# CHALLENGES AND OPPORTUNITIES FOR HYBRID VILLAGE POWER DEVELOPMENT IN CHINA

W. Wallace, J. Ayarza, J. Li, and Z. Wang
UNDP/GEF PMO, No.A2107 Wuhua Plaza, A4 Chegongzhuang Dajie Beijing, 100044, P.R.China
Tel +86 10 68002619, Fax +86 10 68002674, Email: wzhying@public.bta.net.cn
C. Dou
BEIJING BERGEY WINDPOWER Co., Ltd., No.2 Jinyuan Rd., Aoyu Tower, Rm. 506, Beijing, P.R.China
Tel +86 10 61272466, Fax +86 10 61272477, Email: cdou@bergey.com.cn

ABSTRACT

Hybrid village power systems consisting of wind and PV renewable energy technologies with diesel backup and battery storage have been demonstrated to be an effective means of supplying electricity to remote unelectrified rural regions in China. China in fact initiated the National Township Electrification Program at the end of 2001 to electrify more than 1000 townships in western China that includes 17 MW of predominately PV/battery systems. This paper will review the past experience and current barriers associated with the sustainable development of hybrid village power systems in China, and will discuss several unique opportunities and caveats generated by the current wave of government support for rural electrification based on these systems.

## 1. BACKGROUND

Through the expansion of provincal electricity grids, development of local hydro resources, and, more recently, promotion of other renewable energy alternatives, China has achieved remarkable rates of electrification of over 95%. Notwithstanding the benefits of access to services reliant on power, today over 7 million households across China still lack access to electricity. Most of these people live in rural areas of western China, leading lives far-removed from those of their prosperous urban cousins in China's eastern provinces. In recent years access to power has increased only incrementally, and its highly uneven distribution represents significant social challenges for the nation. Unelectrified populations in China today inevitably live far from the grid, and the prospects of obtaining grid power from local utilities that increasingly are scrutinizing their balance sheets is remote.

Based upon China SDPC [1] statistics, by early 2002, China still had more than 70 million people and 21,000+ villages without access to electricity. These townships, natural villages and households are principally found in remote areas of China's Western Provinces, (see Table I). Some communities use diesel mini grids to provide electricity for a couple of hours at night, and most others use candles and kerosene lights and batteries for small-scale applications. However, Western China and the coastal island regions enjoy some of China's best wind and solar resources. In these locations it is therefore worthwhile to consider the potential of renewable energy applications as a least cost energy supply solution. China's Western regions, including Tibet, Guizhou, Gansu, Inner Mongolia, Qinghai, Xinjiang and Sichuan, are home to the majority of the country's unelectrified populations.

**Table I.** Unelectrified villages and households in China.

| No. | Province/Autonomous Region | Villages | Households |
|---|---|---|---|
| 1 | Tibet | 5,254 | 289,300 |
| 2 | Guizhou | 3,377 | 1,294,000 |
| 3 | Inner Mongolia | 2,360 | 249,590 |
| 4 | Sichuan | 1,499 | 648,300 |
| 5 | Ningxia | 1,306 | 64,000 |
| 6 | Hubei | 1,050 | 121,500 |
| 7 | Gansu | 1,045 | 488,700 |
| 8 | Qinghai | 774 | 101,100 |
| 9 | Henan | 700 | 577,000 |
| 10 | Guangxi | 700 | 388,600 |
| 11 | Xinjiang | 563 | 316,000 |
| 12 | Yunnan | 528 | 1,003,800 |
| 13 | Hunan | 518 | 279,500 |
| 14 | Hebei | 400 | 13,800 |
| 15 | Fujian | 350 | 33,000 |
| 16 | Shaanxi | 344 | 289,100 |
| 17 | Shanxi | 259 | 112,000 |
| 18 | Hainan | 253 | 160,300 |
| 19 | Chongqing | 163 | 191,900 |
| 20 | Jiangxi | 50 | 287,000 |
| 21 | Anhui | 50 | 80,500 |
| 22 | Liaoning | 4 | 4,800 |
| 23 | Guangdong | 0 | 50,800 |
| 24 | Heilongjiang | 0 | 9,100 |
| 25 | Beijing | 0 | 0 |
| 26 | Jiangsu | 0 | 0 |
| 27 | Jilin | 0 | 0 |
| 28 | Shandong | 0 | 0 |
| 29 | Shanghai | 0 | 0 |
| 30 | Tianjin | 0 | 0 |
| 31 | Zhejiang | 0 | 0 |
| 32 | Taiwan | - | - |
| | Total | 21,547 | 7,053,690 |

