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The Best Practices for Off-grid Solar Energy

----- A case study on China

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Abstract

While the beauty of solar energy is well known, there exist a lot of barriers to the greater use of photovoltaic solar home systems in meeting the basic power needs of the substantial population in developing world. Among them reviewed are purchase, delivery and maintenance related barriers in policy and institutional perpectives. A few good practices are examined accordingly. Finally, a case study on the development of solar PV of China are conducted, covering the current situation, the existing problems, the applicability of international practices and recommendations.

Executive Summary

There is little doubt that the use of new and renewable energy sources should be supported in building a sustainable energy sector worldwide. The resources we have come to rely on (oil, natural gas, coal and uranium) are becoming scarcer, more difficult to find, and more expensive and /or difficult to use in an environmentally sound manner. Thus, over the past few years, movement toward reliance on renewable resources makes a great deal of sense. Renewable energy sources still account for a sizable and ever-increasing proportion of total energy supply in some countries and regions. For instance, they contribute to about 8 per cent of US energy demand.

Solar energy is considered by many an attractive and practical option for the future, one that is technically and commercially feasible as well as socially and environmentally desirable. The maximum insolation incident on the earth's surface on a clear day is about 1000 watts per square meter. The technologies are developed to harness such free and abundant energy for directly heat, daylighting and indirectly electricity purposes. Some of them already make economic sense since the enormous technology advancement and increasing market penetration have driven the prices down remarkably in the past decade or so, even making few of them, such as solar water heater, competitive in the market predominant by the conventional fuels. In particular, they have the distinct advantages in meeting the fundamental electricity needs of households in remote rural areas comparing its costs to that of grid expansion or diesel generators. In contrast, there are nearly two billion people around the world with no access to modern energy.

This paper looks st the existing major barriers that hamper greater market penetration of solar PV/SHS into existing-high-demand areas around the world, including high initial capital costs, gap in delivery and information dissemination, and lack of after sale service and maintenance as well as poor national strategy and international cooperation on solar PV. The innovative mechanisms and institutional arrangements in coping with these barriers in certain part of the world are reviewed. Finally, included is the case study of China on its current situation of solar PV uses, existing problems, applicability of international practices in solving these problem and recommendations.

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Introduction

Solar technologies can be broadly cataloged into two categories: solar thermal and solar electrical. Solar thermal technologies use the sun's heat energy to hear substances (such as water or air) for applications such as space heating, pool heating and water heating for homes and businesses. Often the products used for this application are called solar thermal collectors and can be mounted on the roof of a building or in some other sunny location. Solar efficient housing (often referred as passive solar house design) is a prime area for low temperature solar thermal system design. In many temperate and tropical climate zones, it is entirely feasible to design zero energy structures requiring no energy input other than solar to maintain comfort living conditions on a year round basis. The most common application of solar thermal is domestic hot water supply. Hot water heaters make more economical sense than do residential central heating systems, which may be needed for only a few months of the year.

The sun's heat can also be used to produce electricity on a large utility-scale by converting the sun's heat energy into mechanical energy. Photovoltaic is a semiconductor-based technology which converts light energy directly into an electric current that can either be used immediately or stored, such in a battery, for later use. PV cells are in many ways the most attractive solar energy source. They have no moving parts, can be quickly installed in large or small modules, and can be used anywhere there is sunlight. Moreover, they need little maintenance, have little environmental impact beyond those of dedicating space to their use, and offer the long-term prospect for mass production and application in most parts of the world. The simplicity and ease of use render it ideal for small off-grid applications, such as lighting, water pumping, battery charging, and vaccine refrigeration.

Great strides have been taken over the past decade in the technology and economics of solar energy utilization. Take PV cells for an example, lifetimes have been extended to 20 years. Efficiencies have been improved from 9.8% to up to 21%. PV module costs have dropped from about $50 per peak watt to about $6 per peak watt today, considerably expanding opportunities for practical use of PV power (Charter, 1991). Further cost reductions can extend PV use in the future in several applications, for example, for peak-shaving purposes in urban areas.

A discussion of other applications not directly converting visible light or solar heat is not within the scope of this paper. For example, biomass may be converted to electricity through conventional combustion technologies, an essentially CO_2 neutral process contributing about 14% to the world energy consumption. Other renewable energies such as wind or hydropower also have a long tradition; about 7% of the present world electricity production are based on the exploitation of these resources (Kuhne and Aulich, 1992). Also beyond the scope of the paper are hybrid systems integrating direct solar use with other renewable energy or diesel systems.

