

Experience for Sustainable Development of Rural Energy in China

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- **Abstract:** *China has made great progress in the past 20 years in lifting rural populations out of poverty and in providing modern services such as access to electricity to remote rural villages and households. Still more than 20 million rural farmers and herdsmen in more than 20,000 villages remain unelectrified. Increasingly, the concept of sustainable rural energy and economic development is being incorporated into the rural development plans of the Government of China. Since 2002, the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have cooperated with the National Development and Reform Commission (NDRC) to support China's national rural energy programs. This paper will review the UNDP's experience in providing support for sustainable rural development, including experience with renewable energy service company (RESCO) management models in a multiple village power project in Bulunkou in Xinjiang Province, and support of China's Song Dian Dao Xiang (SDDX) rural electrification program to provide electricity to more than 1000 townships in seven provinces in western China.*

Keywords: *Village power, sustainable rural development, hybrid systems, poverty alleviation, productive applications*

▪ 1. Introduction

China has made great progress in the past 20 years in lifting rural populations out of poverty and in providing modern services such as access to electricity in remote rural villages and households. Still more than 20 million rural farmers and herdsmen in more than 20,000 villages remain unelectrified and many of them are below the poverty line. Increasingly, the concept of sustainable rural energy and economic development is being incorporated into the rural development plans of the Government of China, such as the National Development and Reform Commission (NDRC) and the Poverty Alleviation Office (PAO) of the State Council. In 2002, the State Council authorized the NDRC to implement the Song Dian Dao Xiang (SDDX) national township rural electrification program to provide electricity to more than 1000 townships in seven provinces in western China. The program had a total investment of 4.5 billion RMB and over a two-year period installed more than 15 MW of solar photovoltaic-battery storage systems in more than 660 townships, and installed 275 MW of small hydropower systems in more than 300 remote townships. At present the Energy Bureau within the NDRC is aggressively pursuing the Song Dian Dao Cun Program (SDDC), which is directed at electrifying the 20,000 remaining unelectrified natural villages in western China [1].

Since 2002, the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have cooperated with the NDRC to support China's national rural energy programs. The NDRC/UNDP/GEF Project "Capacity Building for the Rapid Commercialization of Renewable Energy in China" has developed experience with a renewable energy service company (RESCO) model in a multiple village power project in Bulunkou in Xinjiang Province to address several institutional issues associated with sustainable village power

development. Such issues include ownership mechanisms, operation and maintenance, tariff setting, financing battery replacement costs, business development, promotion of use of productive applications and village enterprise development, and poverty alleviation. The Project has also directly supported the NDRC's SDDX program by developing a renewable energy village power management training course and business models to build capacity in organizations responsible for operating village power systems. A baseline survey was also executed for the Song Dian Dao Xiang systems to develop a database for evaluation and assessment of current performance, urgent needs, and guidance for the future SDDC projects. This paper will provide an overview of the UNDP support for sustainable rural electrification development in China.

▪ 2. Bulunkou Hybrid Village Power System

2.1. Project Description

During 2002, the UNDP/GEF supported the design and installation of a hybrid village power system in Bulunkou Township in the Kezhou District of the western Xinjiang Uygur Autonomous Region near the China, Afghanistan, and Pakistan border. The Bulunkou electrification project was co-financed at a value of approximately \$590,000 (US) by the UNDP/GEF, the Xinjiang Development and Reform Commission, and the Akto Township Poverty Alleviation Office. Initially the project provided electric service to 380 households totaling about 1,900 residents at five separate village locations in Akto County.

The purpose of the project was to demonstrate sustainable project development mechanisms associated with the management, O&M, and selected component replacement costs of the systems and to introduce concepts supporting productive applications and village enterprise development. The intensive association with the Chinese personnel and institutions participating in the project also provided an education and learning platform for evaluating local attitudes, needs, and capabilities. This information would later be used to improve the development of training programs and provide recommendations to the central government in China.

2.2. System Description

The Bulunkou project consists of a cluster of five hybrid village power systems containing PV, wind, battery and back-up diesel generator components. The basic configuration for each of the systems is one or two Bergey Excel wind turbines with a nominal rating of 7.5 kW each, 2-4 kW of PV systems (Siemens JW-085 modules), a 500 Ah battery bank (2V valve regulated, sealed lead-acid batteries totaling 220 V per string) Chinese Helpon and Shuangden (GFM-500) batteries, a 15 or 30 kVA Dingxin manual start diesel generator, a Beijing JiKe solar charge regulator (JKCK220-30), a Beijing JiKe AC distribution center (JKCK220-75 or JKCK220-150), and a 15 kVA SunPower INV220E02 inverter. The systems were installed under contract to Beijing Bergey WindPower China with the assistance of the Keyi New Energy Development Company from Urumuqi in Xinjiang (see Table 1).

