Case Study

Applications of Solar PV On Rural Development in Bangladesh

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Abstract

This paper focuses on the prospects and problems for application of solar photovoltaic (PV) on rural development in Bangladesh. Several private entrepreneurs, the Rural Electrification Board (REB), Local Government Engineering Department, and a number of nongovernmental organizations (NGOs) are working to install solar PV in rural Bangladesh to meet basic energy needs. The application of PV technology for rural electrification is indirectly increasing the income as well as the living standard of the rural poor. There is also a positive linkage between application of solar PV and meeting the objectives of the United Nations' Millennium Development Goals (MDGs). The basic applied forms of solar PV in rural Bangladesh are solar home system (SHS) and microutility (electrification of rural markets). Feedback from the users of these systems indicates that solar energy–based electricity has been providing very satisfactory service to consumers.

Keywords: Rural Development, Solar PV, Solar Home System, Microutility, Tariff Collection

1.0 Introduction

The per capita energy consumption of about 77 kg oil equivalent (kgoe) in Bangladesh is very low compared to the world average of about 1,474 kgoe (Asian Development Bank, 2000). Biomass fuels account for 73% of total energy consumption. The shares of the major fuels are wood (65%), agriculture residue (22.1%), and animal dung (7.8%) (World Bank, 2000). Indigenous natural gas is the major energy source in the country and is mainly used for the production of electricity and fertilizer. The other commercial sources are crude oil, which is imported, and hydroelectricity.

The REB is responsible for building a grid network and supplying electricity to the rural areas of Bangladesh. The Bangladesh Power System Master Plan projects a doubling of electricity-generating capacity by 2010. The huge investment required to satisfy the electricity demand means that homes, business centers, and other establishments in many villages and isolated areas may not be connected to the grid in the near future by conventional electricity generation and distribution methods.

The government of Bangladesh has a noble vision to provide electricity for all citizens by the year 2020. But at present only 32% of the total population is connected to grid electricity (Rahman, 2006). For the near future, it is impossible to connect every remote village and offshore island to the national grid system. Since expanding the national grid in those isolated areas is very expensive and not cost effective, solar PV could be an effective alternative to fulfill the electricity demand in these off-grid areas.

A solar PV system is an important emerging option to supply electricity with quality light, reliable service, and long-term sustainability (Ibrahim, Anisuzzaman, and Kumar, 2002). This system not only would provide reliable, clean, and environmentally friendly energy but also could create employment opportunities in the vicinity of its operation. Despite these appealing features, solar PV systems do not yet have broad market acceptance because of the existence of barriers arising from the need for large-scale implementation. The main obstacle is high initial costs. Lack of demonstration of the technology, limited awareness, and uncertainty over after-sales service are the other barriers in the promotion of solar energy–based electricity.

2.0 Literature Review

The first solar PV–based rural electrification project in Bangladesh was initiated with the financial support of France, with a total installed capacity of 62 kilowatts peak (kWp), of which 29,414 kWp came from battery charge stations and the rest from SHS (Barua, Urmee, Kumar, and Bhattacharya, 2001).

Khan (2006) studied the utilization of renewable energy for world poverty reduction as well as for meeting the objectives of the MDGs. The MDGs may not be met unless rapid progress is made in extending efficient and affordable energy services to the poor in support of productive economic activities or social development. His study shows some links between the development of energy services and meeting the MDGs in the context of reducing poverty, achieving primary education, promoting gender empowerment, and ensuring environmental sustainability.

Islam (2005) reviewed policy formulation and institutional development processes for harnessing renewable energy sources in Bangladesh. In particular, he studied the Draft National Energy Policy 2004 and Draft National Energy Policy 2006, seeking to determine the barriers to the implementation of solar PV technologies in rural Bangladesh. He found that the importance of renewable energy sources had not been duly recognized in the policies. He found a need to bring changes in the thinking process, data analysis, and planning methodology to incorporate a renewable energy development program under the framework of national energy policy. Isolated efforts may not provide satisfactory outcomes in the medium- to long-term time horizon.

Hiranvarondon, Hill, and O'Keefe (1999) suggested that dissemination of solar PV systems required an implementation strategy that should initially identify the type of system needed. Governments could accelerate the dissemination by removing barriers to market expansion, by removing excessive duties and taxes, and by removing subsidies on products that compete with solar systems. They also listed the role of key players involved in the promotion or dissemination of solar systems in developing countries: national governments, donor agencies, educational and research institutions, and private sectors/NGOs.

Cabraal, Cosgrove, and Schaeffer (2000) noted that successful solar PV–market development for rural electrification requires the removal of financial and institutional barriers. The other major issues to be considered are the high initial costs, the establishment of a responsive and sustainable infrastructure and the guaranteeing of quality products and services. These findings were based on their studies in Indonesia, Sri Lanka, the Philippines, and the Dominican Republic.

