dry with very little rain. The annual rainfall is below 400 mm in most parts of the region and in fact Ruoqiang county, Xinjiang has the record for the lowest amount of rainfall in the country with 3.2 mm. Ruoqiang is also the richest area in terms of solar resources. The region has more than 2,500 hours of sunshine each year and the sunshine percentage is more than 50 percent throughout 60 percent of the region. As it is high above sea level the humidity is low and the solar radiation is intense. The monthly average clearness index is as high as 50 percent, or even 66.8 percent in Lasa, Tibet. The total annual radiation is more than 1.4 million Kcal/m^2 in most parts of the region. Winter is longer here than in other parts of the country and is extremely cold. The average ambient temperature in January is below $-10^{\circ}C$ and sometimes falls to as low as $-30^{\circ}C$. Throughout the region in general, heating is required for approximately four months, but in some parts it is required the whole year round. Transportation is very inconvenient and 70 percent of the area has no rail or water transport. Fossil fuel, mainly coal, is transported by trucks. As a result, the fossil fuel price is as much as 1,000 Yuan in RMB for one ton in some places. Due to the poor natural conditions of the region i.e., lack of vegetation and shortage of biomass energy and fuels, farmers have to use straw and animal dung as fuel. For example, about 150 million kg of dung are burned each year in Dingxi county, Gansu, and 400 kg per month of dung are burned to heat a single room and perform simple cooking in Naqu of Tibet. This of course prevents the dung from being used as organic fertilizer with the result that the soil quality is deteriorating and there is some ecological imbalance. However, the region's abundant solar resources can be utilized in the form of solar houses, solar cookers and flat-plate solar collectors as these are all high in thermal efficiency and

low in terms of investment costs. Since 1979 such solar appliances have been popular throughout the region.

SOLAR HOUSES

When passive solar technology was introduced into China from the West, it was originally used in this region. The first passive solar house in China, with an area of 39 m^2, was constructed in Gansu in the winter of 1978. Insulating materials were incorporated into the east, west, and north walls, and the south wall was designed to function as the thermal storage wall (Trombe-wall) with a window acting as the direct gain system.

This first solar house (Fig. 1) was not ideal in terms of efficiency but it played an important part in stimulating further research and development of solar houses in China. Since then, passive solar houses have been developed rapidly over a period of 6 years. At the end of 1985 there were about 129 passive solar buildings in the western part of China, constructed in many different styles, and covering a total area of over 54,000 m^2 (Table 1).

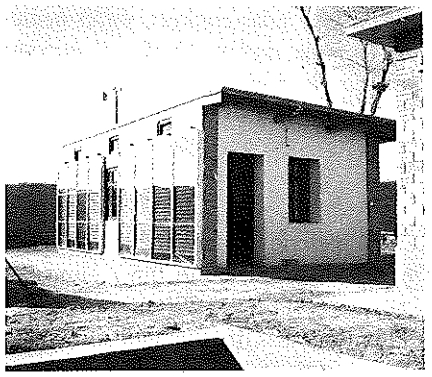

Fig. 1 First solar house in China.

Table 1
Distribution of solar houses in the western part of China

Name of province	Number of houses	Area of houses, m^2	Period of construction
Gansu	69	17,229	1978 – 1985
Tibet	44	30,050	1983 – 1985
Qinghai	8	2,628	1978 – 1982
Inner Mongolia	1	350	1980 – 1984
Xinjiang	2	605	1981 – 1985
Ningxia	3	131	1982 – 1984
Shanxi	2	3,100	1982 – 1985
Total	129	54,093	

Solar energy is mainly used for space heating as it is not too hot in summer. Solar energy technologies such as Trombe-wall, direct gain and sunspace systems are applied to the buildings, while the thermal resistance and calorific value of buildings are increased and the permeation of cold air from outside is reduced. Most building materials are locally available and are low-cost i.e., brick, stone, adobe, sheep dung, and straw. If the costs of the former houses are increased by a factor of 8-30 percent, the ratio of energy saving will be 50-80 percent, and the difference between the temperature outside and inside the house can be maintained in the range of 10-30°C. For example, one of the solar houses constructed for farmers in Dunhuang county, Gansu was continually tested for 2 years. The results showed that the monthly average temperature inside the house was 5.8 to 9.5°C without an auxiliary heating system, whereas the ambient temperature was −10.3 to −2.4°C (Figs. 2 and 3). In comparison, the temperature in one of the traditional farmer's houses near to the solar house shown in Fig. 2, was around −2°C. The passive solar

