THE USE OF PHOTOVOLTAICS FOR RURAL ELECTRIFICATION IN NORTHWESTERN CHINA

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Abstract: The use of renewable energy technologies in China is becoming increasingly important to meet the needs of a large rural population. Solar and wind renewable resources in particular are available in regions of China that at present have no access to conventional grid power. Two regions in China that have an acute lack of electricity are a large region in northern and western China and the coastal island region of China. These regions have attracted the attention of the Chinese government in terms of increasing the quality of life and standard of living conditions of the rural population. These regions have also attracted the attention of domestic Chinese companies and of international companies, governments, and multilateral development organizations as a potential market for renewable energy rural electrification systems. This paper focuses on the bilateral cooperation between the United States Department of Energy and China in providing assistance for the use of renewable technologies for rural electrification in northwestern China.

Key Words: Stand-alone PV Systems - 1: Developing Countries - 2: Sustainable - 3

1. INTRODUCTION

Approximately 70% of China's 1.2 billion population live in rural areas. Of this rural population, Chinese agencies have reported that 70 to 100 million people have no access to electricity in terms of proximity to an electrical grid [1]. A large number of these people also do not have near-term prospects of obtaining electricity through grid extension because of the high costs of building transmission lines to remote locations. There is also a large rural population throughout China, which is difficult to quantify, that live in electrified regions near local transmission lines, but who are not connected to the grid because of electricity shortages or other access problems.

A large region in northern and western China contains a rural population with characteristics that include: i) low population density and dispersion over a large land area, ii) high percentage of minority populations, iii) lack of access to an electric grid, and iv) variable income levels, with a large number of people living at or below the national poverty level. This area generally includes the provinces of Xinjiang, Qinghai, Gansu, Ningxia, and Shaanxi, and the autonomous regions of Inner Mongolia and Tibet. In most of this region, the existing electrical generating capacity is based on hydropower and coal-fired plants that provide grid power primarily to the larger urban centers.

The U.S. Department of Energy (DOE) initiated bilateral cooperation with China in 1995 in the field of renewable energy under the Energy Efficiency and Renewable Energy Protocol agreement signed with the Chinese State Science and Technology Commission (now the Ministry of Science and Technology). Within the scope of this protocol, DOE and its National Renewable Energy Laboratory (NREL) have been working under a project annex with the Chinese Ministry of Agriculture (MOA) associated with rural energy development using solar photovoltaics (PV), wind, biomass and other technologies. This paper describes joint projects that are being pursued with the MOA and other agencies to promote rural electrification in northwestern China.

2. SCOPE OF CURRENT EXPERIENCE IN CHINA

2.1 Market in Northwestern China

The inhabited rural areas of northwestern China consist of farmland and grasslands. Annual incomes are generated mainly by farming and ranching, with ranching dominated by raising sheep. Annual household incomes fall in the range of 800 to several thousand RMB per year (8.2 RMB = $1 US), but annual incomes can be 30,000 RMB and higher for the wealthier segment of the rural population. The rural population of Gansu has among the lowest annual incomes in China, and the rural population in Inner Mongolia has among the highest annual incomes in China.

Table I: Estimate of unelectrified towns, villages, and remote households in selected provinces in northwestern China.

Province	Towns	Villages	Households
Gansu	20	1300	603,000
Qinghai	94	770	100,000
Xinjiang	51	1180	408,000
Inner Mongolia	47*	1450	350,000
Total	212	4700	1,461,000

Source: i) Ministry of Agriculture for Gansu, Qinghai, and Xinjiang and ii) Inner Mongolia Planning Commission for Inner Mongolia; based on provincial statistics for end of 1997. *Aggressive electrification program in progress.

2.2 Photovoltaic Development in China

The development of PV in China is still in an early stage. In 1997 the annual production of PV modules in seven domestic manufacturing plants was approximately 2 MWp. The cumulative installed capacity of PV in China at the end of 1997 was approximately 11 MWp. Major applications included telecommunications, household electrification, agricultural and industrial uses, and consumer applications. Power for telecommunication stations is presently the largest market for PV, but PV for solar home systems is the most rapidly growing market sector. At the end of 1997 there were about 70,000 installed PV remote household systems with a total capacity of 1.3 MWp in China [2]. A typical small solar home system installation is shown in Figure 1.