Nieuwenhout et al. (2000), studying the use of solar energy systems in households in developing countries, noted that there was no single best organizational model to promote the dissemination of SHS. On the other hand, dissemination depends on institutional, legal, socioeconomic, and cultural conditions in these countries.

These studies illustrate that the factors contributing to the successful promotion of solar PV–based rural electrification are (a) suitable financing schemes to address the problem of high initial cost, (b) adequate means of providing regular and proper maintenance and supplying spare parts, and (c) viable choice of available configurations to suit the consumers' needs and affordability.

3.0 Solar Electricity and the Applications of Solar PV

Electricity generated from sunlight is called solar electricity and the process of converting solar light into electricity is known as the photovoltaic process. In this process direct current (DC) electricity is produced. The major components of solar PV systems are (a) solar panels, (b) batteries, (c) charge controllers, and (d) DC electric appliances (e.g., lamps, small fans, or televisions).

A solar panel consists of many cells produced from silicon. Each silicon solar cell can yield 0.5 volt DC. Solar panels are installed at a 23° alignment with the ground in Bangladesh, though this alignment depends upon the installation's geographic location. In Bangladesh the sunlight falls directly in summer and transversely in winter. So, it is most efficient to slant the panel at 45° in summer and between 15° and 20° in winter. Since it is troublesome to adjust the panels at different angles with the change of seasons, the technical experts decided to place the panels at 23° to optimize the light received to avoid moving the panels to track the sun. Care has to be taken to avoid barriers that would obscure sunlight and thus reduce the panels' efficiency.

Solar panels produce current during daylight hours, so to utilize power at night the customer may need to store the current in a bank of batteries that can release the power when needed.

Solar PV systems have already made significant headway in Bangladesh. Recent pioneering attempts in this field have generated enthusiasm, but they have also exposed some barriers. Table 1 indicates the existing and potential applications of solar PV in rural Bangladesh.

Table 1. *Existing and Potential Applications of Solar PV in Rural Bangladesh*

Type of application	Description of application
Rural electrification	Power supply to remote villages. Battery-charging stations.
Water pumping and treatment system	Pumping for drinking water. Pumping for irrigation. Water purification.
Health-care system	Lighting in rural clinics. Vaccine refrigeration. Blood storage refrigeration.
Communication	Remote TV and radio receivers. Remote weather measuring. Mobile radios.
Agriculture	Livestock watering. Irrigation pumping.
Transportation	Road sign lighting. Railway crossing and signals. Runway lighting. Navigation buoys.
Security system	Security lighting. Remote alarm system.
Income generation	Battery-charging stations. Radio, TV, and video pay stations. Village industry power. Refrigeration services. Electrification of rural markets.

The major advantages for using solar PV systems are (a) the customer is the owner of his or her own power-generating system, (b) no billing for charges occurs, (c) electricity is generated for more than 20 years without any traditional fuels, (d) no fuel cost is involved, (d) solar PV systems are durable, (e) the systems are suitable for any part of the country (e.g., underserviced areas), (f) no noise pollution is generated, and (g) the production of power is environmentally friendly.

Solar PV systems can be successfully utilized for world poverty reduction. The MDGs include the reduction of poverty, hunger, disease, illiteracy, environmental degradation, and gender inequity. These goals may not be met unless there is rapid progress in extending efficient and affordable energy services to the poor. Table 2 shows the linkages between MDGs and solar PV.

Table 2. *Linkages Between MDGs and Solar PV*

MDGs	Links to solar PV
Reduction of poverty and hunger	The implementation of solar PV may generate jobs, industrial activities, microenterprises, and more opportunities that may reduce poverty and hunger.
Achieving of primary education	Children in remote villages can study at night with the help of solar PV light. Electricity in rural schools can attract students.
Promoting gender equality and empowerment of women	Women are mostly responsible for household activities in rural areas. Performing maintenance activities on SHS can promote gender equality and can empower women.
Reducing child mortality	Solar PV electricity can help in the lighting and the storage of vaccines in rural clinics, which can reduce child mortality.
Reducing HIV/AIDS, malaria, and other diseases	Solar electricity for communication, such as radio and television, can spread important public health information to reduce deadly diseases such as AIDS and malaria.
Ensuring environmental sustainability	Solar PV is environmentally friendly, which can reduce air pollution and the adverse impact of climate change.

4.0 Solar Home System

The only type of modern renewable energy technology that has had some success in Bangladesh is solar PV. From the limited demonstration and institutional uses of a decade ago, solar PV is now being taken directly to ordinary rural households and communities. This success has been possible because of the direct implementation of solar systems in rural households by NGOs that have received financial backing from donors. With the help of soft loans and grant facilities of donors, almost 100,000 SHSs have been installed in different parts of Bangladesh. Table 3 shows the number of SHSs installed by NGOs.

