

# Prospect of PV Home system for Promoting and Stimulating Economic Development of Rural Bangladesh

M. Fayyaz Khan<sup>1</sup> and M. Mahmud Khan<sup>2</sup>

<sup>1</sup> Department of EEE United International University, Dhaka, Bangladesh

<sup>2</sup> Department of Health Science, Tulane University, New Orleans, USA

E-mail: [fyk@eee.uui.ac.bd](mailto:fyk@eee.uui.ac.bd)<sup>1</sup>, [khan@tulane.edu](mailto:khan@tulane.edu)<sup>2</sup>

**Abstract**—Poverty alleviation is the principle pre-condition for economic development of a developing country. In Bangladesh each village has about 355 households below the poverty line and the average income of these households is below Tk 3,500/-per month [1]. Rapid population growth and extreme scarcity of agricultural land require development of alternative sources of employment and income. Although the rural economy of Bangladesh is going through diversification, the pace of the progress can be significantly enhanced through human resource development and creation of alternative investment opportunities. In this paper, we argue that introduction of PV Home system could work as a catalyst in the process of transforming rural economy of Bangladesh. The PV Home system is likely to create opportunities home based income generating activities as well as better educational attainment for household members. Therefore, the PV Home system would have both short term and long term impacts on economic growth and diversification of rural economy.

**Index Terms**—PV home system, rural households, annual flow, forward and backward linkage, solar radiation.

## I. INTRODUCTION

TRADITIONAL fuels account for 99% of energy consumed in rural Bangladesh households. Only about 38% of total population in Bangladesh [2] have access to electricity and it would take around 35 years to provide electricity to all. About 73% of primary energy consumption in Bangladesh is generated from bio-mass especially through burning of wood and crop by products [3]. Due to high consumption of bio-mass source of energy, Bangladesh is experiencing rapid deforestation thereby enhancing the green house effect. Supplying electricity to most of the rural people by national grid is almost impossible in the near future due to the following factors:

- Low per capita consumption
- Extremely limited generation capacity
- High investment cost of transmission and distribution
- Geography of Bangladesh

100 million people out of 140 million in Bangladesh do not have access to electricity. Nearly 60% of total area of Bangladesh is not covered by electricity supply lines.

Therefore, it is unlikely that the coverage of electricity transmission can be increased significantly in the near future.

For remote places and remote islands, the prospect of supplying electricity through grid is next to impossibility within foreseeable future. In absence of electric grid, the alternative often proposed is the use of diesel Generator sets to supply electricity. Using generator has its own set of problems. First, generators themselves are quite expensive and running the generators to produce electricity could be very costly. Even when some households can afford to buy and run the generators, lack of fuel supply often limit the use of the generators. Reliable and adequate supply of fuel requires well-developed market structure and unless the demand for the fuels is high, it is unlikely that an efficient market can be sustained for a rural community. At the same time, demand and use of fuel has additional social cost: the foreign exchange constraint, environmental pollution, risk of carbon monoxide poisoning, risk of fire etc. Kerosene as fuel gives rise to smoke and fire hazards. Bio-mass may be a good alternative source of energy. However, for this, collective and integrating farming has to be developed to make bio gas plant cost effective. Under these circumstances, PV home system may be an alternative source of renewable energy for rural people of Bangladesh.

## II. PV HOME SYSTEM

Bangladesh receives an average daily solar radiation of 3.82–6.42 kWh/m<sup>2</sup> [4]. The country has a total area of 1.47x10<sup>11</sup> m<sup>2</sup>. With a solar system efficiency of 10%, a total of 5.2x10<sup>9</sup> kwhr units of electricity can be generated annually. According to the World Bank survey [5], there is an existing market of 0.50 million households in Bangladesh. Around 160,000 units of solar home system have already been installed in the rural areas of Bangladesh and the annual growth in demand is estimated to be around 5%. PV home system is a solar panel with sets of battery, charging device and some circuit protection devices. A simple block diagram of a solar home system is shown in Fig. 1. Normally during day time, solar panel produces electricity and charges the battery through a charge controller. The purpose of the charge

