

Approaches of Sustainable Development of Rural Electrification by Off-grid PV & Wind Power in China

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ABSTRACT: In *Chinese Renewable Energy 11th Five-Year Plan* and *China Long and Middle-termed Development Layout*, it was put forward to develop power supply of renewable energy in the rural area and was regarded as the important measures to promote the development of economy and society of the countryside. In the next 15 years, solving the problem of power supply to the no-electricity population and improving the renewable energy utilization level in rural life is arranged as one of the critical issues of renewable energy in China.

In this study, the following work has been carried out here, 1) The relevant issues on the rural electrification in China by off-grid PV and /or wind power are investigated and analyzed; 2) With the sustainability of rural electrification in China by off-grid PV and /or wind power, the models of finance & subsidization, program organization and management, technologies and system optimization of the program implementation are proposed herein; 3) A scheme of the rural power supply sustainable facilities is brought about herein; the proposal on the rural renewable energy power supply in China is presented herein as well.

Key words: Rural electrification, sustainable development, off-grid PV power, off-grid wind power.

NOMENCLATURE

GEF	- Global Environmental Facility		abbreviated as SDDX), represents the Township Electrification Program by Renewable Energy in China.
NDRC	- National Developing and Reform Commission of China	SDDC	- Song Dian Dao Cun (in Chinese pronunciation, abbreviated as SDDC), represents Rural Electrification Program by Renewable Energy in China
OBA	- Output- based Aid		
O/M	- Operation & Maintenance		
PV	- Photovoltaic		
RE	- Renewable energy		
RESCO	- Rural Electricity Service Company	SHS	- Solar Household System
SDDX	- Song Dian Dao Xiang (in Chinese pronunciation,	Wp	- Peak watt

1. INTRODUCTION

In the view of long-term and sustainable development, due to the exhaustion of the fossil fuel, renewable energy will become alternative energy next decades. In the west rural areas of China, wind energy and solar resources are rich; the distributed off-grid power system with wind and solar power will be preferential in rural electrification.

Nowadays, about 350 thousand households in remote rural areas were supplied by off-grid PV, wind power or the hybrid systems, with being funded by international cooperation or domestic investment projects.

China central government has accorded a very high priority to provision of electricity access to rural communities and households. Consequently, only about 10 million people remain to be electrified in the Western Provinces. With SDDC Program, it is to ensure that electricity services to the remaining populations are provided in economic and sustainable manner to improve the quality of life and alleviate poverty of the rural peoples.

Under the SDDC, 20,000 non-electrified villages in seven west provinces (regions) are expected to be electrified over five years period. The dispersed households will be electrified by home systems and bigger villages will be electrified by mini-grid power systems. It is expected that SDDC concessions or other contracts will be granted to qualified organizations that will be responsible for provision of the PV and PV hybrid power systems for designated villages and for providing long term maintenance and other support services.

Due to the varieties and differences of the geological condition, economical level, resident main source of income and natural resource and so on in the west China, the investment mode, fees sharing for the O/M and component replacement may need to be considered and dealt with respectively, for example, difference does exist between Tibet and Xinjiang in lots of aspect.

1.1 Renewable Energy Promotion Law

On Jan. 1, 2006, the China Renewable Energy Promotion Law came into force. The law strengthens the business environment for renewable energy investments, including renewable energy based rural electrification.

Renewable Energy Promotion Law will greatly speedup electrification process of villages and household deprived of the electricity by means of PV or wind power system. With the off-grid power system, the tariff subsidy calculation and awarding is necessary to be set in advance. The enacting of the Renewable Energy Law will have a powerful impetus on the development of off-grid renewable energy power system and rural electrification in China definitely.

