Economic Evaluation of the PV Micro Utilities Installed by Grameen Shakti for Rural Electrification in Bangladesh

S.M. Najmul Hoque [1],*, Barun Kumar Das1, S. Kumar [2] & M Mahmud Roni1
[1]Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Bangladesh
[2] Energy Field of Study, Asian Institute of Ttechnology, Thailand
shumon99234@gmail.com, barun_ruet@yahoo.com, kumar@ait.ac.th and roni_93_me@yahoo.com

ABSTRACT
Sharing expensive technology can serve many users, even poor users. Grameen Shakti has developed a special program named PV micro utility to make it easier for those who cannot afford SHSs individually. Under this program, Grameen Shakti allows people to share the cost and the subsequent benefit of using a SHS. In this study, operation and financial mechanism, analysis of cost of systems, tariff system, simple payback period, NPV and IRR of the micro utility systems have been analyzed to show the financial viability of PV MU from the PV MU owner's perspective. Results suggest that these systems have simple payback period of around 4-6 years. The NPV of systems varied from 27,000 BDT to 144,000 BDT. The levelized electricity cost of PV MU systems is 70 BDT (~0.86 $)/kWh in Bangladesh. The owner has to spend only 7.50 BDT/day but can earn at least 30-40 BDT per day, and up to 130-200 BDT/day.

Keywords - Rural Electrification, Solar PV, Grameen Shakti, Bangladesh, Economic Evaluation.

1. INTRODUCTION

There cannot be any economical development without electricity. Only 47% of Bangladeshi people have access to grid electricity [1] and only 8% are connected with the governmental natural gas supply system and, most of them live in cities [2]. As a result, rural communities suffer from an under-utilized economy and depressed business activities. This lack of energy and power reduces business hours and does not enable people to access modern technology and equipment which are required for development. Mobility of the people is also hampered after dusk due to security problems. Grameen Shakti solar program has addressed many of these issues by extending business hours and increasing business turnover. However, many people cannot afford Solar Home Systems individually. This is one of the barriers to the scaling up of the Grameen Shakti Solar Program and the revitalization of the rural economy, through the use of Solar PV technology. This paper presents the economic analysis of solar PV micro utility installed by Grameen Shakti in Bangladesh.

2. METHODOLOGY

Information about 150 PV micro utility systems at 11 different locations in Bangladesh was collected. The places of data collections are shown in figure 1. Dinajpur, Mymensingh, Gazipur, Manikgong, Dhaka, Khulna, Barishal, Bhola, Chandpur and Rangamati were the districts from where the data were collected. Thirty five systems from nine places among those 150 systems were selected to monitor by field visit. Survey was done during October, 2011 to January, 2012 to study the technical feasibility and social impact of PV MU system.

Whereas, operational and financial mechanism, analysis of cost of systems, tariff system, simple payback period, NPV and IRR of the micro utility systems have been analyzed to show the financial viability of PV MU from the PV MU owner's perspective under financial analysis. All the cost and benefit are converted in to monetary values and project life is considered as 20 years.

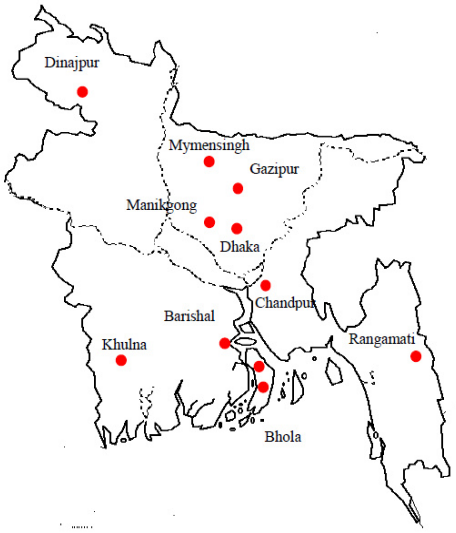

Fig. 1 Data collection at different places in Bangladesh

However, the benefits like environmental impacts, long term benefits of children education due to having good quality of light at home, social benefits of having trained technicians in rural areas or creation of new business opportunities due to SHS is excluded. To calculate the financial analysis following equations are used [3]:

Payback period= I/(R-E)
NPV= CO+ PV
Present value= Σ Cn/$(1+r)^n$
IRR= i1-NPV1 * ((i 2 - i 1) / (NPV2-NPV1))

Where I: Investment, R:Return, E: Expenses, CO: Initial Investment at period 0 which is a negative figure, Cn: total cash flow, r: discounting rate, NPV1and NPV2 for two different interest rates and NPV1 is positive and NPV2 is negative.

