Policies to Promote Photovoltaic Technologies in Developing Countries Considering Bangladesh as a Reference Case

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Abstract

Electricity is a distant dream for many families in developing countries. Photovoltaic (PV) technology is emerging as an effective tool to fulfill the demand of people in developing countries, especially in rural and isolated areas. However, there are some technical and non-technical barriers, such as institutional, social and cultural issues, which hinder the widespread use of PV systems in rural areas. Solar Home System (SHS) uses a PV module to provide power for lights and small appliances with dissemination potential for sustainable rural livelihood in developing countries. Installing SHS units in rural villages is the most important step, but to ensure lasting success, the program needs to secure upfront approval from the majority of the villagers, including village leaders. An implementation model similar to Infrastructure Development Company Ltd. (IDCOL) in Bangladesh is a good example for other developing countries. The future dissemination potential of SHSs depends on technological advancement and price reduction in installation.

Keywords: Photovoltaic technology, PV, Solar Home System, SHS, IDCOL, Grameen Shakti, Bangladesh, developing countries, dissemination, solar electrification

1. Introduction

Environment and climate change have a great effect on the earth, creating floods, a rise in sea levels, droughts and other forms of extreme environmental changes. The amount of greenhouse gas (GHG) emissions from air travel alone is increasing due to fast economic growth and globalization. Some people question the fairness and equity of the global regulations and mechanisms. The problems of climate change affect everyone on the planet. Carbon emissions have been emitted by the developed countries since the Industrial Revolution, and therefore the developed countries should take more responsibility. However the developing countries should also contribute to the solution by finding a balance between social development, economic development and low carbon emissions. The road to a low carbon world is diversified. In the end, GHG emissions are a global, unavoidable problem. We need to make efforts together.

There is no modern industrial development without technology, or without technological innovation. Therefore, it is necessary to define the desirable features that the technology should present to promote sustainable development. *"Eco-innovation is the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resources use (including energy use). Novelty and environmental aim are the two distinguishing features."*(Rene Kemp and Pearson, 2007) There are many drivers for eco-innovation: regulation, cost reduction, profits from commercialization, pressure from communities, green ethos, improving company image. In cases for which reducing environmental impact offers no operational benefits or commercialization benefit, regulation may be the clearest driver for eco-innovation (Anthony and R Kemp 2009).

Eco-friendly technology for electrification is a dire need for developing countries where electricity is a distant dream for many families. For example, the electrification rate in developing countries is 74.7% and there are around 1,314 million people who live without access to electricity (IEA, 2011). Rural areas especially tend to be electrified late compared with city areas because most of the important functions are generally centered in the big city areas. As for the reasons why the developing countries are left behind in terms of electrification, one may cite inadequate supply of electricity, lack of government provisions, poor financial capacity to establish electricity infrastructure, geography (isolated islands, sandbanks, high mountains, etc.), among others. Even in such seemingly difficult situations, there are some possibilities that renewable energy technology can meet the needs of people in developing countries for electricity because it generates electricity from nature, available anywhere, without large-scale infrastructure such as grid connections. Photovoltaic (PV) systems have huge potential to provide access to basic electrical services to the people who live in rural areas without electricity. There are some cases where PV systems have been installed in developing countries. PV systems have relatively small output capacity and are mostly stand-alone systems that consist of several components: a PV module, a battery, a controller, some cables and a frame to set the PV module on a roof. A user of the PV system can use electricity generated by the PV module and stored in the battery. The amount of electricity generated by the PV system is adequate for people to operate appliances that have small electricity consumption; nonetheless it is considered as beneficial for people who did not have access to electricity until installing the PV system.

The main objective of this paper is to derive policy implications to accelerate the dissemination of PV systems in the developing world. We analyze a successful case of PV electrification in a developing country by reviewing related papers, and examine the benefits and challenges of adopting PV systems. Finally, we extract key factors for success of PV electrification programs in developing countries. The structure of the paper is as follows: section 2 considers barriers to PV technology adoption in developing countries and section 3 describes the benefits of using PV systems. Section 4 introduces a Bangladesh's case as a successful case of PV electrification programs and details the programs. Section 5 discusses a way to diffuse the PV technology in the developing world. The final section provides a conclusion.

2. Obstacles of PV Technology Adoption in Developing Countries

There are several factors hindering the widespread deployment of PV systems and creating obstacles to the deployment of PV electrification projects in developing countries.