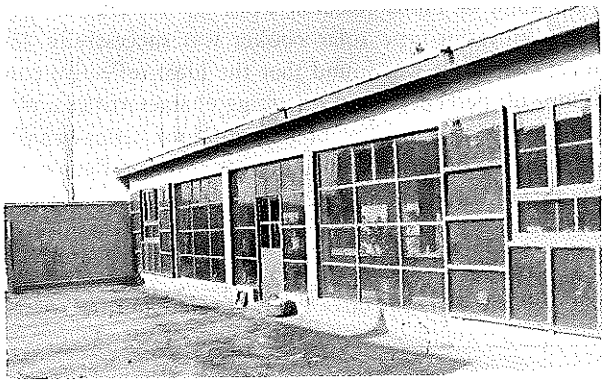

Fig. 2 A farmer's solar house at Dunhuang county, Gansu province.

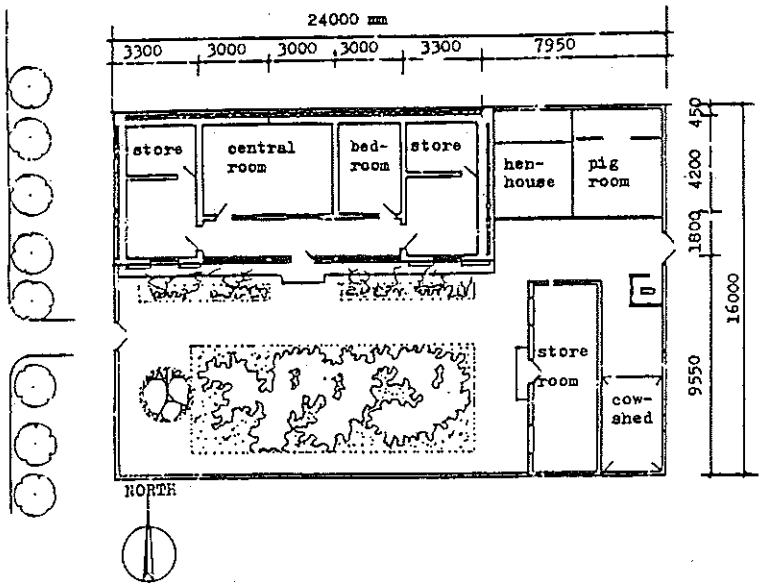

Fig. 3 Typical Chinese farmer's residence plan.

houses not only save energy, but they are clean, warm, bright, and have a simple construction method and low cost comparable with traditional buildings. Moreover, they substantially improve the dwelling condition of farmers in areas where fuel is short.

Future research in China in the field of solar space heating and cooling will be devoted to developing computer software programs related to passive solar housing, and developing special materials and components needed to build the solar house. A photographic collection of solar architecture will also be compiled. Such activities will help speed up research and development in this field and are a prelude to making the passive solar house popular throughout China.

SOLAR COOKERS

In the People's Republic of China research work on the solar cooker was begun in 1956. In 1976, a reflective concentrating-type solar cooker was successfully developed and used by farmers in Lintan county, Gansu. It was found that the ideal reflective concentrating-type has a high heat efficiency (about 60 percent), good operating characteristics and various cooking functions such as cooking rice, baking pancakes, boiling potatoes, string-beans and other vegetables, as well as stewing chicken or meat during daylight hours. Some reflective materials have been developed also, such as the vacuum aluminium-plated films of polyester fiber.

Table 2
Parameters for three types of solar cookers

	Model		
	GN-6	LZT	Solar cooker for picnic
Aperture area, m^2	2.5	2.4	1.18
Focal distance, m	0.85	0.8	0.88
Maximum height of operation, m	1.25	1.22	1.11
Maximum distance of operation, m	0.85	0.8	0.88
Suitable latitude, degree	<46	<51	<60
Characteristics power, W	1,100	1,200	650
Focal spot temp., °C	660	400	400
Focal spot area, cm^2	93.6	180	55
Material for shell	Magnesite	Cast iron	Glass fiber reinforced plastic
Reflective materials	Aluminium mirror	Aluminium plating film	Aluminium plating film
Gross weight, kg	100	120	12
Thermal eff., %	62	60	65

According to incomplete statistics, up to the present about 73,000 solar cookers have been used by farmers in the western part of China. One of these solar cookers can save about 1,000 kg of biomass energy per year. For example, the whole village of Songshuwan in Yongjing county of

Gansu province currently uses solar cookers and as a result the amount of coal used has been reduced by about 30 percent.

The theoretical design of solar cookers has at present reached a mature stage and there exists a series of complete design methods. Therefore, the time is ripe for their further application.

