Financial Analyses and Social Impacts of Solar Home Systems in Bangladesh: A Case Study

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Abstract- Rural illumination in Bangladesh primarily depends on the kerosene based hurricanes and lamps. In addition, car batteries and dry cell batteries are used to run TV, radio and small watt fluorescent light. This study was carried out in two selected villages in Khulna district, Bangladesh. Six case studies were analyzed to check financial feasibility and questionnaires survey method was followed to find out the impacts of solar home systems (SHSs) on social life of rural people. The economic analysis of 20, 40, and 42 Wp SHS shows the high economic benefits. The study also illustrates that, the solar home systems with small income generation are more acceptable than solar home systems used only for lighting purpose. Moreover, the quality of light provides more opportunity for household work and increases study period in the night and hence improves the quality of lifestyle in rural areas.

Keywords-Energy crisis; solar home system; financial sustainability; social impact.

1. Introduction

Electricity is the prime mover for the advancement of all economic and industrial activities. However, lack of power security is still the major challenge not only in Bangladesh but also all over the world. Bangladesh, a poor and over populated country has a total population of 163.655 million. About 59% of total population live in rural and isolated areas and most of them have no electricity access. At present, about 20% of the total population in the world has no electricity access whereas in Bangladesh, almost 51% of total population live without electricity. This scenario is more acute in the rural and isolated areas in Bangladesh where only about 25% have electricity access [1]. Electricity generation in Bangladesh is mainly depends on fossil fuel that depleting hastily [2]. In December 2013, installed generation capacity was about 10264 MW of which only natural gas contributes almost 64.5% [3]. In addition, emission from this fossil fuel is another concern to the environmentalists throughout the world. Although, electricity generation capacity in Bangladesh has been increased significantly during the past few years, the country has huge crisis due to the increasing demand in almost each and every sector. In the fiscal year 2012-2013 the maximum electricity generation was 6350 MW, still there was a load shedding of 1000 MW [3]. Government of Bangladesh has a vision for electricity access to all by the year 2020. However, it is quite impossible to achieve the goal without other energy sources except fossil fuel. Therefore, emphases have been given to generate electricity from various renewable sources and to mitigate environmental pollutions. Among the available renewable energy sources in Bangladesh solar, biomass, and wind are the prominent candidate. The location of the country is between $20^0$34' and $26^0$38' north latitude and $88^0$01' and $92^0$41' east longitude, suitable for solar energy utilization [4]. Daily solar radiation in the study area (Khulna district) is about 4.55 kWh/m^2. Solar energy conversion technology i.e. solar home systems are the most accepted technology among all the technologies to electrify the rural areas. Simplicity, uninterrupted, and emission free electricity are the major reasons for its huge acceptance. So far in Bangladesh, about 2 million SHSs/SHLSs with solar water

pump and solar central unit of total capacity 81 MW has been disseminated [5]. However, lacks of information and financial limitations are the major barrier for economic sustainability of SHSs in rural areas of Bangladesh. This study exposed the financial viability and social impacts of SHSs in selected villages in Khulna district, Bangladesh.

2. Study Area and Methodology

Two villages, Domra and Hossainpur of Rupsha Thana under Khulna district were selected for this study as shown in Fig. 1 [6]. Almost 18% of the household and small business enterprise use SHS. Most of those SHSs are implemented by Grameen Shakti and Srijoni Bangladesh. Six case studies were analyzed to find out the financial feasibility and social impacts of the SHSs used in the selected areas. The data were collected through questionnaires, interviews, group discussions and field observations with user of SHSs. Microsoft excel software has been used to calculate Net present value (NPV), Simple pay back period, Benefit to cost ratio (BCR), and Internal rate of return (IRR).

3. Case Studies and Findings

Among the six case studies, four were small business enterprise and two were households. Generally, the respondents used different types of traditional energy sources especially kerosene for lighting and grid charged battery for running the TV, radio, and fan before installation of SHSs. It has been estimated that one liter of kerosene emits about 2.5 kg of CO_2 [7]. The CO_2 reduction cost is considered about BDT 240 per ton in Bangladesh [8].