Political Factors: The perceptions and attitudes of a political system greatly affect the acceptance and growth of technology in any society. Furthermore, whether or not a government has the capability to manage a project also impacts the success of a project. In most cases, the government takes the initiative and must design the project with consideration to objectives, timing, and financial mechanisms, among others. If the government fails to properly design the project, its success will be limited.

Economic Factors: Cost is an important factor that guides the adoption and growth of innovative technology in a country. Developing countries often lack the initial allocation as well as matching funds to make feasible investments. Many countries often acquire costly technology without making provisions for building sufficient infrastructure to run them (M. Rajesh, 2003). In the case of PV technology, this technology is still costly for people who live in rural areas in developing countries. Therefore they cannot afford to purchase a PV system.

Cultural Factors: Language is one of the major factors that impacts the easy assimilation of new technology by many developing countries, by hindering the transfer of technology. Radio and TV programs, computer software and printed texts are produced in different countries against different cultural backgrounds.

Technological Factors: With regard to the acceptance of a particular technology, factors such as access, cost, teaching functions, interactivity and user-friendliness, organizational issues and speed afforded to change are important issues. Once a technology is selected, there are certain other factors that require the attention of policy makers. Care and technical proficiency is needed to handle new technology. To this end, training is important. Many developing countries lack enough personnel to train in the new technology. Moreover, constant retraining of manpower to acquaint them with changing technology is also key.

In addition to the above factors, there is another challenge: lack of reflection on past lessons for a project. Most of the PV-related projects in the developing world were sponsored by donors and non-government organizations (NGOs). Although the design and implementation of the projects should be elaborated in the projects, there are some cases where an immature project design limits the final achievement. It was found that few programs are based on the lessons or experience gained from previously implemented programs and those programs tend to meet with limited success (Urmee and Harries, 2009).

3. Benefits of PV Technology through Installing Solar Home Systems (SHSs)

Stand-alone PV systems for residences are sometimes known as Solar Home Systems (SHSs). A SHS consists of a PV module, a battery, and a controller, among others. Figure 1 shows a typical SHS. During the day time, the PV module produces electricity and charges the battery through the charge controller. The purpose of the charge controller is to control the rate of charging and save the battery from over-charging. Other than providing the necessary protection, the charge controller disconnects the load if the battery is discharged beyond a certain limit. Then a user of the SHS can use electricity from the battery during the night. Generally, SHSs for rural areas in developing countries are designed with relatively small output capacity to save SHS costs and allow consumers with low incomes to purchase SHSs. SHSs allow users to use small appliances such as lighting, black and white TVs, and radios, among others.

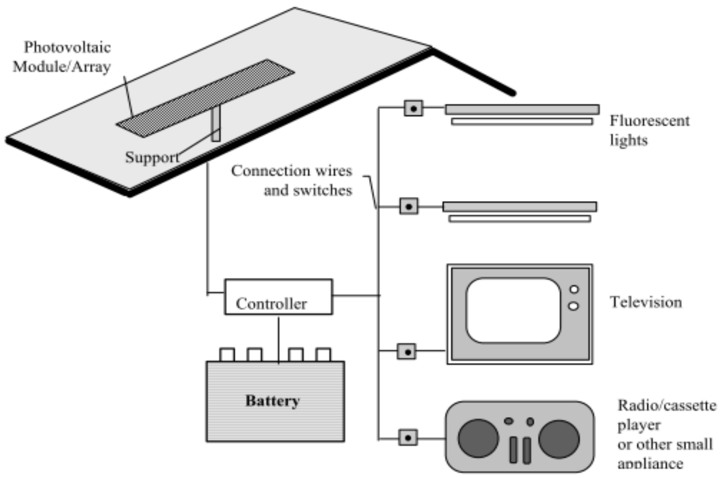

Fig-1. Typical solar home system
Source: (Siegel and Rahman 2011)

The benefits of SHSs could be many, some directly related to SHSs themselves and others related to the availability of electricity. In general, any system should produce two types of benefits or outcomes: backward linkage effects and forward linkage effects. Backward linkage effects are related to the SHSs themselves, in other words, the inputs and services needed to allow effective operation of SHSs. The backward linkages may be related to the sale, repair and maintenance of batteries and solar panels in the local community. The forward linkages of the system are related to use of electric power and production of new activities, outputs and services.