3. FINANCIAL ANALYSIS

The viability of any project or business can be determined from financial analysis. In this study, operation and financial mechanism, analysis of cost of systems, tariff system, simple payback period, NPV and IRR of the micro utility systems have been analyzed to show the financial viability of PV MU from the PV MU owner's perspective.

3.1 Financial Scheme of PV MU in Bangladesh

The operational and financial mechanism of PV micro utility program in Bangladesh is shown in Figure 2. It is somewhat similar to the SHS program. The main difference is that this is designed for rural market places and under this program the owner has to rent electricity to his neighbor (shop). The PV micro utility concept was started to provide electricity to the extremely poor people of the country. The owner pays only 10% down payment, and the rest (90%) is payable in 42 monthly installments with no service charge [4]. For other packages of individual SHS, installment period is 36 months; down payment was not less than 15% and the service charge per year is 5% to 8%. GS is responsible for providing (free) maintenance during the installment period. GS also replaces the parts if needed in this period. After the installment period, the owner of the system can agree with GS for one year free maintenance by paying 300 BDT.

There is no meter for electricity bill measurement for this system. The users of this kind of system pay on a daily or monthly basis. GS normally does not fix the amount charged by the owner to the user. The payment varied from 5-10 BDT/day/CFL for daily system. For monthly system, payment for electricity was found to vary between 200-300 BDT/ month/CFL (Source: Field visit, 2011).

In most of the cases, owners have a main switch and turn it on just after sunset. Duration of service varied according to the contract between owner and user but it was found that this duration was about 3 to 5 hours/day. According to the contract, owner will have no responsibility for CFL used by the user. The users have to maintain and replace their CFL as per their needs and use.

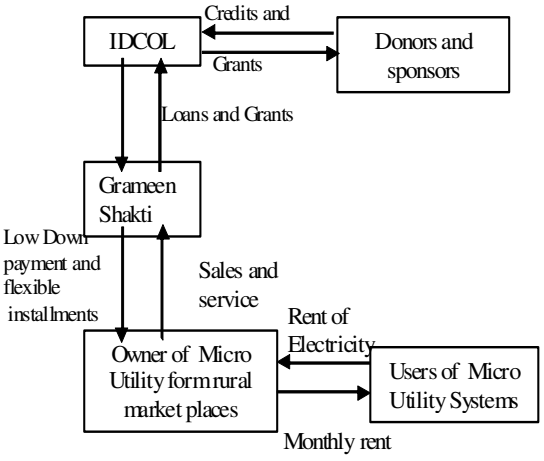

Figure 2: Operational and financial procedure

3.2 Cost of PV micro utility system

Under the Grameen Shakti micro utility program, 40 to 85 W_p systems are used as micro utility in the rural market places in Bangladesh. The cost of a 40 W_p system was 23,600 BDT, whereas for a 85 W_p system, the cost was 44,800 BDT.

Battery, PV panel and charge controller are the three main components of the PV system. GS also provides structure for panel and battery, lamps and ballast, switch, switch board and necessary wires during the installation period. But, the owner or user had to buy other equipments if they need, such as, adapter, DC-DC converter for radio, cassette and mobile charger, etc. The breakdown of total cost of a 50 W_p system is shown in table 1. Battery and solar panel were the main two reasons of the high cost of the PV system. Solar panel contributed to 28%, whereas battery cost was around 30% of the total cost though most of the batteries were produced in Bangladesh. The cost of charge controller was only 3% of total cost as GS was producing charge controller locally within the country. Three years after sale service and installation cost 13.50%, overhead cost 10%, cable, switches and others 7.50% and lamp shade 5% were the significant others costs.