Table 1: Configuration of Bulunkou village power systems

Village	PV (kW)	Wind (kW)	Diesel (kVA)	Inverter (kVA)	Rectifier (A)	Battery Strings	GPS Location
Bulunkou Cun	4	15	30	30	32	2 Helpon	N38°39'511" E74°56'584"
Subashi South	0	7.5	15	15		1 Shuangden	N38°24'035" E75°03'411"
Subashi	4	15	30	30	32	2	N38°25'700"

North						Shuangden	E74°03'782"
Ka Lake	0	7.5	15	15		1 Shuangden	N38°26'699" E74°02'411"
Gaize Cun	2	15	30	15	32	2 Helpon	N38°46'499" E75°19'139"

▪ 3. Management System

Under the lead of the Akto County Poverty Alleviation Office and in collaboration with the Xinjiang Development and Reform Commission, a “Rural Energy Service Organization” (RESO translated as “rural power service station” from Chinese) was established as the management organization responsible for the Bulunkou village power systems. The organization has similar characteristics to a RESCO (Rural Energy Service Company), but has been given a non profit status by the local government to avoid paying taxes and is managed directly by the local township government. An association with the Poverty Alleviation Office network in China is particularly important since this office has a special mandate to address rural poverty alleviation issues throughout western China. An association with the Xinjiang Development and Reform Commission is also a critical linkage to the national rural electrification programs in western China.

The RESO has three full time employees serving management and accounting functions and one on site technician at each village power system. Initially, electrical technicians from outside the village communities were brought in for the day-to-day operation of the systems. After two years, the outside personnel were replaced by local technicians after training by the experienced personnel. Replacement and rotation of both management and technical personnel in the RESO is frequent as people move to new jobs, but a system of training local personnel to move into vacated positions has been established.

▪ 4. Key Issues and Lessons

Ownership: Ownership is a critical issue that not only establishes the legal and financial obligations for the system, but also develops a sense of control and empowerment for the system owners and operators. In the case of the Bulunkou Township project, the systems are formerly owned by the Akto County Poverty Alleviation Office on behalf of the government, which, in conjunction with the Xinjiang Development and Reform Commission, has issued a formal agreement to the township government to operate and maintain the system through the RESO. Government ownership of the system assures that the RESO is responsive to their obligations and also increases the efficiency of revenue collection and distribution; however, transfer of ownership to the management company is an option in the future to provide increased incentives to operate on strong business principles.

Operation and Maintenance: Day-to-day operation of the village power systems is performed by on-site technicians with training. The Beijing Bergey WindPower China Company has to date provided back-up technical assistance for potential problems requiring professional trouble-shooting expertise and for extensive maintenance functions. The system has now been operating for 4 years. Equipment malfunctions have been primarily associated with lightening strikes on the wind turbine generators and design failure of one type of battery procured for the storage system. Equipment repairs to date have been handled through warranties and one supplemental battery replacement and by the local technicians with occasional expert assistance.

Tariff Schedule: Electricity tariffs were set and approved by the local government after assessments of costs and

ability to pay by local communities. There was the realization that the entire financial investment in the system could not be recouped through electricity revenues; but costs associated only with system management, O&M and replacement of the battery bank were estimated to be approximately 6-7 RMB/kWh. Lower tariffs were set based on income levels in the local communities and a cost-sharing arrangement was agreed with the local government to pay RESO management salaries. This tariff structure will provide revenues for normal operating costs for the system, but will only partially cover the costs anticipated for future battery replacements. The local government has committed to resolving this financing issue with the Bulunkou Township government by a cost sharing mechanism. The tariff structure is shown in Table 2. It is at present difficult in China to set tariff rates above these levels for remote rural communities.

Table 2: Tariff schedule for the Bulunkou village systems

User	Tariff (RMB/kWh)	Tariff (USD/kWh)*
Industry/Commercial	1.8-2.0	0.22-0.24
Government	1.6	0.19
General Population	1.2	0.14
Poor Peasants	Paid by Government	

*1 USD=8.0 RMB

Tariff Collection: Collection of revenues is the responsibility of the local system operator and the RESO manager, who carries the authority of the local government. Since Bulunkou Township is populated by a nomadic herdsmen population, which frequently resides outside villages and has a predominantly barter economy, cash is generated on a highly seasonal basis. Usually tariffs are collected once or twice a year. Tariff collection has gone through several stages of development as a function of RESO management personnel, but has now stabilized with up to 100% tariff collection at several of the village sites in the project. In order to insure more efficient tariff collection, the RESO has decided to install card meters and require customer prepayment in the future.