## 2. NATIONAL TOWNSHIP ELECTRIFICATION PROGRAM

During late 2001, the State Council of China authorized more than 1.8 billion RMB (>218 million USD) for the National Township Electrification Program (Song Dian Dao Xiang) in western China to provide electricity to more than 1000 townships. Hybrid systems are mainly composed of PV/battery systems. The program represents one of the most aggressive rural electrification programs ever attempted worldwide based on the use of renewable energy. The scale of the program also imposes a number of challenges in implementation. Small hydro, solar, and wind will be used in the project, the distribution of which is shown

below (see Table II).

**Table II.** Distribution of power systems in the National Township Electrification Program

| Type | Number of Systems | MW |
|---|---|---|
| Small Hydro | 378 | 200 |
| Solar Power | 666 | 20 |
| Solar/Wind Hybrid | 17 | 0.8* |
| | 1061 | |

*Power of wind turbine generators in the projects

The numbers of townships in ten major provinces and autonomous regions participating in the project are shown below (see Table III).

**Table III.** Distribution of townships by province in the National Township Electrification Program

| No. | Province/Autonomous Region | Electrified Village |
|---|---|---|
| 1 | Tibet | 350 |
| 2 | Inner Mongolia | 39 |
| 3 | Sichuan | 273 |
| 4 | Gansu | 29 |
| 5 | Qinghai | 86 |
| 6 | Xinjiang | 109 |
| 7 | Yunnan | 2 |
| 8 | Hunan | 19 |
| 9 | Shaanxi | 18 |
| 10 | Chongqing | 9 |
| | Total | 934 |

After the National Township Electrification Program is completed, China will become the country with the greatest number and density of installed hybrid village power systems in the world.

## 3. VILLAGE POWER MANAGEMENT

One of the most significant issues impacting the long-term sustainability of village power system deployment in China is the management system used to operate such systems. Management models for village power systems in China have usually been based on village cooperatives (village government or village power management committee) using local operators based in the village. Other management approaches are contract management or leasing to a utility company. In 2000, the United Nations Development Programme in China supported a survey of 85 village power systems in China, which included a detailed site survey of 16 hybrid village power systems [2], one aspect being the performance of the management system used to maintain and operate the power system. Of these 16 systems, 74% were operated by the village government or village committee (the most common approach in China), 13% by contract, and 13% by a utility company. Only a few systems in China have contracted to private individuals for management.

Several factors contribute to a lack of long-term effectiveness of current management approaches. Factors include inadequate training of system operators, lack of technical backup, insufficient financing and revenue streams, and lack of incentives to motivate management performance. Although there is a competent system integrator and equipment supplier base in China, the level of hybrid system integration and installation (with some exceptions) is not yet at an international best practice level. In addition, hybrid system equipment and installation standards are only in the development stage at present and not yet applied in the field. Because village power systems are heavily subsidized by government grants, they are also predominately government-owned, which poses fundamental constraints on management and cost recovery systems, as well as the development of sustainable deployment mechanisms.

## 4. CHALLENGES

Historically, village power development in China has faced a number of technical and institutional challenges that have yet to be resolved. It is particularly important that with current strong Government support for a major expansion of rural electrification systems based on renewable energy in China that a greater effort be made to address the most serious issues representing potential failure modes for the national program. Several of the key challenges are discussed in the following sections.