Except these, tube lights and steel structure for panel contributed 2% and 1% of total cost respectively. This break down of cost was also similar for 40 and 60 W_p system as price variation was not much. On the other hand, percentage of battery and panel cost was little bit higher for 80 and 85 W_p system. It was found that for 80 and 85 W_p battery and panel cost were 33% and 30% of the total cost respectively.

Table 1: Break down of cost of PV MU in rural Bangladesh

Components	Price (%)
Battery	30%
Solar panel	28%
3 Years after sales service and installment collection	13.50%
Overhead cost	10%
Others (cable, switch etc)	7.50%
4 Lampshades	5%
Charge controller	3%
4 tube lights	2%
Structure	1%
Total	100%

3.3 Levilised cost of PV MU electricity

The total expense of a PV MU system in its entire life is calculated in terms of the levilised cost of PV MU electricity. The calculation was done for a 50 W_p system as most of the owners used 50 W_p system.

During field visit, it was found that many 07 years aged batteries were still operating. So, 02 batteries were assumed to be replaced during the entire 20 years project life. Salvage value of battery was considered (subtracted) from the new battery cost as it was around 23% of initial cost of the battery, and was given to the owner if the owner sells his old battery to GS.

The panel life is assumed to be 20 years [5,6,7,8]. Minimum life and average cost of CFL was assumed to be 02 years and 120 BDT (Source: Field visit, 2011). By considering no price escalation and zero salvage value of panel after 20 years, it is found that cost of PV MU electricity is around 70 BDT (~0.86 $)/kWh. Price escalation is assumed to be zero because increasing trend of battery cost can be levilised by decreasing trend of panel and charge controller. Costs are assumed at present market price. This calculation was done for worst case scenario. At, worst case, if 03 batteries are needed are replaced then the electricity cost of PV MU is 80 BDT (~.96$) /kWh. Chaurey and Kandpa calculated the cost of PV electricity for SHS and micro grid in India was 38.80 and 38.76 Rs/kWh respectively [6]. In China, it was 0.67-0.73 USD/kWh [9].Besides, 50 W_p system allows 04 CFL and owner of the system has to maintain one if he rents other three. It is also seen that the owner of the system has to expend only 7.47 BDT/day according to the actual scenario and even in worst case this cost is 8.58 BDT/day.

A PV MU owner can earn at least 30-40 BDT/day by renting three lights and saving from kerosene. The earning can be 130 BDT-200 BDT/ day or more if owner start any new business activity. Increase of equipment cost is not considered for this calculation because increasing trend of kerosene and diesel cost can also increase the saving of owner.

The cost of PV MU in Bangladesh can be reduced by producing all the equipments within the country. During field visit, it was found that there was lack of quality PV accessories in the market. Bangladesh government should help to produce Si and solar panels within the country. Though the panel cost is reducing in the international market, the panel price depends on dollar exchange rate- it is increased to 80 BDT from 70 BDT within the last two years (2009-2011). The government also should think about policy and direct subsidy for solar PV electricity production to popularize the PV MU.

3.4 Payback period, NPV and IRR

Payback period, NPV and IRR of the monitored PV MU systems were calculated and presented in table 2. Payback of PV MU varied mainly because of income from renting electricity, saving from kerosene, extra business activity by the owner after installing the PV system and amount of profit increase after installing the PV systems. For this analysis, extra business activity and amount of profit increase after installing the PV MU system are not considered as these variables were very much unstable, difficult to estimate and depend on many factors. Environmental benefit also not considered for this analysis as the owner of the system cannot claim environmental benefit according to the contract.

Table 2: Simple Payback, NPV and IRR of PV MU systems

Parameter	Systems W_p			
	40	50	60-65	80-85
Simple Payback period (year)	6.28	5.70	5.30	4.20
NPV (8.6%) NPV (14.9%)	40,919 24,528	58,358 35,145	77,412 47,020	136,302 84,943
IRR (%)	95	107	127	213

Simple payback is an indicator that shows the time frame of the return of an investment. On the other hand, NPV is calculated by bringing all the cost and revenue to the year zero with the average deposit and lending interest (8.6% and 14.9%) of last five years [10]. Sample calculation for simple payback, NPV and IRR are shown as appendix-A. IRR is the discount rate that makes present value zero. For a project, shorter payback period and higher NPV and IRR are desirable to risk free investment.