In the *Layout of National Renewable Energy Mid-Term and Long Term Development*, the policy of electrification of the rural area non-accessible to the power was much stressed as follows,

“In the area where grid extension is not economical, by making use of the local resource advantages, the renewable energy technologies of micro scale (including Pico scale) hydro, wind and solar PV power, etc will be applied to supply the basic electricity for the population deprived of electricity. In the area where Pico-hydropower resource is abundant, micro (Pico) hydropower will be preferentially developed to supply the power for one million household residents; In the area short of Pico-hydropower resource, the PV power, and the off-grid solar/wind hybrid power system will be built in accordance with the local situation in order to supply electricity for one million household residents. In 2015, the electricity will access to all the population deprived of electricity by means of grid extension and off-grid renewable energy power generation system”.

1.2 SDDX program

In 2002, the NDRC launched the Song Dian Dao Xiang (SDDX). By the end of 2005, 721 photovoltaic (PV) and PV-wind

hybrid stations had been installed to provide electricity to non-electrified townships with 1.3 million people, 300,000 households in seven western provinces. The stations were located in remote off-grid sites with communities. The PV and PV-wind hybrid stations of SDDX were characterized by high initial investment, long life span of the PV modules, no fuel consumption, and a major recurring expense every five years or so are battery replacements and a main customer base of poor households with limited ability to pay the tariff.

Although the rollout of the stations was completed within a tight time schedule, a number of key issues that will condition the long term sustainability of the systems and services were not resolved.

The SDDC design shall take into account the lessons learned and avoid the problems of SDDX from reoccurring.

1.3 Other rural electrification programs in China by international cooperation

A number of renewable energy-based electrification projects supported by international and bilateral agencies were implemented mainly as follows.

Sino-German Financial Cooperation Program-Solar Energy Program (2002-2008): in Western 4 Provinces of China, with being funded by the Sino-German Financial Cooperation Program, about 100 off-grid PV and PV/diesel hybrid power stations have been already built in Xinjiang, Yunnan, Qinghai and Gansu and are supplying electricity to the villages after hand-over to the responsible service agencies. The installed PV and PV/diesel hybrid systems are being operated by the provincial service companies.

WB/GEF REDP Program: Purpose of the Program is to assist in technology improvement and capability building by subsidizing 350,000 sets of SHS with \$1.5USD/Wp in western China, total planed capacity is 10MWp.

Shell Solar Silk-Road Project (2002-2006). The total investment is 2.5

million USD, among which 60% investment is from Netherland government with 1.5 million USD, and 40% is from Chinese party, with amount of 10 million USD. The cooperation program is to subsidize the farmer' solar home power system, the location of the project implementation is in Xinjiang.

1.4 International experiences on rural electrification by using PV power

In Bolivia, under the World Bank and GEF-assisted Decentralized Infrastructure for Rural Transformation Project, concession contractors bid to sell, install, and maintain a minimum number of PV home systems for a pre-specified grant amount. A performance-based OBA grant is available to provide maintenance services.

In Philippines, under the World Bank and GEF-assisted Rural Power Project, the Sustainable Solar Market Package approach has been introduced to energize remote rural villages. A contract is awarded to a company to supply and install PV systems for public facilities in groups of villages in target market area. The company must commit to selling and installing PV systems in at least 25% of the households for which a 40-60 percent OBA grant is offered. The company must provide maintenance services for an initial five year period that is extendable. The maintenance for public facilities is paid by a government grant while consumers pay the direct cost of maintaining their own systems.

2. LESSONS FROM PREVIOUS RURAL ELECTRIFICATION PROJECTS BY USING OFF-GRID PV AND /OR WIND POWER

(1) The philosophy of "power supply & the service" is not defined. Ultimate target of rural electrification is to supply power and the corresponding long term and reliable service. It is proved that, with majority of rural electrification programs, the

fundamental principle of “supply long term and reliable power and the corresponding service” was not highlighted, which resulted in series of subsequent problems with rural electrification non-sustainability in China.

(2) The optimized design according to real local solar and wind resource were not done, so that the configuration of the plants is not ideal to gain the outcome. Though multi-energy hybridization was considered, the optimization design was not used. Furthermore, the minimum level of power supply, which can be subsidized by government, has not set reasonably without referring to the actual situation.