Below is a partial list of potential forward linkages of SHSs

- Higher level of economic activities at home after dark
- Higher exposure to information
- Improved educational attainment of children and adults
- Lower number of accidents or other mishaps due to availability of lighting
- Better entertainment

One of the most important benefits may be related to education and educational attainment. Availability of electricity within households will encourage higher educational attainments especially for children. There is positive feedback regarding children's study time after SHS installation. For instance, one study reported that 46 SHS users (out of 66) in Bangladesh answered 'totally agreed' to the question on whether children's study hours increased after installation of a SHS, and the remaining 20 users answered 'agreed' (Hossain Mondal and Klein, 2011). This suggests that in their research all SHS users support the contribution of SHSs to children's study time.

The other significant benefit for users of SHSs is that the SHSs provide entertainment. A desire to obtain some entertainment such as watching TV or listening to the radio is a basic and natural desire for people who are leading a monotonous life. Therefore SHSs can satisfy their wishes and it is beneficial to the people. This desire can also be motivation to install SHSs. There is one study that examined household lifestyle changes after the adoption of an SHS. It found that more than 95% of households in a field survey mentioned the benefits of access to entertainment programs, especially in the case of TV use (Komatsu, Kaneko, and Ghosh, 2010).

As an indirect benefit from using a SHS, users may improve not only the quality of light but also air quality in their rooms. In the rural areas of developing countries, the typical sources of light used in private households are petroleum pressure lamps and also candles or oil-wick lamps. In such cases kerosene is often used for the lamps as fuel. The benefits of using kerosene is that it has a high energy content, is easily transportable, remains liquid over a large temperature range, is easily storable, and available worldwide. However the main drawback to a kerosene lamp is that it generates harmful smoke and an odor, and a room is filled with gas while using the lamp. Therefore SHSs are expected to contribute to creating a brighter and cleaner indoor environment.

The important advantage of SHSs is that SHSs do not emit CO_2. If people who live without electricity in rural areas in developing countries use a SHS instead of lamps that require needs fuel, SHSs can reduce a certain amount of CO_2 emissions. One study reported that SHS installation in developing countries can contribute to a reduction in GHG emissions. The study estimated the amount of GHG emissions reduction by comparing a household that uses kerosene lamps with a household that has installed a SHS. The results showed that GHG reduction is equivalent to approximately 6 t of CO_2 in the case of a 15 Wp SHS and equivalent to around 9 t of CO_2 in the case of a 50 Wp SHS (Posorski, 2003). Therefore SHSs are thought to create an environmentally preferable situation.

4. Case study: Bangladesh

4.1. Background information for energy in Bangladesh

Bangladesh is one of the developing countries that are facing severe energy problems. Only 41% of the total population have access to electricity in Bangladesh and the number of those who do not have access to electricity are estimated at 95.7 million people (IEA, 2011). Even in electrified cities scheduled load-shedding is frequently implemented, as the demand for electricity is greater than the supply, especially in the hot season. To overcome the situation, the government of Bangladesh set a noble vision to provide electricity for all citizens by the year 2020 (Power cell, 2006). In consideration of the electrification ratio in rural areas of Bangladesh, the way the government constructs electricity infrastructure and develops an electricity distribution system to meet the governmental goal will be important. While the Rural Electrification Board (REB), a government supported organization, is trying to build a grid network and supply electricity to the rural areas, it seems to be difficult to achieve the governmental goal due to the huge investment and time required to connect the whole of Bangladesh, including remote villages and offshore islands, to the national grid system. Some challenges in attaining the governmental target are as follows:

- Extremely limited electricity generation capacity
- High investment cost of transmission and distribution
- Geography

As expanding the national grid in those isolated areas is quite expensive and not cost effective, PV systems could be an effective alternative to fulfill the electricity demand in these off-grid areas. PV systems are an important emerging option for supplying electricity with quality of light, reliable service, and long-term sustainability.