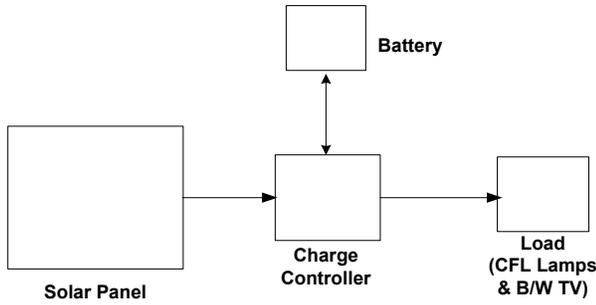


Fig. 1. Block diagram of a solar home system.

controller is to control the rate of charging and to 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. PV home system once installed is almost maintenance free except for topping up of batteries needed from time to time.

III. WHAT IS THE COST OF THE PV HOME SYSTEM?

The PV home system requires initial investment with little or no other maintenance costs during the life time of the system. To estimate the annualized cost of the system, the investment cost will be distributed over the life time using the following formula:

Present value=

$$a_0 + \frac{a_1}{(1+r)} + \frac{a_2}{(1+r)^2} + \frac{a_3}{(1+r)^3} + \frac{a_4}{(1+r)^4} + \dots + \frac{a_{n-1}}{(1+r)^{n-1}} + \dots \quad (1)$$

where  $a_0, a_1, a_2, \dots$  are the annual flow from the system per year and  $r$  is the interest rate.  $n$  is the total life of the system in years. The average life of a solar system is 20 years and therefore, we can use  $n=20$  in the equation when calculating the annual flow of service from the solar panel. Another capital cost is the cost of the battery. Since the average life of the battery is five years, for calculating annual flow from battery, the value of “ $n$ ” will be 5.

The cost of the solar panel is Tk 10,500. Using 20 years of life, and assuming that the flow of service is constant over the years, the annual value “ $a_{panel}$ ” becomes:

$$a_{panel} = \frac{\text{Price of panel}}{[1 + \frac{1}{(1+r)} + \dots + \frac{1}{(1+r)^{n-1}}]} = \frac{10,500}{[D]}$$

If the long-term interest rate is 15%,  $D=7.198$ . If the interest rate is 10%,  $D=9.365$ . With 15% rate of interest, the annual flow from the panel becomes Tk.1,459. Using the information for battery (price of Tk 4,500 and life of five years), the annual flow from battery per year becomes  $(4,500/3.855 =)$  Tk 1,167. The other costs for charge controller, cable, supporting structure etc. is assumed to be Tk.1000 and assuming 20 year life for these items, the other cost per year should be about Tk139.

TABLE I  
COST PER DAY FOR DIFFERENT ENERGY SOURCES

Energy source	Running cost per day	Remarks
PV Home System	Tk.8.50	Calculation based on 4hrs operation/day with cost/Kwhr = Tk. 35.52
Diesel Generator	Tk. 12.12	Based on 4 hours of operation with cost/Kwhr = Tk.50.50
Oil Based Lamp (KUPI, Hurricane)	Tk. 25	At least 10 Oil based lamps are required each lamp requiring Tk 2.5 per day.

Therefore, total cost of battery, panel and other items becomes Tk. 2,765 per year.

This panel and the battery (of size 60 AH) should able to run 4 CFL (7W each) lamps and one black & white TV (30W) giving a connected load of 60W. Total energy generated by the system should be about 85kWHR per year and so the cost per KWH becomes  $(2765/85 =)$  Tk. 35.52