Once a new technology reaches the commercial stage and its economic competitiveness is approaching that of other technologies already in the market, then financial, institutional and other factors take on major importance as they dictate when and how the new technologies will become competitive. The purpose of the paper is to examine those factors affecting the development and diffusion of solar technologies in developing countries and to identify ways of overcoming constraints to introducing these technologies into the marketplace, which would result in increased use of solar energy sources on an economic basis. This paper deals with off-grid applications of photovoltaic solar home systems (PV/SHS) in rural and remote areas.

Solar PV is affordable to an increasing segment of the Third World's off-grid rural populations. Rural households currently using kerosene lamps for lighting and disposable or automotive batteries for operating televisions, radios, and other small appliances are the principal market for the SHS. Approximately 400,000 families in the developing world are already using small, household solar PV systems to power fluorescent lights, radio-cassette players, 12 volt black-and-white TVs, and other small appliances. These families, living mostly in remote rural areas, already constitute the largest group of domestic users of solar electricity in the world. For them, there is no other affordable or immediately available source of electric power. These systems have been sold mostly by small entrepreneurs, applying their working knowledge of this proven technology to serve rural families who need small amounts of power for electric lights, radios and TVs. The World Bank estimates that 50,000 SHS have been installed in China, 40,000 in Mexico, and 20,000 in Indonesia.(http:www.worldbank.org)

However, according to the United Nations Development Program, 400 million families (nearly two billion people) have no access to electricity. The European Union's renewable energy organization EuroSolar estimates the global market for solar photovoltaic home lighting systems is 200 million families. Based on market studies in India, China, Sri Lanka, Zimbabwe, South Africa and Kenya (KENPREP, 1997) conducted by various international development agencies over the past 5 years, the consensus is that approximately 5% of most rural populations can pay cash for an SHS, 20 to 30% can afford a SHS with short or medium term credit, and another 25% could afford an SHS with long term credit or leasing.(http://undp.org)

In the rest of the paper, an insight look is made into the existing major barriers that hamper greater market penetration of solar PV/SHS into high-demand-existing areas around the world, including high initial capital costs, gap in delivery and information dissemination, and lack of after sale service and maintenance as well as poor national strategy and international cooperation on solar PV. As almost all renewable energy technologies share some similar features, these barriers may be common to them. The innovative mechanisms and institutional arrangements in coping with these barriers in certain part of the world are reviewed. Finally, included is the case study of China on its current situation of solar PV uses, existing problems, applicability of international practices in solving these problem and recommendations.

Barriers and barrier removal practices

High initial capital costs or lack of access to credit

High initial capital costs have been a major hurdle for widespread dissemination of solar PV. As a matter of fact it is the case with most renewable technologies. Solar technology has very low operating costs---and thus the lower life-cycle costs than conventional alternatives---the high initial capital costs of the technology often forms an insurmountable barrier to its use, particularly for small rural energy users. Individual households and small rural communities, which are a large untapped market for renewable energy, frequently lack access to credit to cover the up-front cost. Consumer credit is not generally available and no specific funding pool dedicated the marketing of renewable has been established yet.

Most conventional energy sources have established infrastructure for the technology, which can add significantly to its capital cost (McClellan). However most commercial financial institutions are unfamiliar or uncomfortable with small-scale renewable energy options and, therefore routinely ignore or reject them. The World Bank, for example, is the single most important source of external capital for energy activities in the developing world, with Bank lending for this sector amounting to approximately US$ 3 billion per year. Most important multilateral lending agencies have poor track records on financing small-scale power projects (not even on a wide-scale basis to achieve economies of scale) and are only recently reconsidering sector lending to promote small-scale energy systems development.

Barriers to introducing and financing solar energy systems also exist at the community or village level. Too often, small-scale borrowers are perceived as having no collateral. The solar home systems are considered consumer goods by banks, so are excluded from credit options for productive purposes. Similarly, household photovoltaic electrification may not occur simply because there is no institutional mechanism of loan recovery. (http://self.org)

Overcoming this barrier calls for innovative approaches such as micro-financing cooperative systems, end-service payment, equipment leasing and flexible loans. Small-scale energy consumers in the developing world who stand to benefit from small-scale renewable energy systems need better access to affordable financing. Of particular interest are financing programmes that mobilise local resources and facilitate the bundling of discrete small credit schemes into major financing opportunities for major multilateral and bilateral agencies.