4.2. PV projects in Bangladesh

(1) Solar Projects by REB

REB has implemented solar pilot PV projects that are supported by a French financial grant since 1993. The main objective of these projects is to try to apply various PV systems to rural areas in Bangladesh and obtain feedback from users for improving the design of the activities in remote rural areas. The rural population living in areas far from the national electricity grid, such as isolated river islands, was chosen as the project's target because the grid would not be able to reach these areas due to the difficulties and cost of construction of electricity transmission lines. Therefore PV systems are considered as effective in these areas. 13,602 SHSs were already installed by the projects in several remote rural areas by June 2009. The amount of installed capacity is approximately 744 kW (Rural Electrification Board, 2009). In monitoring of the projects by a foreign consultant, REB and other institutions, it was indicated that improvements of maintenance services for PV system consumers in such remote areas are necessary.

(2) Solar Electrification Projects of BPDB

Bangladesh Power Development Board (BPDB), a semi-government organization, is also responsible for the distribution of electricity in some rural areas and it has carried out a solar electrification project in the Chittagong hill tracts area where it is difficult to distribute electricity for geographical reasons. Through the project, 300 SHSs and 4 centralized solar units were installed and the amount of the total installed capacity in the hill area is 54kW. In addition, BPDB provided 1800 SHSs in two other remote areas, Belaichari and Barkol (Rofiqul Islam, Rabiul Islam, and Rafiqul Alam Beg 2008).

(3) IDCOL Solar Program

Infrastructure Development Company Limited (IDCOL), a government-owned institution, was established in 1997. The purpose of establishment of IDCOL was principally to promote renewable energy technologies on a commercial basis in Bangladesh. By providing long-term financing to private sector infrastructure projects and renewable energy projects, IDCOL aims to supplement the government's goal of electrifying all of Bangladesh by 2020 and at the same time, raising the standard of living of rural people.

IDCOL solar program was started with the help of International Development Association (IDA) and Global Environmental Facility (GEF) in 2003. Although the initial target of the program was to install 50,000 SHSs by 2008, the aim was achieved 3 years ahead of completion date. Therefore IDCOL revised the target number of SHSs to be installed to 200,000. Following this success, IDA, GTZ (or GIZ, the German agency for international cooperation), KfW (a German government-owned development bank), Asian Development Bank (ADB) and Inter-American Development Bank (IDB) extended their support. After achieving its aim, IDCOL has revised again its target to 1 million SHSs by 2012. This revised target was already achieved in 2011. The project has successfully promoted the installation of SHSs in terms of number of installations. Fig.2 shows the number of SHSs installed in Bangladesh.

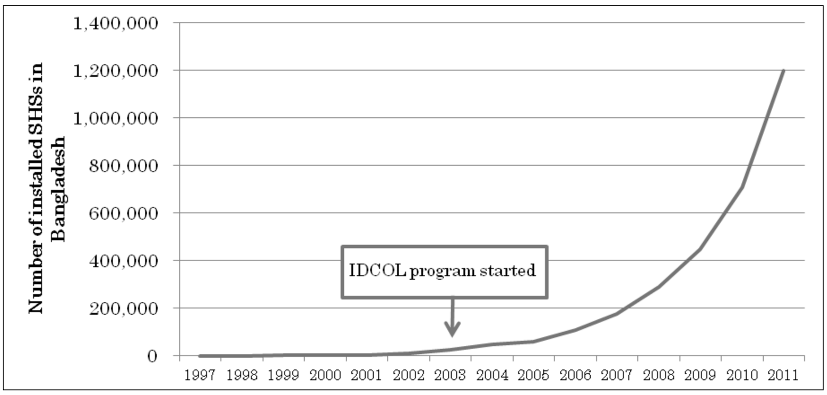

Fig-2: Number of SHSs installed in Bangladesh
Source: I. Sharif, 2010 and IDCOL

One of the reasons why the IDCOL program has promoted SHS installation successfully is that all participants are well incorporated into the structure of the program. The participants and roles of each partner are described as follows:

- **The Bangladesh government:** managing official procedures for collaborating with international donor agencies, supplying funds to IDCOL and creating incentives (waiver of duties, tax benefit etc.)
- **Donor Agencies:** providing finance and advice for the program based on global experience in renewable energy projects
- **IDCOL:** financing partner organizations, monitoring the program and furnishing technical assistance (training, logistic and promotional support).
- **Partner Organizations (POs):** POs include non-governmental organizations (NGO), private companies and micro-finance institutions. POs select areas and customers, and sell SHSs at the grass-root level.
- **Manufacturer / Supplier:** selling necessary products and components for SHSs to POs
- **Professionals:** providing valuable counsel to the project and evaluating the program, as they have expertise in technology and rural development