Training and Service: Initial management training to the RESO and technical training to the local technicians was provided by Beijing Bergey WindPower China and the Keyi New Energy Development Company, supplemented by management training from the UNDP/GEF Project. Subsequent training has been provided by RESO personnel for new employees, and in principle training must be an on-going activity due to frequent replacement of personnel. Training sessions have been recorded by the UNDP/GEF Project and distributed as VCD videos in Chinese and the local dialect. Since VCD players are common in China, this medium of information sharing can be powerful and cost effective. The RESO also provides training to the users of the system to reinforce the importance of using energy efficient loads and learn how to use productive loads.

Productive Applications and Income Generation: A heavy emphasis has been placed on introducing the concept of using productive applications of rural electric systems to generate income and improve living standards. One key to execution of this concept was the design of systems to incorporate future load expansion and the use of productive loads beyond minimum household requirements. Examples of productive applications in the Bulunkou project are: regional tourist hotel, restaurants, carpentry and shoe repair shops, electronic equipment repair shop, retail stores, weaving, and a proposed gemstone polishing operation associated with local mining. Information delivered by television has also had impacts on improving herding livestock.

▪ 5. Impacts of the Village Power Systems

Socio-economic Impacts: During May 2006 a review and assessment of the Bulunkou Township rural electrification project was conducted by the consultant Kristin Stroup from the Energy and Security Group in the United States. The socio-economic impact assessment of the study found profound impacts on the village populations as a result of electrification. One of the major impacts was the introduction of television as a window to information from the outside world, including educational programs, entertainment, and culture, creating a greater awareness of China and the international community. Television also provided information that contributed to occupational improvement and increased income capacity (herding, livestock tending, farming, etc.). The predominantly Muslim Kyrgyz minority population also reported that television and lighting increased social interaction within villages and with other communities outside the electrified regions. Satellite phones have also become available that facilitate social and business communication outside villages.

Education and health services have been greatly impacted as well. As a direct result of the local government's commitment to the project, 34 computers have been acquired for the Bulunkou Township school system with Internet access, which is highly unusual for rural communities in China, and is expected to have major impacts reverberating beyond the classroom. Other electronic equipment in the schools contributes to an increase in teaching capacity for the local educators, including allowing use of educational videos and reception of satellite educational programs. The Bulunkou Township health clinic has acquired new medical equipment, including X-ray (powered by a separate dedicated diesel gen set) and EKG machines, and has expanded services for women and children. The clinic doctor and nursing staff have also increased and hospital beds are being added to improve services and expand capacity at the clinic. Township residents can now be treated more effectively locally that they could previously by travel to the district hospital at great expense and time.

Productive applications using the electric power system have increased in the township including improvements in about 35 daily use retail stores and restaurants, making use of lighting (and television) to expand business hours during the evening and attract customers. New repair shops have also opened, including shoe repair and carpentry shops. Increased tourism at the Ka Lake hotel and restaurant, originally receiving power through the project, but now supplying their own power, has resulted in the expansion of production and sale of handicrafts and the offering of services to tourists.

The general trend observed in Bulunkou shows increases in household income over the past four years. The increase in income tends to be larger for the families previously having higher income than for the lower income families, and electricity can be considered a contributing or enabling factor behind much of the income growth. Increased income improves the standard of living, which includes increased convenience due to lighting and appliance ownership, and improved infrastructure and services. In addition to the stores and restaurants that have opened in Bulunkou over the last several years, in the near future there will be access to a cellular signal, the Internet, and improved drinking water. Though cellular access and drinking water are not direct results of the renewable energy systems, these systems were the catalyst for the improvement in services overall. The choices available to people have expanded in myriad ways since the introduction of the village power systems, and this is the main indication of socio-economic development [2].

RESO Expansion: During the installation and commissioning phase of the Bulunkou project, China's Song Dian Dao Xiang program was initiated resulting in the concurrent installation of several additional systems in the vicinity of the Bulunkou Township. Based on the success of the Bulunkou project, the Xinjiang government

assigned responsibility for managing several of the SDDX systems to the Bulunkou RESO. The Bulunkou RESO now manages a total of 10 village power systems providing service to 2,000 families in the township. The opportunity for the Bulunkou RESO to manage a cluster of village systems within a manageable area has increased the efficiency of the organization's operations and its ability to generate income.

▪ 6. Support of China's National Programs

During 2003 and 2004, the Chinese Government supported the installation of approximately 15.7 MW of renewable energy hybrid village power systems (primarily PV/battery systems, but also including some wind and some diesel back-up generators) and 274.8 MW of small hydro systems in rural areas in a major program designed to electrify the remaining 1066 unelectrified townships focused in primarily seven provinces in western China. To date 964 villages have been electrified in the Song Dian Dao Xiang Program [3]. Table 3 provides a summary of the distribution of systems and installed capacity among seven provinces in western China to date. Currently, planning for a second stage of rural electrification is being directed at the estimated 20,000 remaining smaller remote unelectrified natural villages (*Song Dian Dao Cun Program*), located in the western regions of China.