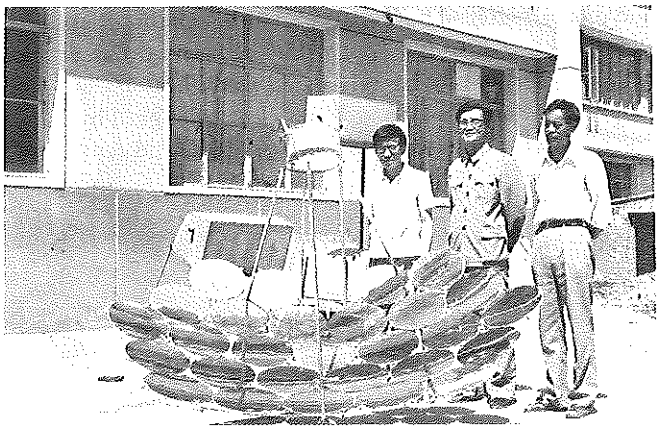

Fig. 4 GN-6 Solar cooker. The persons standing by the solar cooker are the designers.

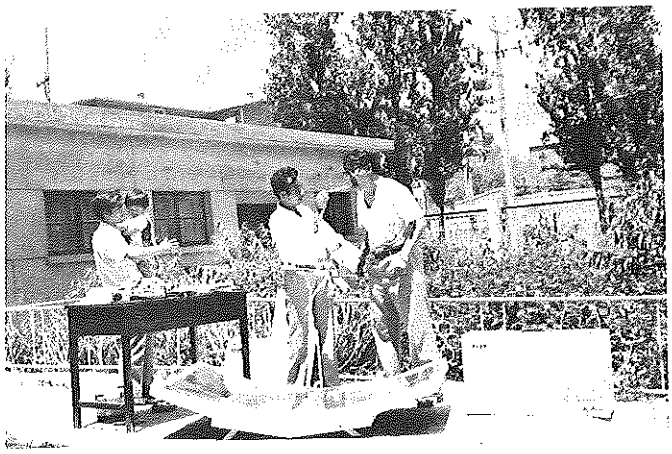

Fig. 5 GN-8 Solar cooker. The authors are standing first from the left and right.

SOLAR WATER HEATERS

Solar water heaters are not so widespread in the western rural areas of China as in the cities. This is chiefly because the lower standard of living in the countryside has resulted in a smaller demand for hot water. No doubt, as rural living standards rise, the demand for solar water heaters will also rise.

Nowadays, there are about ten factories in China producing solar collectors. Among these, the larger ones are Lanzhou Factory of Solar Energy Equipment, Xian Guanghui Machine Works, Dukou Factory of Sichuan and the West Solar Energy Corporation of Tianshui (WSECT). The main types of collectors produced are: the flat case with a zinc-plated iron sheet type; welded tube using water and gas type; plate-tube of black iron sheet type; and stainless steel plate-tube type. The total production is about 40,000 m^2. However, the most popular solar water heater in the countryside is a kind of small integral hot-box type. Although this is less efficient than the others, the price is lower and therefore it is appropriate for the farmers who, at present, have lower standard of living. Up to the present time about 10,000 water heaters have won popular acceptance in the rural areas, especially the TRS-1 Solar Water Heater designed by Gansu Natural Energy Research Institute, which has a high thermal efficiency (40-80%) and can be used all year round (Fig. 6).

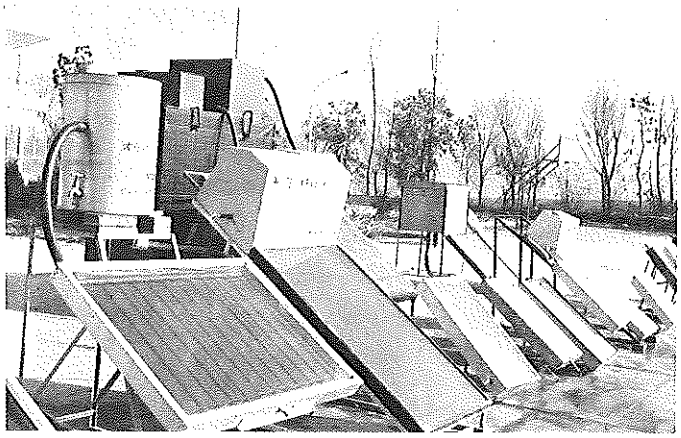

Fig. 6. TRS-1 stainless steel solar water heater second from left.

PHOTOVOLTAIC UTILIZATION IN THE WESTERN AGRICULTURE-PASTURAGE AREAS OF CHINA

Cow pen with electrical fence. Some pilot projects concerning these have been launched in Inner Mongolia and other places starting in 1979 and good results have been obtained.