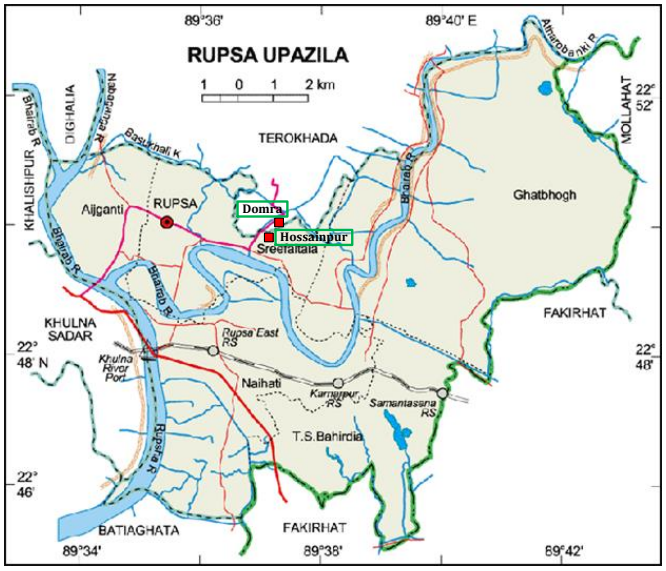

Fig. 1. Geographic location of study area

✓ Case study 1

Kajol Kundu, a stationary shopkeeper used 2 generator powered bulbs and 1 electric charger light for lighting purpose. He has replaced these lighting systems by a 42 W solar panel from nearby Grameen Shakti (GS) center. Before installation of solar panel he had to pay BDT 10 per day to generator owner and BDT 280 per 6 months for replacement of electric charger light. In addition, he had to go nearby electrified village or market for charging the light. Now, he is using 4 fluorescent lamps and spending more time in night at shop (increased from 10.00 PM to 1.00 AM) that increases his daily income. Moreover, he is enjoying phone charging facility and also various entertaining program in TV with his customers. The replacement saves about BDT 4210 per year. Fundamental information of case 1 is presented in Table 1.

Table1. Fundamental information of case 1

Name of the user: Kajol Kundu	Age: 37
Education: S.S.C	Address: Village-Domra, Post Office- Ajagarah, Thana-Rupsha, District-Khulna
Family members: 6	Occupation: Shop keeper
Panel size & battery capacity: 42 Wp, 12 V; 60 AH; 10 HR	Offers: Four fluorescent tubes,connection for mobile phone & TV
Total installment: 36	Amount of down payment: BDT 4500
Implementer: GS	Purpose: Lighting, charging mobile phone& watching TV
Monthly amount of installment: BDT 700	Daily income increased: BDT 200
Total installation cost: BDT 29700	Package price: BDT 27000

✓ Case study 2

Sujoy Dey used 2 generator powered bulbs and 1 electric charger light for lighting his stationary shop. Now, he has installed a 40 W solar panel from nearby Srizoni Bangladesh center and has enjoyed uninterrupted lighting facility from 3 fluorescent lamps. He had to pay BDT 10 per day to generator owner and BDT 280 per 6 months for replacement of electric charger light. He used to go nearby electrified village or market for charging the light before installation of solar panel. This replacement saves about BDT 4210 per year. Fundamental information of case 2 is presented in Table 2.

Table 2. Fundamental information of case 2

Name of the user: Sujoy Dey	Age: 30
Education: S.S.C	Address: Village-Domra, Post Office- Ajagarah, Thana-Rupsha, District-Khulna

Family members: 5	Occupation: Shop keeper
Panel size & battery capacity: 40 Wp, 12 V; 56 AH; 10 HR; 6 RBT	Offers: Three fluorescent tubes,connection for mobile phone & fan
Implementer: Srizoni Bangladesh	Purpose: Lighting, charging mobile phone& air from fan
Amount of cash payment: BDT 20200	Daily income increased: BDT 200

✓ Case study 3

Golam Rahman Dhali earns his livelihood by shop keeping and used 1 generator powered bulb for lighting his shop up to 10.00 PM at night. He had to pay BDT 6 per day to generator owner for this lighting system. Recently, he has replaced the lighting systemby a 40 W solar panel with 2 fluorescent lamps from nearby Srizoni Bangladesh center and increased his daily income by BDT 100. This new lighting system saves about BDT 2190 per year. Fundamental information of case 3 is presented in Table 3.

Table 3. Fundamental information of case 3

Name of the user: Golam Rahman Dhali	Age: 45
Education: Class VIII	Address: Village-Hossainpur, Post Office- Ajagarah, Thana-Rupsha, District-Khulna.
Family members: 5	Occupation: Shop keeper
Panel size & battery capacity: 40 Wp,12 V; 56 AH; 10 HR; 6 RBT	Offers: Two fluorescent tubes.
Total installment: 36	Amount of down payment: BDT 1200
Implementer: Srizoni Bangladesh	Purpose: lighting
Monthly amount of installment: BDT 365	Daily income increased: BDT 100
Total installation cost: BDT 14340	Package price: BDT 13000

✓ Case study 4

Mithu Rahman, grocery shop owner used 1generator powered bulbs up to 10.00 PM at night and then used 1 electric charger light for lighting purpose. He had to pay BDT 6 per day to generator owner and BDT 280 per 6 months for replacement of electric charger light and also to go nearby electrified village or market for charging the light. He has replaced these lighting systems by a 40W solar panel from nearby Srizoni Bangladesh center and installed 2 fluorescent lamps for illumination of shop that saves about BDT 2750 per year. Fundamental information of case 4 is presented in Table 4.

