A huge number of off-grid settlements in China are being electrified in one of the world's largest – and almost certainly most rapid – renewables-based rural electrification programmes. Yet installing 20 MW of PV in less than two years is no easy job. Jean Ku, Debra Lew and Shenghong Ma explain the background and report on progress.

Sending electricity to townships

China's large-scale renewables programme brings power to a million people

Despite rapid economic progress in China, and impressive electrification statistics, there are still about 30 million people without access to electricity. Bringing electricity to remote townships would not be financially viable if it meant extending the electrical grid to all townships across the vast regions of northern and western China. However, the use of renewables and micro-grids now brings electrification of these rural areas within reach for the Chinese Government, which is instituting a US$340 million electrification plan, one of the largest renewables-based rural electrification programmes in the world.

The Township Electrification Program, known in Chinese as *Song Dian Dao Xiang* ('Sending electricity to townships') is both ambitious and unique, because it is wholly initiated and funded by the Chinese Government, is committed to using renewable sources of energy for power production, and focuses on village power systems. Most significantly, the programme is being implemented at enormous speed and at an unprecedented scale. From start to finish, the Township Electrification Program will only take 20 months. Although renewable energy programmes exist all over the world, none match the schedule and scope of this one. For instance, after several years of intense preparation and negotiation, the World Bank/GEF Renewable Energy Development Project in China will install 10 MW of PV in solar home systems over five years. Meanwhile, about 20 MW of PV and 840 kW of wind turbines have been installed under the Township Electrification Program in less than two years. To put the scope of this programme in context, in 2001, solar cell production in the entire world was only 395 MW. The second phase of the programme, intended for 2005–10, is even more ambitious, expanding the 1061 townships by another 20,000 villages.

The Township Electrification Program was launched in 2001 with the immediate goal of establishing 1061 village power systems. Of the villages, 706 operate using PV, PV–diesel or PV–wind hybrid systems, with a total of 20 MW of installed PV (these are shown in Figure 1). In November, the central government assigned programmes to regional governments, and from April to July 2002, five nationwide public tenders were conducted to select system integrators to design, procure and install systems. A total of 15 system integrator companies were selected and issued international tenders for PV, wind turbines, batteries and electronics. Companies such as Siemens, Astropower, Sharp, Kyocera, Shell, BP Solar and Bergey Windpower are supplying equipment for the programme. The installations for the programme were completed in June 2003. The Government is still working on guidelines for tariffs and system ownership. Then, service companies will be installed. The provinces participating in the programme are Tibet, Xinjiang, Qinghai, Gansu, Inner Mongolia, Yunnan, Sichuan, Shaanxi and Hunan, with PV and wind technologies at work in all provinces except Yunnan and Hunan.

Township electrification with PV follows on from experience with installations further east, such as this school near Beijing DEBRA LEW

ADMINISTRATIVE STRUCTURE

The Township Electrification Program is being implemented through the Chinese central government's top-down administrative structure.The government ministry responsible for infrastructure development and policy, the State Development Planning Commission (SDPC) (now re-organized into the new National Development Reform Commission or NDRC), is leading these activities.The central government has invested $240 million to purchase hardware, and local provincial agencies will cost-share $100 million to pay for training centres and institutional development.

Training and infrastructure development efforts are being supported by Beijing Jikedian Renewable Energy Development Center (JKD), bilateral US and German renewable energy programmes, and the Institute for Sustainable Power (ISP) . Following the merger between the State Economic and Trade Commission (SETC) and SDPC, responsibility for the Township Electrification Program was assigned to the National Development and Reform Commission (NDRC). These projects will be integrated into the national strategic programme. Furthermore, the Township Electrification Program will link with the United Nations Development Program (UNDP)/GEF 'Capacity Building for the Rapid Commercialization of Renewable Energy' Project, and possibly the World Bank/GEF 'Renewable Energy Development Project' and the Global Village Energy Partnership.

PROGRAMME SCOPE

China is divided into provinces which are made up of counties, which are in turn composed of townships, then administrative villages, then natural villages, and finally households. For this programme, NDRC selected those 1061 townships that lack any access to electricity, and to which grid extension would be unfeasible.At this stage, only the township seat (the village where the local government resides) was electrified. In the next phase of this programme, *Song Dian Dao Cun* ('Sending electricity to the village'), the 20,000 administrative villages that lack access to electricity will be electrified.