Small-scale lending for renewable energy is viable when the proper institutional framework exists to administer such a programme. The joint UNDP/World Bank, US Department of Energy, and the Netherlands project entitled FINESSE (Financing Energy Services for Small-Scale Energy Users) is an example (ESMAP, 1989). Under FINESSE, large multilateral lenders provide loans "wholesale" to an intermediate, in-country institution for "retail" lending at the village level. This approach prevents the large multilateral institutions from having to incur high overhead costs to administer small-scale loans, while nevertheless putting them in the small-scale lending business. It is again exercised in GEF/World Bank Solar Energy in Indonesia.

Consumer financing. The need for purchaser credit becomes clear when one compares the purchase of a solar home system by a rural household in the developing South with the purchase of an automobile by a household in the industrialized North. Both purchases represent costs equal to approximately 50 weeks of income. In the case of the car purchase, a well-established financial infrastructure links customers to manufacturers to capital markets, and a wide array of financing choices is available from banks, leasing companies, and dealers. But in the SHS market, financing is unavailable, and a customer typically must pay the full price up front. Imagine the negative effects on the automobile industry if every customer had to pay the full cash price. Although the situation varies a great deal from country to country, studies by Enersol and others indicate that only about 5 percent of rural households in developing countries have the ability to purchase a system outright with cash and that various forms of financing allow another 50 percent to enter the market. Clearly, available credit is an important need if a market for solar home systems is to take shape. (http://self.org)

Because issues of affordability and credit-worthiness remain obstacles for lenders in the developing world, the need has been recognized to create broad-based credit operations that service large numbers of SHS purchasers simultaneously. Such an operation already exists in Indonesia, where 5,000 customers are currently receiving financial assistance to purchase solar home systems from an Indonesian SHS company called Sudimara Solar, which provides customer financing in addition to distributing the products. Sudimara has a 100 percent payback rate from customers but has been unable to get Indonesian banks to provide credit independently. Banks have not been willing to step in to help purchasers directly since the SHS industry is still so new that banks remain wary. Lenders are not likely to become involved on a broad scale until more projects like Sudimara expand and are replicated elsewhere, building greater lender awareness and confidence.

Nor are more sophisticated financing schemes available like the purchase of loans by third parties, which is common in U.S. debt markets. Seeking to develop alternative financing options that could provide SHS manufacturers and distributors with working capital, Sudimara might bundle and sell its receivables to a factor or outside investor. The investor would be given a percentage of the interest paid by purchasers, and Sudimara would be able to provide financing to another round of customers. If payback rates remain as high as they have been for Sudimara in the past, this arrangement could provide an almost limitless source of capital with which to expand SHS sales. As the amount of bundled receivables from the SHS market grows, a debt fund mechanism might be developed to hold receivables from many projects, into which many investors could buy. This would help achieve the economies of scale that are available in the automobile, credit card, and bank debt markets.

Leasing Arrangement. Soluz, a for-profit entity affiliated with Enersol, is experimenting with a different kind of financing technique a leasing scheme in the Dominican Republic. Nearly 1,000 poor rural households are to be hooked up to solar systems tailored to their individual needs. Households will pay just a few dollars each month for the service, even less than they would owe if they had purchased a system on credit. This is an unusual arrangement because conventional wisdom holds that households which purchase systems will take better care of them and pay for them in a more orderly manner than households which lease systems. So far, however, Soluz's collections on its leased units are at 100 percent, and there have been no major care and maintenance problems. Within a year, Soluz hopes to have gathered enough financial data to approach investors for capital to replicate this model. Some solar commentators are now speculating that leasing could be the distribution model of the future, especially in poorer countries, and that it will make solar home systems even more available to the rural poor. In fact, it is comparable to how most end-users pay for electricity: not with a large up-front outlay of cash for a new power plant, but through small monthly usage fee (World Bank, 1994).

Revolving Funds are community-based organizations that allow individuals to borrow cash and pay it back over time, usually on terms that are less strict than those of commercial banks. The successful revolving credit schemes implemented by Enersol in the Dominican Republic resulted in over 1000 systems being installed over 5 years with a capital seed of about $20,000 (SELF, 1992). Revolving credit was made available specifically for PV in communities at the same time lighting systems are being introduced. From those desiring solar systems, small community 'solar' groups formed; they were capitalized by seed grants which typically funded five systems. More systems were financed by payments as they came in from system buyers. It needs to be fine-tuned to the needs of the community being served.