IV. COMPARATIVE STUDY OF PV HOME SYSTEM WITH OIL-BASED AND DIESEL GENERATOR

Diesel generator: The minimum size (2KW) of Diesel generator available in the market costs around Tk. 19,000/- and the expected life of the generator is assumed to be 10 years with a major maintenance required in every five years. The annual flow rate for the generator with 15% interest rate is Tk 2380/-. In every 5 years the maintenance cost will be around Tk. 3000 and the annual flow rate required for maintenance will be Tk. 416/-. Assuming a load of 60Watt identical to that of SHS with daily four hour of operation, the diesel generator would require Tk.1500 worth of fuel annually (A small generator normally consumes 0.4 liter of fuel/Kwhr). The total annual flow rate for the diesel generator is Tk. 4296/-and the unit cost of energy produced from the generator is Tk.50.50/-.(the high cost per unit of energy is due to the fact that the generator is assumed to be running at 1% of its rated capacity due to small connected load of Solar Home System. The following Table (Table-I) gives a comparative study for different energy sources that may be used for a rural house hold. Most commonly used lighting system for a poor rural household is KUPI or Hurricane (oil based lamps, commonly kerosene is used for these lamps) has been taken into consideration for the purpose of comparison. These oil based lamps have a very poor light energy output and a large number of such lamps (at least 10~12 lamps) are required to obtain identical output to that of a 5W CFL lamp.

Comparative study shows that the overall cost and the cost per day for the PV Home system is low with respect to other energy sources as shown in Table-I. Counting the cost due to environment, sound pollution, fire hazard, cost due to health hazard for CO and CO<sub>2</sub> emission would yield even an higher cost per day for the Generator and the oil based lamp. The cost of oil based lamp will be much higher if we want to get the identical luminous output of 15Watt for 4 CFL/LED lamps. In calculation of cost for the oil based lamp, it is

assumed that at least eight equivalent lamps are required to carry out the work in the night although these lamp output are no match to those of the outputs of the CFL lamps. PV home system would come out to be the cheapest when compared to the other two sources of energy if the other hidden costs as mentioned are counted.

#### V. POTENTIAL BENEFITS OF PV HOME SYSTEM

The benefits of PV home system could be many; some directly related to the PV system itself 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 PV system itself, i.e., the inputs and services needed to allow effective operation of the PV home system. The backward linkages may be related to 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.

The following provides a partial list of potential forward linkages of PV home system

- (i) Higher level of economic activities at home after dark
- (ii) Higher exposure to developmental and health-related informational campaigns
- (iii) Higher school enrollment and participation
- (iv) Improved educational attainment of children and adults
- (v) Enhanced social and cultural interactions among community members
- (vi) Lower level of accidents or other mishaps due to availability of lighting
- (vii) Electrification will reduce rural to urban migration
- (viii) A practical study shows that % income of a family went as high as 15.3% over a year by use of electricity when compared to the income of the same family without having electricity [7]

One of the most important benefits may be related to education and educational attainment. Availability of electricity within the household will encourage higher educational attainments for both the adults and the children. Adult education should be positive economic impact in the short run. Since education is an important input in the modern production process, we expect that the educational attainment and economic output relationship should follow the usual pattern of production function with diminishing marginal productivity of education. The expected relationship between educational attainment of adults and economic output is shown in the diagram below. With improved educational attainment of adults, production should increase without any technological development, as shown by the curve AB in figure 2. What would be the exact economic benefit of the PV system will depend on a number of factors:

- (a) pre-PV system educational attainment of adults,
- (b) effect of PV home system on the level of educational attainment of adults, and

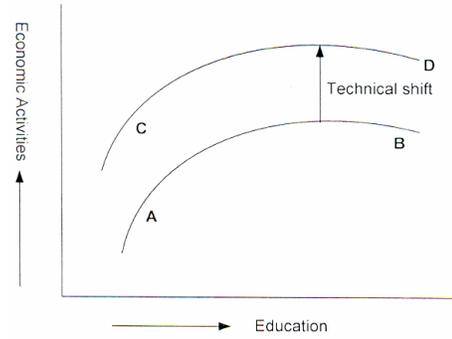


Fig. 2. Production function for Education.

(c) the marginal effect of higher educational attainment of adults on economic output in the short.

As figure 2 indicates, concentrating on short-term outcomes will underestimate the benefits derived from adult education. Better educational attainment of adult may also trigger technological development or adoption of better and more efficient technology in the production process. Improvement of technology should shift the production function from AB to CD, a higher level of production, but technological development is a medium term or longer-term outcome rather than a short-term result.

In the medium-run or in the longer-run, better education of children will also produce increased production. Higher enrollment in schools, better performance in academic activities and higher educational attainment should increase future production. Therefore, if the analysis takes a long-term perspective of 15 to 20 years, total output may improve significantly due to improved educational outcomes in the short-run.