These partners act in harmony in the program and this elaborate structure contributes to creating incentives for POs sell more SHSs and for consumers to buy more SHSs. As shown in Figure 3, a fund for operating the program is provided by the donor agencies, and IDCOL obtains resources through the Bangladesh government. IDCOL finances POs by using the given support so that POs can design SHSs at a relatively low price. Although SHSs are an expensive option for consumers who live in rural areas without electricity in Bangladesh, this financial mechanism of the program allows the consumers to buy SHSs. The program is implemented through POs. POs obtain SHSs or their components from manufacturers or suppliers, and sell them to customers. Under the program, there are around 30 private companies and NGOs are approved as POs. A role of POs is to select the areas and potential customers, provide micro-credit loans to customers, install SHSs and guarantee support for maintenance of SHSs. Generally POs offer cash payments or loan payments as methods of payment for SHSs. This payment option also entices consumers to purchase SHSs. Households must pay a minimum of 10% of the system cost as a down payment. After the down payment, POs conclude a sale or lease agreement and install the system. Table 1 shows a payment scheme of the Grameen Shakti, one of the POs.

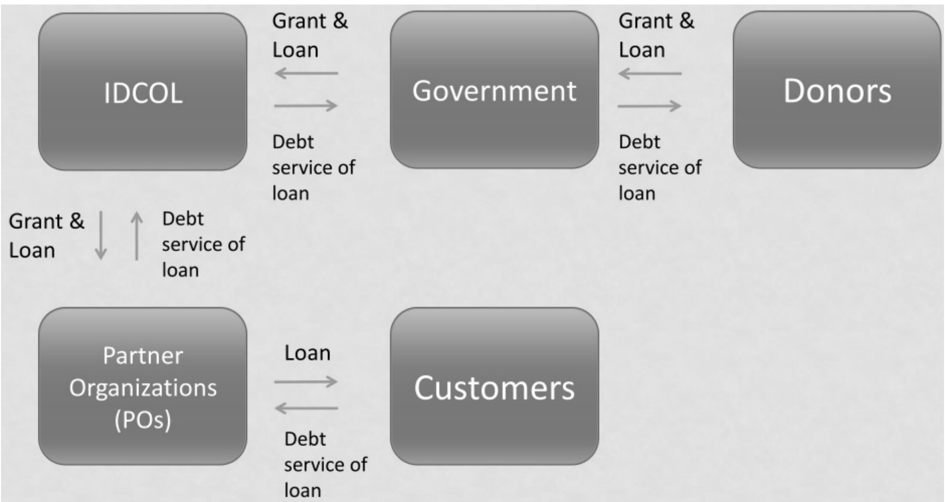

Figure 3: Fund Flowchart for Repayment of SHSs

Table 1: Payment schemes for SHSs of Grameen Shakti (a PO)

Mode of Repayment	Down Payment	Installment	Service Charge (Flat Rate)
Option-1	35 %	12 Months	5%
Option-2	25 %	24 Months	6%
Option-3	15 %	36 Months	8%
Option-4	100%		4% Discount
Option-5	10 %	36 Months	5%(exclusively for micro-utility clients)
Option-6	25%	12 Months	Nil (exclusively for religious institutions)

An important mechanism is the financing model provided by IDCOL. IDCOL designed the model so that every time a PO sells a SHS, the PO will receive two types of grant from IDCOL. One is a buy-down grant that enables POs to sell SHSs at a slightly reduced price. The other is an institutional development grant that is given to POs to extend credit to households and also enables POs to build their capacity by hiring staff, training employees and monitoring credit (K. Sovacool and Drupady n.d.). To promote competition among POs, the grants are decreased as the number of installed SHSs increases. This is called a phased reduction of the grants, which is shown in Table 2.