Figure 1. Solar home system installation in Xinjiang Province, typical of such installations in China.

2.3 System and Application Experience

There is a growing and broad experience base in China for the use of PV for rural electrification applications. Small solar home systems for individual household applications are sold in a variety of sizes from 8 watts to 300 watts. Twelve-volt, 20-watt dc systems are common, consisting of a PV module, charge controller, and battery to provide power for two fluorescent lights and a black-and-white television set. Larger dc and ac systems provide power progressively for a color television set, appliances, and satellite receiver.

Central village power systems using PV and battery storage are also being developed in China. Table II contains selected examples of installed systems in several provinces in China. Such village systems typically supply power for lighting, television and consumer electronic loads, and increasingly washing machines, refrigeration, and small electric motor loads.

The Bureau of Electric Power in Tibet plans to add 300 kW of additional village power systems during 1997-2000. During 1998, PV village power systems at the level of 100 kW will be installed in Tibet and Inner Mongolia. A number of wind/diesel hybrid village power systems in the 10-40 kW size range have been operating in Inner Mongolia and the coastal island region of China. The largest PV/wind hybrid system currently in China (30 kW) is installed on Xiaoguan island in Shandong Province. Household PV/wind hybrid systems in the 150-500 watt range are currently being developed in Inner Mongolia. More than 140,000 small wind turbines in the 100-200 watt size range have been cumulatively installed over the past decade, 80% of which are in Inner Mongolia.

Table II: Selected examples of PV village systems in China.

Location	Date	Power
Zhihema, Qinghai	9/90	400 W
Qiuzhi, Qinghai	5/93	544 W
Shinaihai, Qinghai	9/93	4010 W
Shege, Qinghai	7/96	7000 W
Geji, Tibet	6/90	10 kW
Gaize, Tibet	92	20 kW
Cuoqin, Tibet	94	20 kW
Shuanghu, Tibet	12/94	25 kW
Inner Mongolia (17)	90-97	0.6-10 kW
Xiaoguan, Shandong (PV/Wind Hybrid)	1/95	25 kW Wind, 5 kW PV

Source: Discussions with provincial officials and electric power administrations.

Although significant numbers of field installations of a broad range of PV, wind, and various hybrid systems at the village and household levels have accumulated in China, surveys of the long-term performance of this technology base are incomplete. It is known that the quality of components and of complete systems is an issue in China. Some systems are no longer operating and some have experienced maintenance problems resulting in expensive repairs. Some systems that have been monitored over time have exhibited a satisfactory long-term performance record. There is especially a continuing issue in China with the variable quality of small household system components, particularly batteries and charge controllers.

3. RURAL ELECTRIFICATION IN GANSU

3.1 Project Description

The U.S. DOE and the Chinese MOA have been jointly supporting a solar home system project in Gansu Province in western China [3,4]. The project objective is to support the installation of up to 600 solar home systems and a number of small school systems in remote rural areas of Gansu. Integral components of the project include: i) a training program to provide village technicians and qualified system installers, ii) a component and system testing program to ensure that systems meet minimum quality control standards

and to provide performance information, and iii) use of a revolving account to provide project leverage by using sales receipts to finance the purchase of new systems.

Solar home systems consist of a 20-watt PV module, charge controller, 70-Ah battery, and two 8-watt fluorescent lights. System purchasers also buy a black-and-white television set. In the project, the U.S. side is supplying Solarex VLX-20 modules, 38-Ah sealed lead-acid batteries from SEC Industrial Battery Corporation, and some complete USSC Unikit solar lighting systems. These small systems are used for basic lighting services and television viewing.

Ten 53-watt school systems, consisting of Solarex VLX-53 PV modules, Ananda Power charge controllers, and 65-AH batteries, are also supplied. Chinese companies supply charge controllers and lights for the project and installation and warranty services. The school systems and 300 household systems have been installed to date, of which 40% have been acquired by using the revolving account for the project. In July, 1998 a survey is being conducted for these systems after several months of operation.