Table 3. *SHSs Installed by NGOs (As of May 2006)*

Name of NGO or institute	Number of SHSs installed	Capacity of installed solar system (Wp*)
Rural Electrification Board	5,000	250,000
Grameen Shakti	65,000	3,250,000
Bangladesh Rural Advancement Committee	15,456	770,000
Centre for Mass Education in Science (CMES)	1,025	51,250
Thangamara Mohila Sobuj Shangha	1,003	50,150
Coast Trust	805	40,250
Srizony Bangladesh	2,384	119,200
Shubushati	796	40,000
Integrated Development Foundation	818	40,900

*Wp = Watt peak.

The dissemination of almost 100,000 SHSs has been made possible in part by the Rural Electrification and Renewable Energy Development Project, which is coordinated by the Infrastructure Development Company Ltd. and financed by the World Bank. The soft loan, a grant from the Global Environment Facility, and technical support facilities have attracted partner organizations, mostly NGOs, to implement SHSs in remote areas of Bangladesh (Figure 1).

The Centre for Mass Education in Science (CMES), a national NGO in Bangladesh, conducted a cost analysis of the SHS, examining the price of each system, possible repairs, replacements, maintenance, and depreciation. The analysis suggested that several possible marketing strategies could be piloted by the program. Table 4 indicates the pricing and financing options of the SHS.

A socioeconomic survey of 79 customers of SHSs was conducted in the district of Dinajpur and Rangpur (northern Bangladesh). According to the survey, most of the customers of SHSs were engaged in both agriculture and business (33%), followed by only business (29%). Approximately 48% of customers' annual income level was between 51,000 BDT and 100,000 BDT. Approximately 84% of customers of SHSs indicated that they had no other sources of electricity except solar energy. Most of the customers were using solar energy to power domestic lighting appliances and black-and-white televisions (69%). About 90% of customers were satisfied with the performance of the technology.

Figure 1. Areas of solar home systems in Bangladesh.

Table 4. *Pricing Options of SHS*

Scale of SHS (Wp)	Cash package price (BDT*)	Down payment (BDT)	Loan amount (BDT)	Monthly installment amount (36 installments)	Monthly installment amount (24 installments)	Monthly installment amount (12 installments)
75	34,500	5,865	28,635	1,034	1,432	2,625
50	22,000	3,740	18,260	660	913	1674
40	17,300	2,941	14,359	519	718	1317
30	12,500	2,125	10,375	375	519	951

*BDT is the abbreviation for the Bangladeshi currency, the taka. Seventy taka is approximately equivalent to one U.S. dollar.

5.0 Solar PV Microutility

One of the main economic activities of rural Bangladesh is based on rural markets called *Haat*. Farmers come long distances to the Haat with their products to sell to merchants, who usually come from cities or major towns. The trading continues until evening. Kerosene lamps called *Kupi* and *Harricane* are the major appliances used to illuminate the Haat shops. Some shops use more expensive mantle lamps called *Hazzak* to obtain a brighter light. Diesel generators supply electricity in some rural markets. All of these alternatives are detrimental to the environment.

In a solar PV microutility, a number of solar modules are mounted at one location, preferably in the middle of the load (light, TV, etc.) distribution (Ahammed, 2004). Client shops are then connected to the system, keeping the electrical cables as short as possible. A local technician is trained to collect a tariff, operate the system, and take care of minor technical problems.

The first solar PV microutility was established in September 1999 in Manikgonj Bazaar of Dinajpur district, 400 km north of Dhaka by CMES, serving about 30 shops. Lighting needs of the shops were met by *Kupi*, small oil lamps. Under the project Renewable Energy Technologies in Asia, CMES explained the concept of solar energy–based electrification systems to the shop owners and the Bazaar Management Committee (BMC), covering the topics of operations, benefits, and maintenance (Energy Program, Asian Institute of Technology, 2004). They welcomed the idea. A daily tariff of five taka with no initial deposit was agreed upon and a contract was then signed between CMES and BMC shop owners. Seven solar modules of 50 Wp each, divided into two groups, were installed in two suitable locations of the market. The battery banks and controllers accompanying each group were placed close to two respective solar panels. Similar systems were subsequently installed, serving businesses such as grocery shops, restaurants, barbershops, tea houses, and doctor's offices (see Table 5 for their specifications).

Solar PV microutility may be a suitable model for implementation in rural areas where there is a demand for lighting. One of the major problems in implementing a solar system is its high initial cost (World Energy Council, 2000), a major hurdle in view of the socioeconomic conditions of rural people. But in the concept of microutility, the shop owners have to pay only a five taka tariff per night for a connection with one light. The simple pay-back period for the total investment including maintenance and spare parts is just five years. So, after five years another solar PV microutility can easily be installed in another market with the amount of tariff collected for the first five years. This development can be made possible by managing the revolving tariff funds collected by CMES.