It has been said, with merit, that innovation in financing mechanisms can do more to advance RE projects than technological breakthroughs. There are a handful of examples beyond that mentioned here how such innovative schemes are introduced that are of an impressive success. Experience gained in projects and lessons learned should be applied to the future projects as to ensure that lessons learned are being incorporated in their design.

Information dissemination and system delivery

Donors, lenders, national governments, and village-level users all need more and better information about the potential for meeting the basic energy needs of rural communities through renewable energy. Such options as photovoltaics are seen as expensive and high risk.

Donors and lenders often do not think of renewable energy as an option. They regard it as high-risk despite its successful track record since the mid-1980s, and they mistakenly believe it is maintenance free. Donors and lenders must be educated about the true positive and negative factors in renewable energy technology. The system must be properly sized based on available supply and demand information. Recipients must be educated about the purposes and goals of the particular technology to be used.

National governments, too, are often unaware of the potential of renewable energy technology to meet basic energy needs, with the result that these technologies are left out of the energy planning process. Solutions to this problem include learning from the experiences of neighbouring countries already utilising such technology through seminars and other forms of information dissemination organised by donors and lenders. Governments could set up "consumer energy centres" with responsibility for comparing various renewable energy systems/technologies, establishing distribution networks for the equipment, and training project designers, retailers, installers, and maintenance personnel.

At the village level, potential users of electricity are often not aware of the alternatives available. Therefore, before renewable energy technologies are introduced, care should be taken to obtain the interest and participation of users by explaining the purpose of the installation, its limitations, and its advantages and disadvantages relative to other options, and by determining their exact requirements. This dialogue should continue during the implementation/construction stage. In addition, a selected number of villagers should receive training in operation and maintenance.

Adequate information about alternative choices in energy supply and demand management is essential and yet often lacking—Even where this information is available, however, new technologies and new products need a long time to earn user's confidence especially when they are supplied by industries which have not been well established.

For normal market development, choices should be available to end-users. Lighting choices in developing countries are particularly poor. Solar lanterns are generally not available; Lamps are usually promoted as part of a complete kit, but even then the choice is the retailer/distributor's and not the end-user's; Mostly imported luminaires with tubular fluorescent lamps are available, more efficient compact fluorescent lamps can hardly be found. Locally manufactured fixtures (using imported lamps) are becoming available, but are technically very poor; and equipment is not available there where it is needed most, in rural areas.

It is needed to enrich the menu of options available to rural households, so that they will have more choices to satisfy their immediate needs for electricity, instead of waiting for the grid to arrive in their neighborhood. The problem appears to be a chicken-and-egg situation: Potential rural clients are not supplied with solar electric equipment, although they are willing to invest in such equipment. More choices, and less expensive equipment would certainly help to increase sales. The question then is, how to make this happen and connect suppliers with potential clients.

Manufacturers, wholesalers, retailers should better listen to the suggestions made by rural people, and try to improve the supply of solar electric equipment accordingly. The potential market in developing countries is enormous, but only for the right type of equipment. A recent market study for Kenya (World Bank, 1996) shows that roughly 1.4 million lanterns and 0.9 million small solar home systems are the targets for cash sales, still leaving about 40% of the rural population or 1.6 million households without any electricity supply at all. Although the exact numbers are not very important as they will vary considerably from country to country, it is important to note that the potential market is very large indeed.

As the demand for solar equipment will largely come from rural areas, the infrastructure or delivery mechanism needs to be created there, not only for sales of equipment, also for installation, repairs, and sale of spare parts. Rural people are prone to purchase more quickly if they can buy in their own neighborhood. A more modular approach to equipment with options such as larger modules, modules in parallel, lanterns with one or two lamps, or a detachable lamp, a radio socket, a plug to charge from the mains (for peri-urban areas), etc., will also make solar equipment more accessible to rural households. Low-cost designs are likely to be sold more quickly, and it is up to manufacturers to make sure this is addressed in the redesigning of their models. The lighting market in developing countries is a new market, distinctly different from the weekend or the luxury market in western countries. The sheer size of it warrants a good and fresh look at packaging new equipment. Low-cost luminaires, using high efficiency lamps and other innovative lighting technologies, should be developed and promoted in rural areas.

<u>Lack of after sale service and maintenance</u>

PV systems are not maintenance free. A recent review of PV programs in the pacific Islands (Liebenthal, Mathur, and Wade 1994), for example, found that many PV systems failed after installation, and it was only when supporting services were introduced that the programs began to succeed. These services included training technicians, ensuring timely maintenance, collecting fees on a regular basis, providing proper oversight to prevent the diversion of revenues to other projects and obtaining prompt feedback on needs from local user communities and passing the information on to the supplying utility(World Bank, 1996).