Table 2: Phased reduction of the grants

Item	Amount of Grant Available per SHS		
	Total	Buy-down grant	Institutional Development Grant
First 20,000 SHS	$90	$70	$20
Next 20,000 SHS	$70	$55	$15
Next 35,000 SHS	$50	$40	$10
Next 88,160 SHS	€38	€30	€ 8
Next 35,000 SHS	€36	€30	€ 6
Next 235,000 SHS	€34	€38	€38
Next 100,000 SHS	€38	€38	€38
Next 72,000 SHS	€38	€38	€38

In addition, IDCOL provides a low-interest refinancing loan to POs. It enables POs to refinance 80% of credit to customers from IDCOL over 7-10 years at a 6-8% interest rate. For example, when a customer pays for a SHS in monthly installments over several years, it takes time for the PO that sold the SHS to recover the buying price of the SHS, and this could be an obstacle for the PO to continue business smoothly. In consideration of this issue, IDCOL refinances 80% of the credit amount to the customer. When the installation of a SHS is completed, the PO makes an electronic disbursement request to IDCOL for refinancing and grants. After internal checking, IDCOL conducts physical verification to confirm the installation of the SHS, and IDCOL releases grants and refinancing only if the inspection result is satisfactory.

4.3. Impact of the IDCOL PV program

The IDCOL PV program has successfully increased the number of SHSs installed in Bangladesh. How about the impact on SHS users? There are some studies that focus on SHSs in Bangladesh. A. H. Mondal (2010) tried to clarify the economic viability of SHSs, and underscored the fact that recovering the cost of SHSs is difficult for users who use SHSs only for non-business purposes such as lighting and watching TV, among others. S. Chakrabarty and T. Islam (2011) also concluded that SHSs are financially more attractive when used for small income generating activities. While the studies suggested that SHSs seem to bring less monetary benefit to the users, S. Komatsu et al. (2010) pointed out the benefit of energy cost savings on for the household purse. In brief, the SHS users can save costs for energy resources such as kerosene, and the reduced costs of those energy sources accounted for 20-30% of the monthly payments on the SHS. Therefore the burden of payment on the SHS is somewhat eased.

So far the monetary benefit of SHSs has been debated but social and environmental viewpoints should be incorporated into evaluations, to assess the actual benefits of SHSs, since SHSs have other virtues such as access to entertainment, free from harmful gas of kerosene, and increase in children’s study time, among others. According to the surveys by S. Komatsu et al. (2010) and M. A. H. Mondal and D. Klein (2011), most of the SHS users mentioned the benefits of using electric lights. For example, there are the benefits of extended study time for children, increased working time at night, improvement of indoor air quality, and less effort for lighting, among others. In addition, they found that nearly all of the SHS users mentioned were able to watch TV as a benefit. However it is not easy to quantify these non-monetary lifestyle benefits, or to compare the cost of SHSs and the actual benefits, both monetary and non-monetary. In this sense, it is important to understand the consumers’ satisfaction with SHSs, so that we can ascertain whether or not SHSs are worthwhile for the users. B. K. Sovacool and I. M. Drupady (2011) and A. H. Mondal and D. Klein (2011) concluded that the IDCOL program has an extremely high consumer satisfaction rate. As an environmental benefit, the program overall has contributed to reducing annual carbon dioxide emissions by 165,112 tons (B. K. Sovacool & I. M. Drupady, 2011). Furthermore, the program has brought other social benefits. It has created employment related to POs and distributors of SHSs equipment as well as local jobs in maintenance and installations. For example, Rahimafrooz, a supplier of batteries, has doubled its capacity to meet the demand of the project. Thus the program has stimulated the market related to SHSs in Bangladesh. Moreover, through this job creation, women are now trained in the maintenance and installation of SHSs and it is thought that this program brings women's empowerment in rural communities.

4.4. Challenges of the IDCOL PV project

SHSs can bring many benefits to users. However several challenges are identified.

First, there is a lack of awareness of what SHSs can do. Most rural people do not know or do not believe that SHSs can provide them with light or energy. Sometimes political leaders are also not familiar with the functions of SHSs. Therefore raising awareness of the advantages of SHSs is an important activity in terms of dissemination. In particular, in rural areas in Bangladesh, it is effective to show how SHSs can operate and provide electricity in practice and repeatedly.

Second, there is a risk that natural disasters could destroy SHSs for which users have not yet fully recovered their investment. From time to time cyclones hit Bangladesh and cause tremendous damage. The SHS users might face a serious situation if they lose households goods including SHSs whose payment is not yet finished or recovery is not yet completed.