(3) Project implementation and the management need to be standardized.

(4) For the lack of unified technology requirement, standard, and management, the project quality differs from each other greatly.

(5) The ownership of assets of the power system is not clarified, which leads to the unclear responsibility issues.

(6) Effective O/M service has not been put into effect.

(7) Procedures on site-selection and verification, supervision, inspection and acceptance have not been legalized.

(8) Electricity fee collection and the criterions among the provinces are not unified or regularized.

(9) Plants operators employing, training, management, and dismissal have not been regularized.

(10) After sales service the standardized quality assurance system need to establish, so as to provide the excellent service to the end-user.

3. MODELS OF BUSINESS, FINANCE, AND MANAGEMENT

3.1 Business model

(1) Ownership is one of the most important and fundamental issues. SDDC is a program with features of big capital investment, high service cost, the users are dispersed in large area and not able to cover the full cost etc.,

in order to meet the requirement of least cost, O/M entities must be able to receive subsidy which should cover the gap between the actual cost and the tariff for the end-users. There are only two options to keep the state assets without being lost: 1) to award the ownership to a state owned enterprise for example local utility or other state owned company; 2) to keep the ownership in an authorized governmental organizations (for example Township government); 3) to separate the O/M right from the ownership right by contracting a service company such as RESCO. Otherwise the ownership may be given to the Village Committee or the households, only if a legal arrangement is settled to privatize the state assets.

(2) No matter who is owner of the SDDC asset, the basic rights and obligations of the service enterprise shall include at least 1) owning the power supply business permit in a specified area from provincial commission of power supply supervision; 2) having installed adequate RE systems in accordance with the supply standard and requirement of the costumers; 3) collecting tariff and fees, receiving the subsidy to cover the gap between the actual cost minus the payment from end-users;

(3) The potential service company must be an enterprises profile in order to ensure a sustainable development. The unit could be state owned enterprise such as power utility, private company/ joint venture like RESCO, or self service by village committee, villagers' own; nevertheless, following conditions have to be fulfilled: 1) the state assets must not be lost; 2) least cost must be achieved; 3) the service must be effective and sustainable.

(4) Potential service units is briefly listed as follows,

- Utility Power
- Other State-owned Enterprises
- RESCO (Rural Electricity Service Company)
- Other private companies or joint-venture
- Village Committee or villager

(5) The ownership shall be chosen and decided through bidding process; the tendering company has to provide a bank guarantee with a certain amount of deposit. The owner is responsible for the power supply service for a fixed period (15 years for example) in accordance with the supply standard. The owner collect tariff and receive subsidy and payback the government investment year by a year till all government investments are recovered. In this way, the government risk and management cost will be minimized, the ownership and service responsibility are tied up, the owner shall do the best to run the business.

3.2 Financial model

With investment and finance of rural electrification project, the aim is to gain optimal profit and least cost.

As a stand-alone renewable energy power system, the cost of energy is rather high. So here subsidy to the investment and O/M are very necessary. Tariff cross-subsidy is legalized in Renewable Energy Promotion law and the relevant policies of central government.

With mechanism of tariff cross-subsidy of off-grid wind/PV power, the following issues shall be firstly considered,

Minimum service level: With the issues of minimum service level, the quantity of basic power supply and the guarantee rate of power supply shall be considered. By aiming at determining the basic electricity needs of households that government will be responsible for and critical service facilities basic electricity needs, the findings will contribute to the option of minimum level of service.

Tariff will be decided by referring household income level, energy consumption level profile, residents' willingness and ability to pay and other elements comprehensively. The minimum service level and tariff are the key parameters in the financial model.

Application for electrification: in the

off-grid area, the residents must apply for the electricity connection, which is the first fundamental legal procedure; otherwise the subsequent procedures can not proceed legally.

Cross-subsidy calculation and verification must be done by using a calculating tool.

Subsidy cash flow and its control shall be under supervisions and managements.

Cross-subsidy, cash flow, transferring of the payment and its control and supervision are the important to guarantee the fund to be used scientifically and in reason.