### 4.1 Renewable Energy Resource Information

Renewable energy resource information is a precondition for successful project design and system integration. In China, as in many places in the world, unelectrified populations are highly dispersed in very remote regions, where historical renewable resource data is frequently nonexistent, especially for localized wind resources. As a consequence, many installations of hybrid village power systems are based on poor resource information that can result in poor performance and higher costs than necessary.

### 4.2 Poor System Configuration

Renewable energy solutions to rural electrification should be resource and need driven, rather than based on a specific technology/application. The available renewable resources, the village electrical load demand, villagers' willingness and ability to pay for electrical service, and the economics of alternatives should determine the appropriate solutions to provide power to the communities. While the costs of conventional grid extension are well known to rural electrification planners, the comparative costs of renewable energy systems for producing electricity are less familiar. Current practice in China for system design all too frequently relies on a set system configuration (frequently PV/battery stand alone systems) without regard to the composition of local resources or unique requirements of a specific village.

### 4.3 After Sales Service

Most un-electrified townships in China are located in very remote areas, such as Inner Mongolia, Yunnan, West Sichuan, Northwest Gansu, especially Tibet, Xinjiang, and Qinghai. The road conditions are very poor. A single round trip for a routine maintenance job

may require a two-day drive in a four-wheel drive vehicle. System integrators in general are reluctant to absorb such service costs, leading to a record of poor after sales service in China.

**4.4 User Knowledge Base**

Frequently, system problems arise from the lack of knowledge and experience of the users. Failures can arise from malfunctions in the systems, but many problems are caused by the users, for example, wrong polarity connections, shorting in wires, and improper loads or improper use of the system. Most residents of un-electrified townships in China are herdsmen or farmers with low education. Training and a well functioning service program are essential to keep systems operating.

**4.5 Sustainable Operation and Tariff Revenues**

Renewable energy village power systems in China receive heavy government grant subsidies based on the social impacts of the system on village community life, but with little regard for the resources required to sustainably operate the system. Consequently rural electricity tariffs are frequently set at unrealistic levels and send the wrong price signals. While the use of rural subsidies is common practice, the tariff design needs to reflect both the actual cost and quality of service. The revenue base has to at least cover the operators' salary, equipment maintenance, and replacement costs of batteries. If the tariff revenue does not cover these costs, the inevitable consequence is failure of the systsem.

**4.6 Government Policy, Ownership, and Taxes**

In China a major challenge is the lack of demonstrated and successful management models that have been shown to work in rural areas. A majority of installed renewable energy systems are operated by a technician with limited education assigned by a local government or village committee, and some are contracted to individuals. Operator responsibilities are frequently not clear and contract terms are frequently ambiguous, contibuting to poor cash flow for the system. Contracts can be a motivation tool serving the operator's and villagers' interests, but contract terms frequently fail to allow accumulation of sufficient funding for system maintenance, including battery replacement. An inevitable consequence is lack of operator interest. Utility operators especially are subject to losses during operation of village power sytems, which creates a strong disincentive to manage such sysetms. Currently the Government also taxes electricity revenues from village power systems. Strong incentive policies for committed ownership and tax relief are needed.

## 5. OPPORTUNITIES

In 1999 the Chinese State Economic and Trade Commission and the United Nations Development Programme initiated the Project "Capacity Building for the Rapid Commercialization of Renewable Energy in China," financed by the Global Environment Facility, the Government of the Netherlands, and the Australian AusAid Programme. A major component of the project consists of exploring hybrid village power development models coupled with two pilot projects representing coastal island fishing communities and remote rural villages in western China, in Zhejiang and Xinjiang Provinces, respectively. Several surveys of unelectrified villages and villages using renewable energy hybrid systems have contributed to a database of information for village socio-economic characteristics [2].