It is often the case that the availability of credit to small users and proper incentives to ensure maintenance of facilities and collections by local agents or entities are among the most serious impediments of RE dissemination even when they make economic and financial sense. It is also fair to say that many RE projects in developing countries, based on grants by foreign donors, did not make adequate provisions for sustainability thus leading to failures.

Manufacturers and hardware dealers need to sell hardware, and the sooner the better. Therefore, marketing efforts are usually directed toward maximising immediate sales rather than long-term, sustainable growth. What has happened is that users soon learn that the claims of "no maintenance" and "free power from the sun" are not at all true and after an initial burst of sales, the market goes into decline. While this decline is usually blamed on saturation of a market limited by the high price of the systems, there is strong evidence that the decline in sales is simply due to widespread customer dissatisfaction.

The success of SHS implementation has been greatly determined by quality of the components and the availability of ongoing service and maintenance. When well-designed systems have received regular ongoing maintenance they have performed successfully over many years. However, when poorly designed components have been used, or when no after-sales service was available, systems often fail. Past failures of these systems has undermined local confidence. Fly-by-night salespeople have sold thousands of substandard SHS in South Africa, for example, which failed shortly after installation.(http://www.seia.org). Well-designed components and after-sales service and maintenance have become recognized as essential parts of a successful PV program.

Donors must build cost-recovery components into renewable energy projects - even those funded on a grant basis -- in order to provide a pool of funds for maintenance and component replacement over the long run. The cost recovery component has been shown to increase the sense of responsibility for and involvement with installed systems of any type on the part of local villagers.

Institutional arrangents

Energy service company (ESCO)

An ESCO sells energy services but retains ownership of the system that provides them-that is the hardware is neither sold nor leased. An electric utility is, by definition, an ESCO. Cooperatives, NGOs and private companies can also function as ESCOs. Working examples of such ESCOs include the Tuvalu Solar electric Cooperative Society in the Pacific Islands and SOLUZ in the Dominican Republic (see Box 1). Typically an ESCO procures solar home systems in bulk from regional distributors or on the international market, installs the system and services the power-generating components(which, at a minimum, include the PV module and support structure). The ESCO is also responsible for financial management and administration. ESCOs may also retain ownership of controllers, inverters, and batteries, so that customers pay only for energy services.

The ESCO model has several advantages. First, the monthly cost to the consumer can be reduced by spreading the cost of the solar home system over a period comparable to its physical life (ten years or more). The smaller monthly payment makes the system more affordable, allows the ESCO to serve a larger population within its service territory, and creates a “critical mass” of demand. A large consumer base can help the ESCO provide cost-effective maintenance and administrative service and reduced equipment costs, through standardization and high-volume purchasing.

By aggregating demand, the ESCO can obtain favorable financing terms that are not generally available to individual consumers. ESCOs are often eligible for low-interest loans or grants from private or public sources and are generally considered to be better risks and more creditworthy than individual rural customers. In addition, the transaction costs associated with one large loan are lower than they are for al large number of small consumer loans. The favorable terms can then be passed one to customers in the form of lower service fees.

The ESCO is useful model for delivering least-cost rural energy services in areas where off-grid household PV initiatives can be coordinated with conventional electrification efforts by electric utilities.

Box 1

Examples of Solar Home System Projects Implemented by ESCO

SOLUZ inc., a private US company working with Industrias Electricas bella Vista in the Dominican Republic, operates as a commercial, for-profit venture. Within months of its creation in early 1994, SOLUZ was providing PV systems services to 100 customers in the Dominican Republic. The company expects a ten-fold increase in customers by the end of 1995.

Five rural electric cooperatives in the Philippines serve as ESCOs for solar home systems. The cooperatives own the PV modules, the supports, and the controllers; consumers own the remaining components and pay a fixed monthly fee to cover loan repayments plus administrative and maintenance costs.

The ESCO approach is also used by the Tuvalu Solar Electric cooperative Society and in other PV systems projects in the Pacific Islands. Consumers pay a $40 connection fee, plus a monthly fee of $5 for a one-panel system ($6.10 for a two-panel system) to cover administrative and service expenses; the ESCOs absorb the cost of the PV module. These programs depend on government or donor start-up funds and therefore are not financially self-supporting.