Third, local capacity building in Bangladesh is also one of the challenges in the program because the program is fairly dependent on funds from international development agencies. Without such funds it would be difficult to continue this program. Therefore the program should be focused on local capacity building so that the SHS market can be sustained by its own market mechanism without funds or subsidies. Issues related to local capacity building, improving the quality of batteries for SHSs, better warranty services for SHSs and producing recycling and disposal systems for solar panels and other SHS components. Using local accessories also enhances the capabilities and options of local technicians while servicing and repairing SHSs.

Furthermore, SHSs are still costly for rural people especially extremely poor customers. Although POs offer relatively low prices for SHSs thanks to the program's financial mechanism, they are still beyond the reach of the poorest in Bangladesh society.

5. Policy recommendations for other developing countries

PV systems are a proven technology, so the question is why has they not spread to rural areas in developing countries? The people in such areas need and want electrification, so why have they not adopted it? What policies can be put into place to change their behavior and motivate them to adopt PV technology? To address these challenging questions we will view the problem in behavior management terms using the Push/Pull method of behavior change. If a group of people behave one way, called “No PV Use”, and we want them to change to the new way, called “Using PV”, we have to use a combination of methods. We can ‘push’ the people towards the new way by encouraging them to adopt PV or the government can issue an ordinance making it necessary by law. We can also ‘push’ them by offering easy installation and available finance, which will motivate them to adopt it. From the other side, we can ‘pull’ them towards the adoption of PV by making it look attractive. We can do this by explaining the benefits of electrification and low carbon technologies. We can also increase the demand for PV by lowering the cost and encouraging the people to ask for help from their government.

When trying to determine the best policy to achieve the desired behavior change, programs need to consider many aspects. The level of government involvement should be determined to decide if there should be a mandate, a hand-over to another organization, or a partnership with several organizations. Funding options must be considered to determine if the program should be funded 100% by government or an NGO or an international organization such as the World Bank. The program could be just partially funded and subsidized. Implementation options should be considered to determine if NGOs, the government, or a combination do the actual work. And the level of community involvement must be considered to decide if the villages will get involved and do the work and or if the implementation will be done for them.

By reviewing the case of Bangladesh's PV electrification program, this study suggests some important push and pull factors.

As one of the important push factors, a government should develop a financial mechanism in a PV electrification program to enable consumers to purchase PV systems. This is an effective tool to change consumer behavior. Then the government should also aim to create a PV market so that the market will take root in the country without any subsidies or aid in the future. In the case of Bangladesh's PV electrification program , the financial mechanism was designed as a phased reduction of the grants to promote competition between POs, and POs will gradually become independent of subsidies. Furthermore the government can encourage the financial mechanism of the program through legislation. For example, the government exempts importers from taxes imposed on products related to PV systems. This sort of support is necessary to make the program successful.

As another push factor, there is a possibility of attracting investment to the program. The Clean Development Mechanism (CDM) allows developed countries to achieve part of their reduction obligations through investment in projects in developing countries that reduce GHG emissions. The industrialized countries' investing entities can earn credits for emission reductions achieved through its investment in the developing country towards its own emission commitment. CDM will be used to encourage private sector investments in climate-friendly development activities. In the case of the PV electrification program in Bangladesh, the amount of annual carbon dioxide emissions reduction is 165,112 tons. However, at present CDM is not applied to the program. When a government sets up a program, it is better to try to build in CDM to attract investment from other countries. This approach is not financial assistance but a market-based incentive. Therefore it may promote an improved market situation and encourage local capacity building in the country.

The most important pull factor is to raise awareness of PV systems to change consumer behavior. People who live in rural areas without electricity mostly do not know about PV systems and their actual functions. In addition, many people tend not to believe that the new technology is beneficial for them. Therefore it is important to provide accurate information about PV systems, such as what PV systems can do, how much they cost, how long they can work, and the availability of after services, among others. Implementers of the program should publicize PV systems. Moreover, methods of raising awareness are also important. Seeing is believing, and it is quite effective to demonstrate how PV systems work and provide electricity in practice.

6. Conclusion

We have discussed the problem of how millions of people in developing countries lack electricity and all of the benefits they can get from electrification. Solving that problem with PV/solar energy is a low carbon solution that benefits the people and the environment simultaneously. Countries with high levels of sunshine/radiation are good candidates for PV solutions, but there are many challenges facing PV implementation. After analysis, we concluded that an implementation model similar to the IDCOL PV electrification program is a good solution for developing countries. It is also important to take steps to ensure the program has lasting success.

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