With the micro (Pico-) hydropower, the cost of power is relatively lower, the owner or operating company can balance the operating and maintenance cost by collecting the electricity fee with being same as the tariff of grid extensions program, therefore there is no need of national subsidy for the micro (Pico-) hydropower, fund of instruction of micro (Pico-) hydropower can be raised from the multiple channels, such as from government, investors, end-users itself commonly.

4. CONSIDERATIONS OF IMPLEMENTATION OF RURAL ELECTRIFICATION

Firstly, to determine the basic level of electricity supply, which can be subsidized and allocated by national grid in a specific provinces or the country, for example, a value of 200 kWh power per household per year can obtain a portion of subsidy.

Secondly, according to the solar, wind energy resources condition data in the localities, and the other data such as the power system constructing cost and number of households in a village, by using the analysis & optimization tool to select an appropriate power system and the design that meets the required load at minimum cost, among grid extension, off-grid PV, off-grid wind, Pico-hydropower, and so on. Finally, the primary capital investment and

the total subsidy cost can be calculated out based on the above results of the analysis described above.

5. CONCLUSION AND PROPOSALS

5.1 Conclusion

(1) Rural electrification is a complicated system engineering project; the goal of rural electrification is to realize the sustainability of development with least cost and optimal comprehensive profit. The technical approaches include grid-extension, micro-(Pico-) hydropower, off-grid PV, and wind power and so on. Therefore it is necessary to stress the reasonable plan by linking to the local situation, so as to reach the co-existence of multiple technologies with optimization and novel models of business and finance.

(2) In the implementation of rural electrification, sustainable and harmonious development shall be focused by planning the rural electrification program as whole. The target of the implementation of rural electrification program is to obtain the optimal tech-economical performance, permanent sustainability, in order to enable the residents to gain the long-term, reliable, and high-quality service of power-supply. In a word, the people in the non-electrified area can be able to consume the electricity, to make best use of electricity, and make the electricity be worthy of, and remove the poverty gradually.

(3) With the management of the implementation of rural electrification program, the program proposing, argumentation, construction, and the management shall be regarded as a whole. The procedure of implementation must be feasible and standardized, such as in the sites selection and verification of the project implementation, optimization and argumentation of the technical and systematical plan, quality control and guarantee of the key components, the bidding of the project, construction, and

quality supervision, inspection and acceptance of the completed projects, after-sale service, supervision of government, and so on. In the different stages of the project implementation and with the different project, the detailed checking and testing indexes shall be stipulated, and must be executed strictly.

(4) The general implementation approaches can be summarized as follows, (a) have a in-depth surveying of natural resources; (b) plan the program as whole; (c) emphasize the prophase work; (d) raise the fund of construction and O/M through multiple channels; (e) establish the project legal person responsibility system; (f) stress the management of the project implementation process, quality of project, and the in-stage and final inspection and acceptance procedure.

5.2 Proposals

(1) To carry out the following issues: (a) further to promote the complete resolution to the no electricity rural area in China, so as to offer the references for the other developing countries; (b) to develop the management information system of the non-electrified rural area power construction program implementation; (c) to develop the tool of tech-economic comparison and decision making supporting on non-electrified rural area power construction program implementation

(2) To designate a province as a pilot region (or province), to carry out the followings, (a) to make the overall and careful survey on solar, wind and hydro energy resource in non-electrified area; (b) to make a probe on the population and the relevant information of population in non-electrified area; (c) to make further study and make out the detailed rules of non-electrified area power construction program implementation in the pilot region; (e) within the pilot region, to select the typical non-electrified villages as the pilot villages, and to conduct the relevant research and demonstration, to summarize the experience gained, to

advance steadily the implementation of the non-electrified area power construction program in pilot region.

ACKNOWLEDGEMENT

This study was funded by World Bank/GEF China Renewable Energy Development Program.

I would like to express my gratitude to my colleagues and the experts for their contribution and instructive discussion in the study.

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