Feedback from users of a solar PV microutility in Manikgong Bazaar indicated that users were highly satisfied with having a local and full-time technician, that service was good and the amount of light was sufficient, and that a solar energy system was free from the hazards of smoke. One tea stall owner noted his income had increased significantly, while a grocery shop owner observed that more customers had been visiting his shop. One of the attractions of this microutility system is that users are not responsible for maintaining the system. Involvement of the local community in its management minimizes the users' risks.

The success of solar PV microutilities is attributable to several factors. These include the acceptability of a daily tariff structure and a rate of five taka, as well as proper marketing that explains the solar energy–based system's capabilities, benefits, and constraints in comparison to other available options to potential users. Benefits of the system also accrue because of the use of local institutions: An agreement with the local Bazaar Management Committee includes the terms and conditions of service, maintenance procedure, payment, and financial details of the users. Lastly, training of a technician to take care of the system on behalf of the collective is viewed favorably by users.

Table 5. *Solar-Based Electrified Rural Markets*

Name of rural market	Date of installation of solar system	Special features	Type of consumers
Manikgong Bazaar, Dinajpur	September 28, 1999	7 solar modules (50 Wp each) 7 batteries (12V, 100 AH* each) 7 charge controllers 24 fluorescent lights as appliances	Grocery shop Local restaurant Barbershop Tea stall Village doctor's office
Chinibashdanga Bazaar, Dinajpur	February 1, 2000	6 solar modules (50 Wp each) 6 batteries (12V, 100 AH each) 6 charge controllers 20 fluorescent lights as appliances	Grocery shop Local restaurant Barbershop Tea stall Village doctor's office
Bottali Bazaar, Khanshama, Dinajpur	November 15, 2001	6 solar modules (50 Wp each) 6 batteries (12V, 100 AH each) 6 charge controllers 18 fluorescent lights as appliances	Grocery shop Local restaurant Barbershop Tea stall Village doctor's office
Cachari Bazaar, Dinajpur	August 18, 2001	3 solar modules (75 Wp each) 3 batteries (12V, 130 AH each) Three charge controllers 14 fluorescent lights as appliances	Grocery shop Local restaurant Barbershop Tea stall
Khayrat Nagar Bazaar, Nilfamary	March 10, 2002	6 solar modules (50 Wp each) 6 batteries (12V, 100 AH each) 6 charge controllers 17 fluorescent lights as appliances	Grocery shop Local restaurant Barbershop Tea stall Village doctor's office

*Ampere hour.

A continuous power supply that provided light for five hours every evening led to an increase in the shops' working hours. This change increased the income of shopkeepers. The light was so bright and steady, the illumination from all the shops extended to the roads where even hawkers could do their business. The systems were appreciated by the shopkeepers. Several shopkeepers also wanted to operate televisions, cassette players, and radios and were willing to pay more to draw additional power. Requests for electricity connections through solar energy from many other rural markets in the same community were also received by the technician.

6.0 Discussion and Conclusion

Based on the studies of SHS and solar PV microutility, rural electrification through solar energy provided the following observations:

- Lack of awareness of solar energy technology necessitates demonstration of it to rural people.
- Appropriate financial arrangements, which may include payment in installments, fee for services and other suitable modes, are necessary for rural people to afford the system.
- Technical training can enable users to do trouble shooting for minor problems such as replacing fuses, adding distilled water, and replacing bulbs. This may avoid technician calls and increase system reliability.
- Technician training is essential for developing local technical support, which can also help make the project sustainable.
- Women also should be invited for training, as they are the main users of the systems and can do some of the maintenance.
- Solar systems with different options should be available to consumers so they can choose themselves according to their needs and financial capacity.
- For the electrification of rural markets through solar energy, local collective management yields better results by reducing the risk of theft and nonpayment.
- Solar systems help in generating income, for instance, by extending working hours and creating a convenient environment for business.
- Components/accessories of solar systems should be available locally so that the users can buy them easily when required. This can increase acceptability of the technology by users.

The Bangladesh experience shows that rural electrification through solar power can best be disseminated through the use of demonstrations; this approach generates demand from nearby communities. In supporting solar power generation in rural areas, attention must be paid to local ownership with an appropriate mix of individual and collective ownership and management. Providing a mix of offerings that are appropriate to needs and financial capacity, building local skills for the system's operation and maintenance, and ensuring locally produced and accessible components are also important in developing support for this technology.

Providing electricity for meeting lighting needs of households and rural markets can yield positive results, including improvements in quality of life and increasing income and employment opportunities. These impacts can mean that a developing country can more rapidly achieve the MDGs. The approach used in Bangladesh could be equally applicable to the other developing countries with similar socioeconomic conditions.

7.0 References

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