3.2 Project Participants

The U.S. and China cost-shared the Gansu project on a 50/50 basis with each side contributing $220 K. On the U.S. side, project participants include DOE, NREL, and the Solar Electric Light Fund in Washington, D.C. (SELF). On the China side, project participants include the Gansu Solar Electric Light Fund (GSELF), the Gansu Poverty Alleviation Office, Gansu Planning Commission, and Gansu Economic and Trade Commission. Project implementation is conducted by SELF and GSELF. Marketing support is provided by the rural energy office network of the Ministry of Agriculture in Gansu.

Table III: Companies in China Involved in Gansu Project

Company	Type
Gansu PV Company	Private Entrepreneur
Zhong Xing Electronic Instrument Company	State-Owned Military Conversion
Gansu Zi Neng Automation Engineering Company	Research Institute For-Profit Company
SEC Industrial Battery Company (U.S.)	Joint Venture Mfg. Facility in Shenzhen

Four types of companies are involved in Gansu as shown in Table III. These types of companies are commonly encountered in China. Private companies started by entrepreneurs can be aggressive and innovative, as demonstrated by the Gansu PV Company, which has pioneered very successful advertising techniques in Gansu and has promoted marketing approaches aimed at solving the affordability problem for low-income customers. State-owned companies such as Zhong Xing can be better financed and have critical connections, especially in the government, providing an advantage in government-supported projects. Zhong Xing is a military conversion company now making consumer electronic products, but maintaining its prior business network. For-profit companies affiliated with research institutes are now very common in China and tend to be resource limited. However, these companies can possess valuable technical expertise. Foreign joint-venture companies with Chinese partners are becoming important in the development of renewable energy in China and can provide a critical pathway for the entree of foreign companies into Chinese markets.

3.3 Expansion of the Gansu Project

Based on the experience gained with the solar home system project in Gansu, the Chinese MOA has developed a 10,000-household project in northwestern China. The project will be conducted in 3 years in the provinces of Xinjiang, Qinghai, Ningxia, Gansu, and Shaanxi, and the autonomous region of Inner Mongolia. In 1998 the project is being initiated with 3000 installations in Gansu, Qinghai, and Xinjiang. An integral component of the project is the support of testing and training activities and the development of standards for solar home systems, for which a regional center will be established at facilities of the Gansu Natural Energy Resources Institute in Lanzhou. This facility will provide services for the northwestern region of China. Key objectives of the MOA project include: i) improving the quality of solar home systems through the development of standards and testing protocols and ii) promoting new mechanisms for market development for PV solar home systems in China.

3.4 Applications for Solar Home Systems

Solar home systems are most frequently used to provide energy for basic lighting, television, and radio services. Interviews with owners of these systems indicate that individuals place a high value on the quality of lighting available with fluorescent lights and on the use of TV and radios as an "information window." Information of value includes not only entertainment, but local, national, and international news and cultural information impossible to obtain by other means in remote locations. Solar home systems can also contribute to household income by supporting light home industry, such as sewing and use of small appliances in farm and ranch activities.

Particular interests of the Chinese government in promoting the distribution of solar home systems include: i) education value for school-age children with improved lighting quality and TV/radio information that complements school curricula, ii) language instruction, especially in minority regions, to promote fluency in Mandarin, and iii) transmission of agricultural information, such as weather reports, crop prices, and instruction programs, to support income-producing activities for farming and ranching. These activities contribute to poverty alleviation in rural China, which is a national priority. It should be noted that the State Council Office for Poverty Alleviation in Beijing, which is a cost-sharing partner in the Gansu project, spends over 1 billion $US per year in rural development projects in China.