Source: World Bank, 1996

National program and resource assessment

Establishing a program involves significant effort. The first task is to survey solar and wind resources. Such surveys have long been carried out for hydro programs, as geological and engineering investigations have usually been carried out for many potential sites, and data on river flows have been collected for several decades, but they are rarely available for solar energy. In addition, a program of field tests of equipment with a fairly substantial number of consumers (often several thousand households) will be necessary not only to justify the investment in the equipment, but to establish supporting maintenance services and to monitor progress.

As with any new area of investment, issues arise in connection with risks and uncertainties. In the field of renewable energy, some of the questions raised are at a quite elementary level. For example, some projects designers may not even have assessed the level of solar, wind, and biomass resources, while potential consumers are often not up-to-date on technical developments, costs, and how similar projects elsewhere have performed. The predisposition of institutions to resist change is also a factor that widely impedes new investment and initiative.

Another major task is to familiarize professionals in the electricity industry engineers, managers, financiers, and regulators with the new possibilities. Expanded education and training, including visits to operating projects, may help to change negative perceptions and aid the development of investment programs. Beyond this, the facilities and curriculums of universities and technical colleges may need to be developed to provide appropriate education and training.

The financial requirements needed to develop programs, identify and prepare investments, and provide education and training are generally small in relation to the costs and benefits of the investments that eventually emerge. As with the development of programs using more traditional renewable energy using wood-fuels, the participation of non-governmental organizations in project development can be beneficial. Bilateral aid organizations and non-influential in establishing pilot schemes and offering education and training to engineers and technicians from developing countries. The many applications of PVs in developing countries owe much to such efforts.

At the onset, renewable energy programmes should be aggressive, long-term, policy oriented, and aimed at senior decision-makers in both government and private sector. All the institutions and agencies involved should work more closely in the development and promotion of RETs.

National governments also fail to promote renewable energy systems. They engage in technology price distortions, particularly by subsidising fossil fuels. With such subsidies, diesel generators can often easily out-compete renewable energy systems from a strictly financial point of view, resulting in increased dependence on fossil fuel imports in the case of non-petroleum-producing countries, and decreased fossil fuel export performance on the part of producer nations. In both cases, adverse environmental effects from the burning of fossil fuels are maximised instead of minimised.

Lack of life-cycle costing among in-country government agencies is another major obstacle. In-country agencies concerned with rural power, for example, most often compare apples to oranges (capital- versus operations-intensive energy technologies) in their planning exercises. Since the major cost advantage of renewable energy systems is their minimal maintenance and total lack of fuel requirements, life-cycle costing is essential -- combined with undistorted conventional fuel prices -- to put these systems on a more equal economic footing with diesel generators, for example.

National governments need to re-examine their financing of energy systems, particularly for rural power. They must assess renewable energy options and apply life-cycle costing to provide a level playing field for renewable energy technology, and they must reduce their fuel subsidies.

Cooperation through Partnerships

In energy, as in other areas of development assistance, the private sector and the civil society as a whole must be active partners. UNDP's Public-Private Partnerships Programme helps to promote the involvement of the private sector and the larger civil society in energy, waste management, and water and sanitation projects in urban and peri-urban areas. The programme is based on the premise that many urban-related problems in developing countries are potentially viable business opportunities that deliver environmentally sound solutions within a socially conscious approach.

Private investors account for 95 percent of energy investment in developing countries (IFC, 1997). It is essential, therefore, that these investors become partners in sustainable energy development by focusing on demonstration projects and creating an institutional environment that will lead the private sector to choose efficient and environmentally sound technologies.

As the World Bank is prepared to play its role in the developing world by assisting, through technical advice and lending operations, the faster introduction of sustainable energy technologies, it is actively seeking to join forces with other organizations in a cooperative partnership. These organizations include international bodies, national groups, RD&D institutes, professional and academic organizations, and non-government organizations (NGOs) that have an interest in the common objectives. The World Bank is actively seeking ways to increase the extent and depth of such cooperation.

Case study: China

Introduction

China enjoys rich solar energy resource. The annual sunshine period in two thirds of the country exceeds 2200 hours (Lu, 1993). Especially in the north-west China with vast land and dispersed population but no access to electricity grid, off-grid PV system is an important option to provide power supply and alleviate poverty. The goal of the Chinese government is to develop a PV capacity of 31MW by the year 2000 (CRED, 1996).

In China, PV systems have developed very rapidly, and are widely utilized. The manufacturing capacity had reached 5 MW per year by the end of 1996. More than

30,000 households have installed PV systems. On the other hand, more than ten PV stations and PV water pump stations had been built in Qinghai, Tibet, etc. Total installed capacity is more than 8 MW(Li Junfeng, personal communication).