Table 4. Fundamental information of case 4

Name of the user: Mithu Rahman	Age: 35
Education: S.S.C.	Address: Village-Hossainpur, Post Office-Ajagarah, Thana-Rupsha, District-Khulna.
Family members: 4	Occupation: Shop keeper
Panel size & battery capacity: 40 Wp, 12 V; 56 AH; 10 HR; 6RBT	Offers: Two fluorescent tubes, connection for TV.
Total installment: 36	Amount of down payment: BDT 1200
Implementer: Srizoni Bangladesh	Purpose: Lighting, watching TV
Monthly amount of installment: BDT 365	Daily income increased: BDT 250
Total installation cost: BDT 14340	Package price: BDT 13000
No. of TV before installation: 0	No. of TV after installation: 1

✓ Case study 5

Elora Parvin Keya is a housewife and the respondent of the solar home system. Instead of using 1 kerosene lamp for lighting she has installed a 20 W SHS with 3 fluorescent lamps and point for mobile phone charging from GS. Before installation of solar panel she used 2 litres of kerosene per month which costs about BDT 136 and had to go nearer electrified village or market for charging phone. The replacement of kerosene saves about BDT 1632 per year and corresponding to 60 kg of CO2 per year which also saves BDT 14.4 per year. Fundamental information of case 5 is presented in Table 5.

Table 5. Fundamental information of case 5

Name of the user: Elora Parvin Keya	Age: 30
Education: Class VIII	Address: Village-Hossainpur, Post Office- Ajagarah, Thana-Rupsha, District-Khulna.
Pattern: home	Occupation: Housewife
Panel size & battery capacity: 20 Wp, 12 V; 30 AH; 10 HR	Offers: Three fluorescent tubes, connection for mobile phone.
Total installment: 36	Amount of down payment: BDT 1300
Implementer: GS	Purpose: lighting

Monthly amount of installment: BDT 380	Monthly income increased: BDT 0
Total installation cost: BDT 14980	Package price: BDT 13000

✓ Case study 6

Table 6. Fundamental information of case 6

Name of the user: Md. Selim Shaikh	Age: 35
Education: Class VIII	Address: Village-Hossainpur, Post Office- Ajagarah, Thana-Rupsha, District-Khulna.
Pattern: home	Occupation: Driver
Panel size & battery capacity: 20 Wp, 12 V; 30 AH; 10 HR	Offers: Three fluorescent tubes,connection for mobile phone.
Total installment: 36	Amount of down payment: BDT 1300
Implementer: GS	Purpose: Lighting
Monthly amount of installment: BDT 380	Monthly income increased: BDT 0
Total installation cost: BDT 14980	Package price: BDT 13000

Before installing SHS household Md. Selim Shaikh used 3 kerosene lamps for lighting. According to statement, the lamps consumed about 5 litres kerosene per month which costs around BDT 340. He inspired to attractive scheme of GS and installed a 20 W solar panel with 3 fluorescent lamps and point for charging phone. This replacement saves about BDT 4080 of kerosene cost and reduces about 150 kg CO_2 emission corresponding saving of BDT 36 per year. Fundamental information of case 6 is presented in Table 6.

4. Financial Analysis of solar Home System

Although, the PV technology is an attractive solution for electricity, its cost is a vital question to afford for a least developing country like Bangladesh. The replacement of kerosene by SHS normally involves relatively low costs and provides good and uninterrupted electrification facility. The economic analysis of SHS was based on various financial parameters such as Simple payback period, Net present value (NPV), Internal rate of return (IRR) and Benefit to cost ratio (BCR). Payback period is the period of time that recoups the initial investment. NPV was calculated by bringing all the cost and income to the year zero. IRR is the discount rate that makes the NPV zero. BCR was calculated by dividing total benefit to total cost throughout the project life. A short payback period, higher NPV, IRR and BCR are necessary to ensure that the investment is quickly recovered and risk free investment. All the financial parameters were calculated by using the following equations [9].

$$\text{Paybackperiod} = I/(R\text{-}E) \quad (1)$$

$$NPV = \sum_1^n (B_n\text{-}C_n)/(1+r)^n \quad (2)$$

$$IRR = r_1\text{-}NPV_1\left(\frac{r_2\text{-}r_1}{NPV_2\text{-}NPV_1}\right) \quad (3)$$

$$BCR = \sum_1^n \frac{B_n/(1+r)^n}{C_n/(1+r)^n} \quad (4)$$

Where, I: Investment, R: Return, E: Expenses, B_n: Total benefit, C_n: Total cost, r: Discounting rate, NPV_1 and NPV_2 for two different interest rates and NPV_1 is positive and NPV_2 is negative, n: Lifetime of system (1, 2, 3…….20).