Television relay station powered with solar cells. The area covered by electrical wire netting is less than 40% of the total area of the western part of China. The use of television relay stations powered with solar cells is an ideal method for spreading the coverage ratio. Several television relay stations are actively being set up in Xinjian and Tibet as well as other places (Fig. 7).

Solar cell power supply system. Because of the vast territory and sparse population as well as underdeveloped regional economy, the electrical wire netting covering ratio in the western part of China is lower than in other parts. It is uneconomical and impractical to spread the electrical wire netting to meet the farmers' and herdsmen's requirements for electricity. It is more appropriate to spread the adoption of the solar cell power supply system in the region. A number of pilot projects concerning solar power stations for a village and small photovoltaic systems for

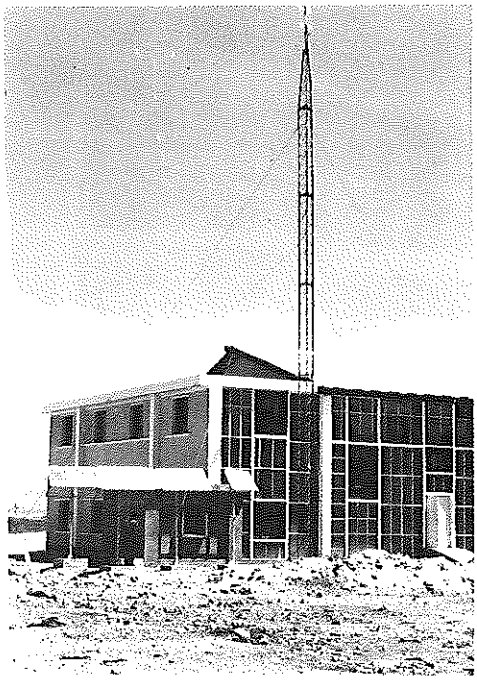

Fig. 7 The world's highest photovoltaic videocast retransmission station (4500 metres above sea level) at Gaize county, Tibet.

a family have been set up in the western region. The electricity production cost is expected to be 1 Yuan in RMB per kWh. One of the major challenges is to find a way to meet the higher maintenance requirements of the solar batteries.

OTHER SOLAR ENERGY APPLICATIONS

There are a number of other solar energy applications in the western rural areas of China, including plastic solar greenhouses, solar heating for cowsheds, pigsties and chicken farms, and solar dryers for drying Chinese medicinal materials.

Plastic solar greenhouse. This kind of greenhouse is very economically viable in the western part of China. The price is reasonable, each square meter of the greenhouse costs 3 Yuan in RMB. The yield of the greenhouse is around 15,000 kg per mu (1.5 mu = 1000 m^2) in a year. The plastic greenhouse of 0.5 mu in Lasa can produce vegetables throughout three seasons of the year, and it can produce about 6,500 kg of vegetables per season.

Solar pigsty. This pigsty is actually a simple passive solar house. It is not only efficient but has a low investment cost. The solar pigsty has already been used successfully to raise pigs. For example, raising pigs in a solar pigsty in winter in Qinghai province resulted in the pigs being heavier than those reared in a traditional pigsty. It has also been used to rear dairy cattles and it was found that the milk yields were increased 1-2 times in the winter and summer seasons. In Inner Mongolia, solar heating of sheep-folds resulted in a higher than usual survival rate. Moreover,

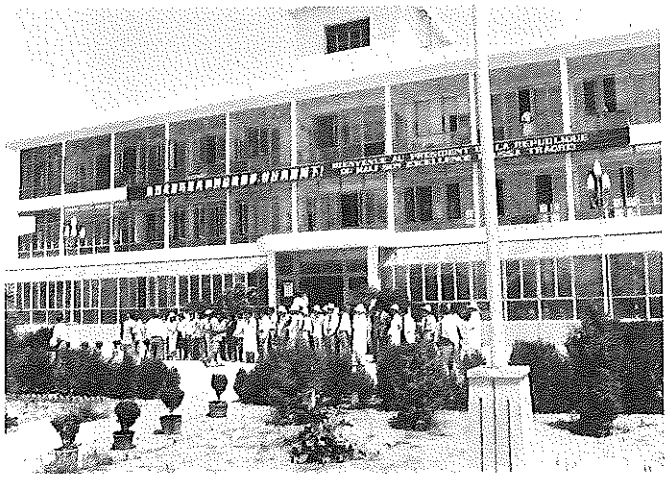

Fig. 8 The main solar building in the solar center of GNERI.

good results have been obtained from heating chicken farms by means of solar energy.