The major barriers to disseminating PV systems are of no big difference from those in other developing countries that are discussed earlier. But they may appear in different forms given the specific conditions of China. It is worthwhile to state a bit more here in order to perceive the existing problems.

Seven PV production lines have been imported from US, Canada and other countries since 1983. The country's total manufacturing capacity of PV has reached 5.5 MW annually (Hamburger, 1995). Although there are more than ten factories engaging in the manufacturing of PV products, production costs is about 10% more than that of the same type of foreign products due to small scales, outdated technology and low efficiency. The under-developed market and lack of competitiveness are restraining domestic PV manufacturing from technological upgrading and renovation.

Generally, the sales of SHS are conducted by the sales companies affiliated with local new and renewable energy institutes. The monopoly of distribution network, lack of market competition and inadequate service system limit the expansion of SHS.

Remote and thus poor areas are the primary market of SHS, where as the customers of SHS, farmers and herdsman are undereducated, and far from knowledgeable on SHS. Consequently, SHS are commonly poorly operated and maintained, shortening SHS's life cycle and slowing down the market expansion.

It's very difficult for rural consumers to purchase a set of SHS system with the life as long as 20 years (CRED, 1996). Currently, Chinese government has not really done anything about credit loans for customers to support them to buy SHS systems. On the other hand, most of peasants and herdsmen cannot afford the system without the subsidy, while only 5-10% of them on the top of income pyramid can do so, according to statistics. Thus, to build a credit loan system is necessary for the expansion of PV-electric power system market.

The high costs of SHS system is also one of the important factors that hampers the widespread application, especially the costs of small system. They are far beyond the affordability of potential customers. But, system costs stick in high level due to the current low-level technology and the dependence on import of raw materials. Based on international experiences, SHS systems are very hard to reach commercialization level through itself development without the help of outside incentives.

The central and local government have not only provided subsidy to solve the power problem for peasant and herdsmen by promotion of SHS in the northwest of China, but also loans to manufacturers. But based on the analysis of production of PV system and promotion of SHS in several provinces, the incentives from these policies are not so effective indeed. Subsidy only covers 10~15% of the whole system price which could not mobilize the enthusiasm of low-income peasants and herdsmen to buy SHS, and this limits the development of PV system.

The local governments also provide all kinds of favorable policy through different solar or renewable energy program. For example, in Qinghai province, about 70,053 out of 100,000 non-electrified peasant and herdsmen families are included in the provincial "Poverty alleviation by power" program. The program planned to install 1.4 MW of SHS and 340 kW central supply PV system at county or township levels. Gansu is the only province which promotes SHS with banking credit, providing users with a concessional bank loan with interest of 4%, sponsored by village or township governments, including 20% of discount subsidy by provincial governments and the remain subsidized by local governments.

Likely solutions and their implications

Subsidy for Capital Cost

As is the case in Japan, Germany and some other countries (http://www.seia.org), China also provides subsidy to the customers. For instance, in Qinghai, Inner Mongolia, Xinjiang and other provinces RMB 300 Yuan per set is granted to every user which covers 5~15% of total system cost. This is acceptable to those with relatively high income. But subsidies only work once since they are not able to be recovered and reused. As a result, even though the scale of subsidy is very small, a huge lump-sum of fund is still needed. For example, to install totally 15 MW of 20 Wp/set SHS with subsidy of RMB 300 Yuan/set, the amount of subsidy reaches RMB 225 million Yuan; with 30 Wp/set system, the amount of subsidy reaches RMB 150 million Yuan. It turns out to be difficult for China to raise such a huge amount of funds in the near future to promote the development of SHS through subsidies (CRED, 1996).

Subsidy for R&D and Manufacturing

It is another common practice adopted both by China and other countries. Some countries such as USA, German and Japan input enormous funds to implement the PV plan, develop the PV technology, enlarge the production scale and reduce the cost of PV system. It is estimated that in future the price of PV will reduce from US$ 0.20/kWh in

1995 to US$ 0.09/kWh in 2010 and US$ 0.05/kWh in 2030 (Joint study team, 1994). The key factor of cost reduction is the improvement of technology. At present, although the production and application of PV in China has reached a certain scale, the gap between China and other advanced countries is growing in terms of production costs, efficiency, quality and stability of manufacturing. Even under the protection of 30% of import duties, the market share of imported PV systems in China exceeded 25% in 1995. Besides the introduction of some capital equipment, it's very necessary to increase investment and strengthen the R&D of PV and the upgrade of manufacturing technology so as to reduce the gap between the domestic and foreign products.