4. HOUSEHOLD PV/WIND HYBRID SYSTEMS

4.1 Background

Inner Mongolia has been aggressive in developing wind and PV for rural electrification. Support includes: i) use of declining subsidies to support technology and market development, ii) assistance to renewable energy companies, and iii) formation of a network of new energy service stations at the county level to install and maintain wind and PV

household systems. Because of the higher level of annual incomes of the rural population, larger household PV and wind systems are affordable. DOE and NREL have been pursuing joint cooperation for the development of PV/wind hybrid household systems in Inner Mongolia with the New Energy Office of the Science and Technology Commission in Hohhot. Other partners include the Inner Mongolia Polytechnic Institute, the University of Inner Mongolia, the Chinese Academy of Sciences in Beijing, the Shangdu Machinery Company in Inner Mongolia, and the JiKe Company in Beijing. In the first phase of the cooperation, the University of Delaware, NREL, and the Inner Mongolia team completed a levelized cost analysis of rural electrification options for several counties. The analysis compared renewable energy options with conventional gas gen sets based on local renewable resources and costs [5].

An attractive option for household systems resulting from the analysis and prior research in Inner Mongolia are PV/wind hybrid systems with battery storage. These systems are more reliable than PV or wind systems alone because of the seasonal complementarity of the wind and solar resources (with wind relatively more available in winter months and solar relatively more available in summer months). Analyses show that wind, PV, and PV/wind hybrid systems are lower-cost options for rural energy systems than fossil-fuel based generators [4,5].

4.2 Current Cooperation

Current cooperation with Inner Mongolia is focused on PV/wind systems consisting of: i) a 100-watt wind turbine combined with 50-70 watts of PV and ii) a 300-watt wind turbine combined with 150-200 watts of PV, with battery storage. These systems are capable of delivering 0.6 kWh/day and 1.6 kWh/day, respectively, with high reliability as a function of local resources at a given site. The systems provide energy for lighting, color television, consumer electronics, and some discretionary load. Systems of 450-500 Watts (Figure 2) can also maintain a freezer load, which is a major driving force for system development.

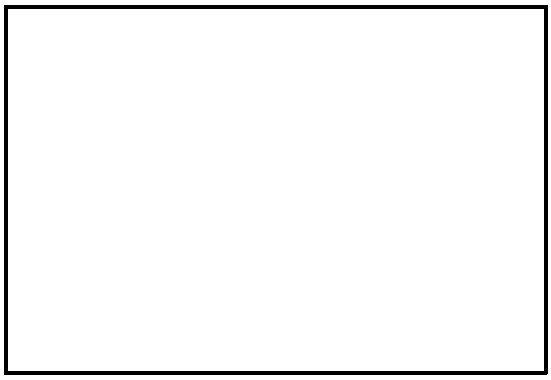

Figure 2. 500-Watt PV/wind hybrid household system in Inner Mongolia. Courtesy of Wang Sicheng, JiKe Company.

In 1998, the New Energy Office in Inner Mongolia will initiate a household PV/wind pilot project consisting of 240 installations to evaluate the technical and economic performance of these systems. The pilot project is part of long-term program to facilitate 80,000 PV, wind, and hybrid household installations. U.S. cooperation in this project will consist of supplying PV modules and some complete PV/wind hybrid systems manufactured in the United States. A system monitoring component of the project will place data acquisition systems on several households to collect system performance data and solar and wind resource data.

5. MARKET DEVELOPMENT ISSUES IN CHINA

5.1 Classification

Based on the experience to date with several rural electrification projects in China, several issues can be identified as challenges to the continued development of these markets. Some of the key challenges can be classified as technical, financial, and institutional.

5.2 Technical

Technical challenges include: i) variable and poor quality of component and system hardware, ii) poor system installation and maintenance, and iii) lack of availability of some domestic components. General recognition of these issues has resulted in a effort by several Chinese agencies to develop certification standards and testing for solar home systems in China. There is also an effort to upgrade the test capabilities of selected institutes to provide certification testing. Multiple agency efforts directed at system certification are not yet well coordinated at the national level.

Distributors of small household rural electrification systems in China frequently express the desire to acquire foreign equipment because of higher quality, particularly PV modules and batteries. For larger PV or PV hybrid systems installed in villages, and for other remote applications requiring more power, some domestic equipment is not available (e.g., most inverters of 5 kW and over are imported). PV module manufacturers in China are also developing plans for expansion, and new entrepreneurs are interested in building new module production or module assembly plants. These areas of need are examples of potential business opportunities in China for foreign companies.