Table 3: Distribution of Song Dian Dao Xiang Systems

Province	Hybrid Systems	Capacity (MW)	Small Hydro	Capacity (MW)
Shaanxi	9	0.1	16	22.0
Qinghai	112	3.9	0	0
Gansu	20	1.0	8	35.2
Xinjiang	110	1.4	1	0.1
IMAR	42	0.8	0	0
Sichuan	40	1.8	205	202.4
Tibet	329	6.7	72	15.1
Total	662	15.7	302	274.8

The execution of the installation and commissioning phase of China's SDDX program has been impressive and represents one of the most aggressive international rural electrification programs attempted to date. However, several key issues have not completely been resolved in the program; including: final disposition of system ownership, a consistent and supportable tariff structure, and long-term management of system operation and O&M costs. The UNDP/GEF Project and several other organizations in China, including programs supported by GTZ in Germany, the World Bank, and the European Union, have collaborated with the National Development Reform Commission to share collective experiences with sustainable rural energy development to incorporate sustainable development practices into China's rural energy program development. The UNDP/GEF Project has provided specific support for several activities that are described below:

Baseline Survey of the SDDX Program: During the first half of 2005, a domestic expert team led by the Energy Research Institute in Beijing conducted a baseline survey of the Song Dian Dao Xiang hybrid village power systems to develop a database for evaluation and assessment of current performance, identify urgent needs, and provide guidance for the future SDDC projects. A total of 70 project sites were selected for detailed visits and surveys, including 66 PV and PV/wind systems and 4 hydropower systems. Additional basic information was provided for all of the SDDX systems by the company responsible for the original competitive bidding solicitations for equipment acquisition and installation in each of the SDDX provinces-the Guoxin Zhaobiao Co., Ltd. The information collected was assembled into a project database and analyzed by the Energy Research

Institute team.

The survey focused on: i) the operating performance of the systems since installation (2-3 years in operation at the time of the survey), ii) identification of system faults, iii) the ownership status of the systems and the types of organizations being employed to manage systems, iv) the load consumption, tariff structure, and success rate for collecting tariffs, and v) level of satisfaction with the systems. An assessment of the 15 year financial requirements for SDDX systems based on system integrator data and experience to date was also performed to estimate the long term operating and maintenance costs for the systems. The results of the survey have been summarized in a project report by the Energy Research Institute [4].

Using the information obtained in the baseline survey a series of GIS maps with associated databases have also been prepared for the seven provinces in the Song Dian Dao Xiang program. This information has been provided to the National Development and Reform Commission for planning and monitoring purposes.

Recommendations for SDDX Program: One of the outcomes of the baseline survey for the SDDX program was a series of recommendations to the NDRC for resolving some of the key issues affecting the future sustainability of the program. Based on these recommendations and other input, the NDRC is considering several actions; including: i) transferring ownership of the systems to the provincial utility companies as the best option to insure a future commitment to professional management and servicing of the systems, ii) using a renewable energy service company model to structure the local management of the systems and selecting management companies through a bidding process, and iii) structuring a financial support system that includes customer tariffs to cover operating costs of the systems plus a level of continued subsidies to cover some of the future equipment replacement costs of the systems. The Renewable Energy Law passed by the National Peoples' Congress in February 2005 provides for a fund that can be applied to support for rural electrification systems that will be financed by the national grid system.

Management Training: A management training course has been developed by the Jikedian Center in the Institute for Electrical Engineering of the Chinese Academy of Sciences for training the local management organizations responsible for the Song Dian Dao Xiang systems. The management curriculum is structured around the use of the renewable energy service company model and incorporates lessons from the international experiences of successful rural electrification programs. The course has been piloted as a train-the-trainers course in Beijing during July 2005 and was piloted at the provincial level in Qinghai during September 2005.

■ **Conclusion**

The Bulunkou Township village power project was initiated with UNDP/GEF support to demonstrate several principles for sustainable rural energy development based on use of renewable energy hybrid systems for village electrification. In cooperation with the local government, an organization was created to manage and operate the systems that is a non-profit entity, but uses business incentives to encourage development. Sustainable development is also supported by a strong emphasis on productive applications, continuous training activities, and expansion of operations. The management organization now controls 10 village power systems providing services to 2,000 households and supporting a variety of productive applications and social services. In collaboration with other organizations, the UNDP/GEF Project is using sustainable development experience from this and other rural energy projects to support China's very aggressive national rural electrification programs in western China.

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