TABLE 1. Technologies used for the Township Electrification Program

Technology	Number of villages	Capacity (MW)
Small hydro	378	200
PV	666	20
PV–wind	17	(total)
Total	1061	220

The most cost-effective solution for electrification of these townships, if adequate hydro resources exist, is small hydro. The installers outfitted the 378 townships which possess adequate hydro resources with small hydro power stations. For the remaining townships, they designed PV systems or, for those with adequate wind resources, PV–wind systems. Each system was installed with a mini-grid to distribute power to

FIGURE 1. **The scope of the Township Electrification Program in China, showing the number of townships using PV or PV–hybrid systems**

homes and businesses in the township seat, with enough capacity to supply basic needs such as lighting, TV and public facilities. Table 1 shows the technologies used in the programme.

HARDWARE

The village power systems are required to work for at least 15 years. The system integrators that won the bids to design and install systems are required to guarantee the systems for three years. Specialized service companies will operate the systems commercially, with users paying a reasonable tariff. Availability, which is defined as the fraction of time that power supply is available, should be 97% for public facilities, and 93% for private users. Basic living needs should be satisfied, and the reserve system capacity should be 30% of the current load.

CAPACITY BUILDING

Few residents of the townships have ever encountered electricity before, yet technical and economic realities will require these residents to be fully responsible for the operation and maintenance of the new electrical systems. Therefore, the training and certification process is absolutely integral to the ongoing success of these systems, and contributes a great deal toward legitimate consumer confidence in these new services and service providers. Ensuring that an adequate number of people are trained to the highest standard also ensures the continued success of the programme, long after the installations are completed.

NDRC has taken seriously its responsibility for sound training and asked the US National Renewable Energy Laboratory (NREL), the German Technical Co-operation (GTZ), and UNDP to support the development and institution of the training programme. The programme will train and certify 135 local trainers and 115 backbone service engineers at the national level. The local trainers will carry out training courses in seven provinces within the programme, to train at least two village operators per township, resulting in a total of about 1400 villager operators.

TRAINING

For the next phase of the programme (the Village Electrification Program, in which the remaining 20,000 unelectrified administrative villages will be electrified), an estimated 40,000 technicians will be needed. A training regulation, released in March 2003, stipulates that the local operator must acquire three levels of certificates:

1. Rural Electric Worker Certificate (basic knowledge and skills for rural power supply, such as safety issues) – this is an existing training programme; the Labour

Department or the Electric Power Training System will issue a power worker certificate.

2. Certificate for general knowledge and basic skills in PV hybrids and PV–wind hybrids – operators who have been certified as Rural Electric Workers will be trained by the Local Trainers, who were trained and certified by JKD.
3. Certificate for operating and maintaining the power system – the system integrator on the site will train and certify the operator, who must have acquired the preceding two certificates, in all O&M procedures for each component of the system. The operators will only be allowed to take positions if they acquire the three certificates, and they will continue to learn on the job, taking required follow-up training from time to time.

PV–wind hybrid systems are commonly used for rural electrification ISP

The US Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) and ISP are working with JKD – entrusted by SDPC to be responsible for the training element of the Township Electrification Program– to establish a training certification system for the Township Electrification Program. The framework is based on the foundation developed for solar home systems for the Chinese Government's Brightness Program, which was initiated with an action plan in 1996 at the 'Global Solar Energy Summit Meeting' to provide environmentally sustainable rural electrification. (Experience from the Brightness Program paved the way for the Township Electrification Program, and many of its elements made their way into the Township Electrification Program.) Based on this framework, the training programme will certify Master Trainers to international standards, and certify three provincial trainers to instruct local practitioners in the installation and maintenance of solar home systems. The curriculum meets the international competency standards as well as the needs of the Chinese market.

Building on the success of this stage of the project, JKD proceeded with the next two phases in the development of a national framework capacity for the maintenance and implementation of the international training accreditation and practitioner certification standards. These are the qualification and accreditation of Chinese auditors, with the capacity to evaluate and audit trainers and training institutions in China to the international ISP accreditation standards; and the formal evaluation and accreditation of a training institution in China as an ISP-accredited site meeting the international standards. ISP is currently providing formal evaluation of a village power training programme for consideration as an accredited training centre; this accredited programme will train the certified Master Trainers in level two of the training regulation.