5.3 Financial

Financial challenges include developing financing and marketing approaches to accommodate the ability of low-income populations to buy rural electrification systems. Because of the emphasis on poverty alleviation, subsidies are heavily used in China to buy down the system cost to the end user. This use of subsidy funding can restrict the ability of the market to expand in a sustainable fashion, suppress business development, and discourage investment. Innovative use of subsidy funding to support business development, provide loan pools, or build capacity for training and infrastructure development can overcome some of these problems.

There is also a general lack of installment-credit experience in the rural sector in China, and some experiments with credit have resulted in high default rates. Nevertheless, consumer interviews indicate that continued experimentation with credit terms and infrastructures has the potential to greatly expand the market for rural electrification systems in China. Discussions with local banks in China also indicate an interest in this loan market, if suitable mechanisms, such as energy service companies, can be developed to aggregate large numbers of small loans.

5.4 Institutional

Institutional challenges include: i) developing distribution infrastructures to provide service to remote dispersed populations, ii) developing the capacity to support improvements in system quality and quality control in manufacturing, and iii) creating conditions to attract investment; for example, policy initiatives and tariff and value added tax (VAT) reform. Targets of international and multilateral development assistance to China include policy reform, business development (assistance in creating business plans, technical, and financial assistance), training, education, and technology transfer.

Local solar home system distributors in the provinces of northwestern China have been aggressive and innovative in developing distribution networks. For example, distributors train and employ village technicians to sell, service, and repair equipment.. Many distributors have established local village outlets or have contracted with village retail shops that sell consumer electronics. These outlets provide sales and maintenance services, including stockpiling spare parts and battery fluid. Entrepreneurs in the agricultural service station network of the Ministry of Agriculture, which regularly deal with farmers and ranchers in extreme remote locations, are beginning to sell solar home systems.

6. NEAR TERM RURAL ELECTRIFICATION ACTIVITIES

In the near term, the development of renewable energy projects for rural electrification in China will increase. For example, the World Bank and the Global Environmental Facility (GEF) is currently developing a renewable energy project in China in cooperation with the Chinese State Economic and Trade Commission. This project will include two components. One component will support commercial wind farm development and a second component will support PV and PV/wind hybrid stand-alone systems for rural electrification. The rural electrification component will provide business development assistance to commercial companies in China and will install approximately 10 MWp of systems in households, businesses, and community facilities [6].

The United Nations Development Programme (UNDP) and the GEF are also developing a program to fund capacity-building projects to increase the rate of commercialization of renewable energy in China. The program focuses on such activities as training, removing financing barriers, building institutional capacity for resource assessment, developing technology standards, and supporting pilot projects [7].

A number of provinces in China are increasing support for renewable energy for rural electrification. For example, Inner Mongolia is one of the leaders in promoting renewable energy, with more than 10 years of experience in supporting small-scale PV and wind technologies for household and village power applications. The New Energy Office of Inner Mongolia has developed a strategic plan for facilitating the installation of 80,000 household systems during the next five years. The Inner Mongolia Planning Commission is also supporting village power systems under the State Development Planning Commission's Brightness Program. The Chinese Ministry of Agriculture will implement a 10,000 solar home system project through its rural energy office network in six provinces in northwestern China.

The electric power utility industry in China is also becoming aware of the value of renewable energy options for meeting national rural electrification objectives in remote regions. Electric Power Administrations in Inner Mongolia, Qinghai, Xinjiang, Quangdong, and Shandong have actively supported renewable energy rural projects involving PV and wind technologies by cost-sharing the financing of projects or by providing management support for projects, primarily at the village power scale.

International assistance to China for renewable energy rural electrification projects is also increasing. The United States, Germany, Netherlands, and Japan are implementing or have discussed specific rural electrification projects in northwestern China and other provinces. These projects collectively could involve a large number of household installations using PV and wind technologies and an increase in village power projects using hybrid systems.

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