Energy Service Company

Practices prove that the sales and services company of energy could work as bridges between PV manufacturers and consumers. On one hand, the PV manufacturer may spread advanced PV technology to consumers and offer services through the energy service company. On the other hand, the energy service company can feedback problems and requirements of customers to manufacturers so that manufacturers can continuously improve its technology and ensure the quality and offer the better products to users. At the same time, ESCO can participate in the circulation of funds of the government, accept various sources of loans, collect development funds, and implement various forms of promotion to farmers (consumers). Farmers may buy PV systems in cash, credits, or loans ESCOs can provide. By doing this way, the demand of PV products could be increased.

Revolving Fund

Revolving fund is considered as a form of subsidy that makes full use of the money available. There are various options to set up revolving fund: direct grants and allocation; bank loans using the grants and allocation as equity. Various kinds of subsidies can be used as loan credit, consequently changing the short term debt payment of working capital.

Revolving fund will adopt down payment, continually enlarge the PV market, meet the need of farmers for electricity, and finally enlarge manufacturing scale, lower the cost, promote the PV commercialization. The successful operation depends on the following basic conditions: (1) a certain amount of capital. In China, it can be poverty alleviation fund, rural electrification fund, or domestic and international grants; (2) a commercial energy service institution, which is responsible for sales, maintenance and services of PV system, and the operation of installment offered to peasants and herdsmen, so as to enable them to use installment when they can afford first cost of installment and repay the remain in the following years; (4) availability of bank loan by justifying the principal in charge.

Compared with direct subsidy to users, revolving fund could increase the application scale of PV/SHS by about 40% (J. Li, personal communication). If low-interest and interest-free loans are available for sales and services, their risks will be reduced and loan interest burden of peasants will be released. At the same time China should increase the ability of peasants and herdsmen to buy PV/SHS with a goal of enlarging the application scale of SHS, though it is too complex issue though.

Generally speaking, unelectrified areas are relatively poverty-stricken areas. Average annual income per capita is low. Compared with the pattern of subsidy for coal fired power by government, PV is an alternative with high capital costs on customers and costs need to be born wholly by peasants and herdsmen themselves. The number of unelectrified families who have enough savings to pay PV products up front is very limited. If we take all the unelectrified peasants and herdsmen as the pyramid, those who could make cash payment for PV are located at the very top of the pyramid. But provided with credit, the number of peasants and herdsmen that can afford PV system will increase, so it will be more acceptable to the costumers.

Based on the actual situation of China, revolving fund is more applicable to the local conditions and easy to be accepted by peasants and herdsmen. It is also relatively easy to implement. In market economy, revolving fund is sustainable in supporting the application of PV/SHS. Revolving fund can also alleviate financial burden of the government, beneficial for development and progress of PV technology.

Conclusions and recommendations

It is hard to say about the best way of solar technological development path to go in any one place. Development paths are being and could be taken but it is too early now to be dogmatic about the best way to go in any one place. Continued innovative experimentation (without harming consumers) is needed carefully to match renewable resources, technologies and system designs with consumer income, population density, distance from existing grids, and so forth.

In China, it is suggested to conduct complete market survey, particularly in the areas of some provinces where non-electrified farmers and herdsmen concentrate. Such information as incomes, population density and distance from the existing grids are crucial for solid market analysis. In the key areas with a large amount of potential customers, it is necessary to set up PV sales and service companies with the similar functions as ESCOs, and form networks.

GOC should integrate the application of SHS into the various level governmental poverty-alleviation program or rural electrification program to obtain funding from these sources. GOC should encourage the active participation of existing PV service companies through financial incentives, help the companies in obtaining bank loan, set up reliable contractual and financing credit between the sellers of SHS and customers, set up effective supervision and implementing network. Establish PV products quality verification system, and related supervision system. Set up R&D fund for PV development. It is suggested that GOC gradually increase its input into the R&D activities to support the research and introduction of key technologies and materials, in order to break through technologically in PV application in China.

GOC should support and encourage the extension of SHS application by reducing VAT of SHS, enforcing the rural electrification poverty alleviation, making use of the international aids and finance in developing PV market. The larger demand will promote the supply and help reach economic scale and high efficiency for local manufacturing industry. The increased production and reduced costs will accelerate market growth. The healthy and sustainable development of solar PV could thus be realized.

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