With US DOE support, JKD, NREL and others completed a master village power system manual in February 2003, with chapters on resource assessment, system design, operation, maintenance and safety for PV, wind, PV–wind hybrid and PV–diesel hybrid systems. A theoretical and practical training programme was developed in March, and the first training courses for Master Trainers, supported by GTZ, have been completed. Afterwards, Master Trainers conducted two training courses for provincial trainers. In total, 29 trainees from Xinjiang, Qinghai, Shaanxi, Inner Mongolia and Sichuan participated, passing the exams and gaining certificates. Some of them are running training courses in their provinces already. Master Trainers will work with provincial system integrators to develop an operation and maintenance manual specific to the provincial systems. An accredited training centre for village power systems will be completed by the time the last systems are installed.

PROGRAMME SUSTAINABILITY

Over the last few decades, small-scale renewable energy systems have been used to electrify rural areas, with mixed success. Many of the failures can be attributed not to the difficulties of introducing a new technology but rather to a lack of institutions and infrastructure necessary to support the programme.[1,2] A critical lesson learned through NREL's work in rural electrification over the past decade is that the density of systems installed in a particular region must be high enough to foster local businesses' viability to operate, maintain, install, and repair the systems. China's programme is on a large enough scale to allow for a viable energy service industry. However, programme success and sustainability also require a healthy infrastructure: trained service technicians, adequate spare parts inventories, collection of tariffs that in turn can fund necessary O&M, and effective education of consumers about energy efficiency and proper usage. Integrated programme design is essential for the long-term sustainability of the Township Electrification Program.

CRITICAL ISSUES

The Township Electrification Program is making good progress, but it is far too early to judge the successes or failures in the implementation of the programme. Such an ambitious programme inevitably faces challenges, and with the hope that the Township Electrification Program will continue to evolve, the following recommendations have been made to address challenges in several areas.

Overall programme design

The Provincial Development Planning Commission (DPC) issued tenders for the Township Electrification Program: one for systems integrators to design, procure and install systems and another for service companies to operate and maintain systems. It is currently unclear who will own the systems, and NDRC is drafting a policy to address the ownership issue.

In order to encourage a reliable, robust, high-quality system with good components, a single tender for bids to design, install, own, operate and maintain systems could be implemented. The bids can still be selected based on lowest cost-per-kWh and other considerations (such as quality and service). In this case, a systems integrator company can partner with a service company to bid, or one company with expertise in both areas can bid. This will ensure that the service division of the company is able to maintain and repair the system and have a supply of spare parts. Another option is to issue the tender for the service companies first, then the selected service companies can issue a tender for turnkey system integrators, with guidance from the provincial authorities. The tariff policy and the equipment supply standards should be established at the start of the programme.

LESSONS LEARNED

In December 2002, a Village Power Sustainability Workshop, organized by NREL and JKD and supported by the US Department of Energy (DOE) and NDRC, introduced lessons learned from village power programmes elsewhere in the world. Major conclusions from the workshop were:

- if system standards are inadequate, having separate companies design systems and operate systems could lead to poor installations, or equipment selection that could result in large O&M and repair costs in the future strong management and operation is essential load management, especially at peak hours, is important
- rational tariffs can fund O&M, system repairs, component replacements, etc.; tariffs can be set so as to discourage excessive use
- trained local energy service companies should manage systems, not villagers
- quality manuals and certification for technicians, trainers and operators need to be provided
- adding wind or diesel capacity to a PV village system may provide more reliable and cheaper service depending on the location and resource
- it is important to consider load growth, as consumers purchase additional appliances.

Selling solar: PV on display at a shop in Tibet IT POWER

System selection and design

The tenders indicated how much PV should be provided to each township. It is not clear that other resources, such as wind or diesel, were considered, even if they provided better reliability at lower cost. Additionally, wealthier townships receive the same amount of power as poor townships, even though the wealthy ones may be able to afford more power.

In the end, it is the energy services, the lighting or refrigeration or TV, that the end-users want, not the PV panels or wind turbines. The most effective role for government would be for it to simply issue requests for provision of energy services, and allow

Household PV–wind system in Inner Mongolia DEBRA LEW

the companies to decide whether a PV–diesel hybrid, a biomass gasifier or a PV–wind system would supply the given load with a specified reliability at lower cost.

At present, these systems have been designed for supplying basic lighting and communication needs. However, this does not necessarily take advantage of the great potential that electricity has to provide income-generating opportunities through productive uses. The ability to do so will require larger systems that may be more cost-effectively provided by PV–diesel, PV–wind, biopower systems or hydro power. This is why it is so important to determine the village's needs and ability to pay before designing a system. Consulting with village representatives and stakeholders should be a first step in system design.