Solar drying. Drying is a necessary process in the production of grains, preserved fruits, Chinese medicinal materials and other agricultural by-products etc. Experiments on solar drying have been carried out in the western region of China since 1978 and have proved successful and brought economic benefits. For example, success has been achieved with a solar dryer designed for drying pilose antlers in the Changan deer farm of Shanxi Province and with a solar dryer for Chinese medicinal materials in Dokou, Sichuan.

INSTITUTIONS CARRYING OUT RESEARCH ON SOLAR ENERGY

The provincial governments in the western part of China have paid considerable attention to developing and utilizing solar energy and there are institutions working on solar energy in every province in this area. The main institutions are as follows:

Gansu Natural Energy Research Institute (GNERI). GNERI is one of the most important institutes in China working on research and development of renewable energy resources. The first active solar house in China was constructed by GNERI and the first Chinese test facility for testing the performance of flat-plate solar collectors was also developed by GNERI. The Solar Heating and Cooling Technical Demonstration and Experiment Center was built at GNERI with the assistance of the United Nations Development Program (UNDP). At present, this institute is undertaking research on solar houses, solar devices, solar resource assessment, materials, conventional energy, and energy resources for rural areas. Technical training courses have been conducted and information exchanges have been carried out with researchers and institutions in USA, Japan, France, Canada and Britain, as well as others. GNERI is also a director member of China Energy and Renewable Energy Resource Information Network and is in charge of this activity in the northwest part of China. A technical journal "Solar Energy Research and Applications" is sponsored by GNERI. About 18,000 m^2 of solar buildings designed by GNERI have been constructed and about 40,000 m^2 of solar water heaters have been sold.

Solar Energy Laboratory of Shanxi Physics Institute. This laboratory is working mainly on the thermal applications of solar energy such as the testing of solar dryers for drying pilose antlers.

Solar Energy Laboratory of Dukou Construction Design and Research Institute, Sichuan Province. This laboratory is also working mainly on thermal applications, such as the flat case collector of zinc-coated iron sheet and the solar dryer for drying Chinese medicinal materials.

Inner Mongolia Construction Institute. This institute has carried out much research work on solar houses.

Qinghai Solar Energy Research Institute. The main research work of this institute has focussed on photovoltaics and the applications of solar energy. A solar cell lighting system developed by this institute for use in herdsmen's tents is gaining popularity.

Xinjiang Solar Energy Research Institute. This institute is working mainly on solar thermal applications. A solar baker developed by this institute has produced good results and has been well received.

Tibet Solar Energy Institute. The main work of this institute involves applying research results to the particular conditions of Tibet. Many solar energy applications have been popularized by this institute.

Solar Energy Research Laboratory of Ningxia Physics Institute. This laboratory is working mainly on solar energy applications. A small integral hot box water heater developed by this laboratory has proved popular in Ningxia. Other institutes working in the field of solar energy are:

The Physics Department of Xian Jiaotong University (photovoltaics).

Teaching and Research Office of the Thermal Engineering Department of Chongqing University (CPC water heaters).

Lanzhou University (photovoltaics).

Construction Design Office of Gansu Industry University (solar houses).

Teaching and Research Office of the Thermal Engineering Department of North-West Industry University (flat-plate collectors).

Solar Energy Research Laboratory of South Gansu Autonomous Prefecture (solar houses).

Solar Energy Research Laboratory of Wuwei Region (solar houses and solar baths).

Lingxia Station for Disseminating Solar Energy Applications (solar cookers).

Construction Institute of General Logistic Department of People's Liberation Army (PLA) (solar water heaters).

Due to its geographic and economic conditions as well as other characteristics, there is considerable potential for the western territory of China to benefit economically for the development and application of solar energy.

The main problem of solar energy applications is the materials used. These are: (1) *Glazing materials.* Until now no plant exists to produce glass with high transmissivity, and resistance to hailstones; (2) *Insulating materials.* Insulating materials with good characteristics for solar energy applications, and of low cost, have not yet been found; (3) *Selective absorbtive coating.* Low cost selective absorbers suitable for solar houses and solar collectors have not yet been developed; and

(4) *Reflective materials.* At present reflective materials are rather low in reflectivity and some have a short life and cannot resist wind-blown sands.

Research is being carried out worldwide to improve the efficiency of solar cells, to prolong their life and to reduce the cost. But in order to achieve widespread use of photovoltaic applications in the western part of China, two main challenges must be met: (a) a low cost, low maintenance battery should be developed; and (b) the serious problem of matching appliances and photovoltaic systems should be solved.

As the regional economy improves then the demand for solar energy application will expand considerably and the research and development work undertaken to meet this increased demand should benefit not only China but other countries in Asia as well.