**Quality of life:** Absence of CO and CO<sub>2</sub> will reduce the respiratory disease and reduce the medical cost. Quality of life will increase.

#### VI. ECOLOGICAL PERSPECTIVE

Contamination of ground and ground water by use of oil and fuel will be reduced due to the use of PV home system rather than the use of fuel-based electricity generation system. Although lead acid batteries are hazardous, recycling of these batteries may reduce the risk of such hazards.

#### VII. OTHER BENEFITS FROM SOLAR HOME SYSTEM

Bangladesh is prone to natural calamities like cyclone, floods and torrential rain and gusty winds. Such calamities often give rise to interruption of power, disconnection of transmission & distribution system. Also power supply has become unreliable due to continuous load shedding. Installation of PV home system will relieve its users from frequent power outages due to natural calamities and frequent

load shedding. This will also reduce the huge investment cost of setting up of power station and transmission and distribution networks which Bangladesh government cannot afford. If contract is awarded to IPP (independent Power Producer) they may not be interested to install power station in remote areas for economical reasons. Also pilferage of power (so called system loss) will also be a major factor for efficient operation of the power station.

#### VIII. STEPS TO BE TAKEN TO MAKE THE SOLAR HOME SYSTEM POPULAR

(a) Mass awareness program could be initiated among the rural people to make renewable energy specially PV home system popular. Government machinery can work closely with the private sector in this regard.

(b) To encourage adoption of PV home system, soft term loans may be offered to eligible rural people. Sale of the system should be improved by requiring 25% down payment of the total price and the rest can be paid over a number of years at a preferential interest rate [6].

(c) Integration of private and government sectors in promoting the PV home system will be required. Developing the know-how and skills related to PV home system will also need better public-private partnership.

(d) Special training programs should be organized for effective use of PV home system.

(e) If possible a group of people may form a co-operative and buy a medium size solar home system (100Wp) with a soft loan from government agencies or NGOs. A study by CMES [8] reveals that in the place Alok Dihi Bazar at Ranir Bandar of Dinajpur district of Bangladesh 20 shops were illuminated by solar home system set up by forming co-operative. Each of the shops had to pay a small security deposit and daily tariff of Tk.4 for 5 hours of electricity. In fact their cost for oil based illumination has been almost double for this.

#### IX. CONCLUSION

Although the investment cost for installation of a solar home system is quite high compared to the average income of rural house hold in Bangladesh, still it may be a good option for thriving business activities and imparting education to the rural people of Bangladesh. The price of solar panel is expected to decrease gradually and it is expected that within next 2~3 years the price of panel will come down to 2\$/W<sub>p</sub>. Similarly, the price of battery is also expected to fall by 20% within the same period. So people in the villages especially in remote areas and islands will be encouraged to purchase solar home system. Even with the high investment cost, the benefits that can be derived from solar home system are immense as highlighted in this paper. So the government, NGOs and other donor agencies should come forward with soft term loans to encourage people to install solar home system. For remote areas and rough terrains where installation of power lines may be difficult and expensive, solar home system may be a good option in terms of economy and reliability of power supply. Major advantage of photo voltaic is that it can be tailored to the specific application or expanded as needed.

#### REFERENCES

- [1] Socio demographic character of households: A study of Government of Bangladesh and DFID, pp 4-5.
- [2] [www.worldbank.org.bd/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/BANGLADESH](http://www.worldbank.org.bd/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/BANGLADESH).
- [3] [www.thebioenergysite.com/news/223](http://www.thebioenergysite.com/news/223).
- [4] M. A. H. Mondal, Opportunities to use renewable energy technologies in rural Bangladesh, Centre for Development research (ZFF), University of Bonn, Germany
- [5] [www.worldbank.org.bd](http://www.worldbank.org.bd)
- [6] [www.adb.org/documents/events/2008\\_IDCOL\\_solar\\_energy\\_Program](http://www.adb.org/documents/events/2008_IDCOL_solar_energy_Program). E. K. Pavel
- [7] [www.rural\\_electrification\\_slides.pdf](#) D. Burnes. Pathways to impact: How rural Electrification affects welfare
- [8] M. Ibrahim *et al.* Centre for Mass Education in science (CMES)