Tariffs and metering

Tariffs have not yet been set for the programme. The most effective tariffs would be based on analysis of several factors: ability to pay, willingness to pay, current energy payments, cost recovery of the O&M and repair of the system, future outlays for expansion of the system, and cost recovery of the system. A tariff that considers these factors can also be an effective load management technique, discouraging the purchase of too many new appliances that the system would be unable to support. A survey of each village can determine current energy outlays of each household (including kerosene, candles and dry-cell batteries). This could be used to help determine the market price for the tariff. Electricity provides a higher quality of service, so the tariff may be higher than the current energy costs for each household. A two-part tariff, with a higher tariff for excess demand above a fixed level, can help to discourage excessively high energy consumption.

Load growth, load management and user education

Load can be managed by setting higher tariffs for high-demand users or by installing current-limiting equipment. Technologies such as digital meters that can be programmed to limit current and daily energy consumption provide a simple and cost-effective means to accomplish this extremely critical aspect of renewables-based village power projects. For PV-based systems, it is very important to make sure that the electronic/programmable meter does not consume more energy to operate than the consumer is using.

Education of users is critical; they need to understand what kinds of appliances are suitable for renewable energy systems (for example, electric heaters, rice cookers and incandescent light bulbs are not suitable). When end-users do not understand that the power from a system is limited, they tend to overuse the system, which can damage and even destroy the batteries.

Operation and maintenance (O&M)

O&M tends to be provided on an effective and efficient basis when the financial success of the system owner is directly

PV–wind hybrid system for an Inner Mongolian home ISP

linked to the performance of the power system and the delivery of power to each customer and collection of customer payments. More private sector involvement from energy service companies and others will help the government to create and establish stable policy guidelines.

Training and monitoring

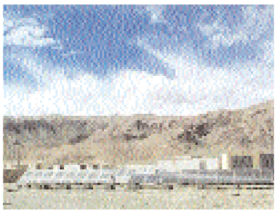
An accredited training facility and programme in each of the project provinces, complete with a central monitoring system, will ensure quality training. The monitoring system will not only control the quality of training, but also define needs for further training. It will also help to improve the training programme for the next phase of rural electrification, *Song Dian Dao Cun*.

Productive uses

Providing reliable, utility-grade power for small, income-generating activities as a part of the electrification of townships and villages is the best use of time and money. The electrification projects can be used to attract and leverage the contributions of non-governmental orgainzations and government agencies, which provide financing and services for stimulating and supporting income-generating enterprises. A battery-charging station is one such business opportunity; people who live close to a mini-grid but are not connected to it could bring lanterns, flashlight batteries or deep-cycle batteries to such a station and pay for a recharge. This could be made available only when there is extra power, thereby providing load levelling and financing for system maintenance and expansion.

CONCLUSIONS

Early analysis of the Township Electrification Program shows the critical importance of comprehensive programme design. Programme sustainability issues revolve around after-sales service, appropriate tariffs, load management, metering, monitoring of systems, reliable batteries, suitable system design, and productive use components. Local and central government in China has provided hundreds of millions of dollars to subsidize capital equipment and installation. Following up by cultivating the framework to train a legion of



PV is a proven technology for rural electrification in China. This system was installed in a Tibetan village in 1990 IT POWER

systems operators, O&M and service technicians, productive use facilitators, programme managers and independent system monitors will be a vital ongoing effort.

Because social welfare benefits from rural electrification, such as lighting or television, do not necessarily increase economic development, and in many cases only add to the debt burden of end-users, the upcoming Village Electrification Program, which is to provide electricity services at the village level, would benefit greatly from a strong productive use component. Conditions that enable productive use include reliable and affordable electricity, availability of tools and machines for productive applications, financing for tools and working capital, capacity building for technical and business challenges, and markets for increased quality and production.

The Township Electrification Program has enough critical mass to spawn a truly robust and sustainable renewable energy infrastructure in China, especially for PV. There is a large enough quantity of equipment in a small enough area to create local business viability. It is still possible to avoid imprudent future subsidies that could put fledging businesses such as PV dealers out of business.

The Township Electrification Program is only the first grand step, providing basic service to one million people living in unelectrified local government seats at the township level. In a subsequent stage the Chinese Government is committed to supply the remaining 20,000 villages that will not see grid extension in the foreseeable future. The lessons learned from the Township Electrification Program will have an immediate impact on future rural electrification programmes in China, including the upcoming Village Electrification Program.

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