The UNDP/GEF Project encourages the use of international best practices for system integration, installation, commissioning, and monitoring, and places special attention on coupling village power system development with business activities for economic development. The Project has identified a range of productive uses of village power for economic development and income generation. In addition the project has identified barriers and needs for enterprise and entrepreneurial support. Hybrid system management systems based on business models have also been developed, in principle using the power of business incentives to create more effective management systems. Currently, such models are being discussed and in part applied to village power development in western Xinjiang. The Project has produced the "China Village Power Project Development Guidebook" [3], which is currently being used as a training tool in cooperation with the SDPC to complement course material for hybrid village power system operators in the National Township Electrification Program.

The large scale national rural electrification project in China offers some unique opportunities for introducing sustainable development strategies in China. The program will produce a critical mass of system deployment at the county and district level in selected provinces that will provide regional development experience and China and international society will be benefited in the following aspects.

**5.1 Information Dissemination**

Through the mechanism of mass project development, the role and knowledge of renewable energy applications for rural electrification will be greatly extended. The expansion of this information base will include: the characteristics of renewable energy systems and their potential for contributing to village economic development, proper system design and integration, and the differences, advantages and disadvantages, and limitations between renewable energy stand-alone power systems and competing alternatives, such as traditional grid extension and stand alone diesel generators. This will contribute to better rural electrification project planning and financing.

**5.2 Optimizing Rural Energy Systems**

Through the development of large-scale village power projects, technical and economic experience with a variety of renewable energy solutions and system configurations can be accumulated. This will help drive people to select the most reasonable energy options and economic alternatives to solve their electric power needs.

**5.3 Improved Management Systems**

Mass project development also allows the testing of business models for system operation and management that at least partially commercialize hybrid village power deployment. Large scale market development also creates a critical mass that can be used to reduce transaction costs for business development. The National Township Electrification Program creates opportunties for the use of the RESCO model, a Rural Energy Service Company, for managing rural energy systems. The model involves the establishment of private companies by experienced system integrators or other entrepreneurs to provide management services to clusters of villages. Experienced technical support can be available to provide technical backup. RESCO entrepreneurs can also have direct linkages with other forms of business development.

**5.4 Government Policy**

Developing stand-alone power systems has to date been mostly considered as government welfare. Project planners and policy makers, for example, in the State Development and Planning Commission and the National Poverty Alleviation Office are ususally more focused on the social impact of rural electrification rather that sustainable development of village power systems. To promote sustainable development, the commercial operation of such systems based on business principles can be one important tool. Government policies that establish tax incentives to RESCO owners and tax relief for tariff revenues is one means to encourage the development of commercial operation practices. Government intervention in setting electricity tariffs based on principles of covering essential costs to insure sustainable operation of systems is required to circumvent local barriers to reasonable tariff regulation. Government organizations, such as the SDPC and the Poverty Alleviation Office, which provide support for rural electrification in remote regions of China are also gradually incorporating the use of renewable energy systems in their rural energy programs and are seeking assistance in improving project deveopment procedures.

**5.4 Transferring the Experience**

Finally, the experience in China for solving the problem of providing electricity to remote rural populations is similar with other developing countries. Any experience and lessons learnded in China will be valuable to other countries. An effective monitoring and tracking system should be setup, which should be a dynamic database. Statistics should be aggregated and circulated on a regular basis.

## 6. CONCLUSION

The development of renewable energy village power systems in China as represented by the National Township Electrification Program is an aggressive effort that faces a number of challenges in implementation. At the same time, the size of the program creates critical mass and opportunities to investigate aspects of village power development based on renewable energy hybrid systems that has not heretofore been feasible. In China especially there is a need to develop better management systems that promote the sustainable deployment of village power systems. Management systems based on business principles, e.g. the use of RESCOs, can use the power of business incentives to help promote sustainable management practices. The UNDP/GEF Project, "Capacity Building for the Rapid Commercialization of Renewable Energy in China," is also promoting the use of business principles in village power system management and more closely linking power systems with productive applications and income generation in village economies. The current wave of village power project development in China, furthermore, has created the conditions that allow creating opportunities for China and the international community to promote sustainable development in partnership with rural communities and various business sectors.

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