For economic analysis all the benefits and costs were determined in monetary value. The financial benefits includes saving from kerosene, light charging, and small income generation due to extension of working hours excluding the environmental impacts and other long term social benefits. On the contrary, total cost includes investment cost of system, repair and maintenance expenses, replacement of components like battery, the charge controller, tube, controller, switch etc. throughout the lifetime of SHS. Furthermore, the following assumptions were made for financial analysis as presented in Table 7.

Table 7. Necessary assumptions for analysis

SHS option		Kerosene lighting	
Item	Lifetime (Years)	Item	Lifetime (Years)
Solar panel	20	Hurricane	5
Controller	6	Chimney	1
Battery	5		
Switch/Cable	5		
Tube	3		

All the calculations were based on the present market price of the equipment and the discount rate was considered as 6%, 8% and 12%. The findings of financial analysis of the case studies previously described are illustrated in Table 8.

Table 8. Findings of financial analysis of case studies

Case Studies	Payback period (Years)	NPV (BDT)			IRR(%)	BCR
		6%	8%	12%		
Case 1	2.22	90426.75	74470.63	52168.83	86.57	4.33
Case 2	-----	81319.80	66845.87	46320.68	46.14	4.76
Case 3	2.28	41737.16	34419.15	24240.62	131.20	3.34
Case 4	1.17	105508.34	88946.15	65625.40	461.90	6.50
Case 5	8.82	-7281.57	-7627.65	-7874.67	-----	0.88
Case 6	3.57	20136.42	15752.55	9766.42	33.85	2.17

Table 8 exposed that the case 1, case 3 and case 4 out of all cases had payback period lower than 3 years and significantly large positive NPV, high IRR and BCR. These parameters are varied due to the variation of financial benefits and costs. On the contrary, case 2 had no payback period as the system was installed by cash. Higher BCR of all the cases except case 5 and case 6 is the indication of economic attractiveness. Therefore, these cases had small income generation which makes them financially viable option. On the other hand, case 5 and case 6 used only for household lighting were not economically viable due their high payback period, negative NPV. Studies [8, 9] showed that the payback period and IRR of SHS in Bangladesh varied from this study due to the variation of kerosene price, financial benefits and costs.

5. Social of Impacts Solar Home Systems

Rural electrification through solar PV provides huge positive impacts on daily life of rural people directly and indirectly. The impacts of SHSs on the livelihood of rural peoples and their opinion about the impacts are presented in Table 9.

Table 9. Impacts of SHSs on rural life

Impacts	Agree (%)	Disagree (%)
No pollution and environmental friendly light	100	---
Lengthen study hour for children	33	67
Uninterrupted electricity	100	---
Better entertainment	33	67
Hamper of study due to entertainment	33	67
Economically beneficial	67	33
Security in night	50	50
Improvement of women lifestyle	33	67
Extension of working hour in night	67	33
Late to bed	83	17

In rural areas in Bangladesh, kerosene is widely used for lighting purpose. The burning of kerosene emits huge amount of CO_2 responsible for indoor air pollution that affects the users' health and the environment.Therefore, reduction of kerosene use is the main impact of the use of SHSs that provide less pollution, clean indoor environment and uninterrupted better lighting systems. SHSs also provide the facility for charging the battery for operating TV and mobile phone. Furthermore, the use of SHSs instead of kerosene improves the women health condition, entertainment facility, home studies, social gathering, and income generation activities.

6. Conclusion

Solar home systems are the more reliable technology for uninterrupted electrification in rural areas of Bangladesh. The results from field study at two villages in Khulna, Bangladesh presented in this paper showed that SHSs with small income generation activities had short payback period, higher NPV, IRR and BCR which indicate the economic viability of the systems. Moreover, SHSs were found to provide noticeable benefits in terms of better quality of light that enhances the improvements in children's education, reduction indoor pollution, improvement of social status and living standards. However, in order to make them more affordable and attractive sufficient training and a good instalment scheme should be provided to the respondents.

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