Results show that PV MU systems operating at rural market places of Bangladesh provide reasonable payback, higher positive NPV and good IRR. Higher W_p system shows lower payback period and more positive NPV and IRR. Because, most of the 80-85 W_p system owner had multiple business in the market and so they used mantle lamp hazzak before installing PV MU that consumes at least half a liter kerosene per day for 04 hours. Income from rent was also higher for higher W_p systems. The projects will be much more attractive if owners do some extra business activity. During field visit, very few owners were found to do extra business like mobile charging business or mobile phone booth. Both government and PV installer should train users about the new business opportunity as well as maintenance training.

Financial evaluation of SHS in Bangladesh was done by Mondal 2010. According to his study, payback period varied 2 to 6.34 years and NPV varied -8422 BDT to 162,181 BDT with a discount rate of 12% [7]. Higher (positive) value of NPV and IRR are found in this study because of the increase of kerosene price as compared to Mondal's 2010 study.

4. CONCLUSION

The following conclusions can be made based on financial analysis:

i) Cost of PV MU systems varied from 23,600 BDT to 44,800 for a capacity from 40 to 80 W_p systems. Solar panel and battery were the two main components for the high cost. Battery comprises 30% of total cost whereas panel cost was 28% of total cost.

ii) Cost of electricity of PV MU systems were around 70.50 BDT (~0.86 USD)/kWh. Owner of the PV MU system has to expend only around 8 BDT/day but he can earn 30-40 BDT/day by renting three lights and saving from kerosene. Earning can be 130 BDT-200 BDT/ day or more if owner start any new business activity.

iii) PV MU systems are financially attractive too. Simple payback period of PV MU varied from 4.30 years to 06 years, and NPV varied 27,404 BDT to 88,408 BDT with a discount rate of 14.9%.

iv) Users of this kind are glad to pay 5-10 BDT/day/CFL as they are getting good quality non interruptible light at a cost lower than that for kerosene.

v) Bangladesh government should think about the local production of all the accessories within the country to control the cost. As of now 10,000 PV MU systems have been installed in the country without any direct subsidy from the government. To popularize PV MU systems, the government should promote policies on direct subsidy through the Rural Electrification Board.

ACKNOWLEDGEMENT

The author is indebted to Asian Development Bank-Japan (ADB-JSP), donor for providing full scholarship to do the study at AIT. Grateful acknowledgements are extended to the Grameen Shakti, Bangladesh for their extreme help and support during the author's internship and data collection in Bangladesh.

REFERENCE:

[1].Power Cell Bnagladesh , Present Power Situation, official website of Power Cell, 2011.Bangladesh. www.powercell.gov.bd

[2].Petrobangla, Official website of Bangladesh Oil, Gas and Mineral Corporation. 2012. www.petrobangla.org.bd

[3]. Mondal A.H., Economic viability of solar home systems: Case study of Bangladesh. *Renewable Energy* 35 (2010) 1125–1129

[4]. GS, Solar Home System Program, Grameen Shakti, Bangladesh 2011". www.gshakti.org

[5]. Chakrabarty S., Islam T., Financial viability and eco-efficiency of the solar home systems (SHS) in Bangladesh. *Energy* 36 (8), 2011, 4821-4827

[6]. Chaurey A. and Kandpal T.C., Assessment and evaluation of PV based decentralized rural electrification: An overview. *Renewable and Sustainable. Energy Reviews*14 (8), 2010, 2266–2278.

[7]. Mondal A.H., Economic viability of solar home systems: Case study of Bangladesh. *Renewable Energy,* 35(6), 2010, 1125–1129.

[8]. Reinders A.H.M.E., Pramusito, Sudradjat A., Dijk V.A.P. V., Mulyadi R. , Turkenburg W.C., Sukatani revisited: on the performance of nine-year-old solar home systems and street lighting systems in Indonesia. *Renewable and Sustainable. Energy Reviews,* 3(1), 1999, 1-47.

[9]. Byrne J, Shen B, Wallace W, The economics of sustainable energy for rural development: a study of renewable energy in rural China. *Energy Policy*. 26(1), 1998, 45–54.

[10] World Bank. Bangladesh: Bolstering Economic Growth to Reduce Poverty, 2011. http://www.worldbank.org.bd