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Financial Viability and Environmental Benefits of Solar Photovoltaic System in Rural Bangladesh

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Abstract - In Bangladesh major group of population (73% of total population) live in rural areas. Without changing their living status Millennium Development Goals (MDG) will not be achieved and to do so it is necessary to ensure the use of electricity in those areas. The concern of this paper is about the role of rural electrification with the help of Solar Photovoltaic (PV) System, in respect of its financial viability and environmental benefits. Relevant information has been collected from 4 households and 2 microenterprises that make use of Solar PV System in various purposes from a village and a rural market-place nearby the village of Sunamganj district in Bangladesh. Use of the Solar PV System, both in microenterprises and other income generating purposes, alongside regular household usage, indicate relatively higher level of financial viability in favor of this investment. However, substitution of the use of only little quantity of kerosene by a Solar PV System indicates relatively lower level of financial viability against the investment. In this paper the term 'financial viability' has been used to mean high levels of Net Present Value (NPV) and Internal Rate of Return (IRR) and low level of Pay Back Period (PBP).

Keywords : *financial viability, solar home system (SHS), microenterprise, net present value (NPV), internal rate of return (IRR), photovoltaic (PV) system.*

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Financial Viability and Environmental Benefits of Solar Photovoltaic System in Rural Bangladesh

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Keywords : financial viability, solar home system (SHS), microenterprise, net present value (NPV), internal rate of return (IRR), photovoltaic (PV) system.

I. Introduction

Electricity is essential for rural economic development as well to achieve the millennium development goals. Now about 1.6-2.0 billion people mostly in rural areas of developing countries have no access to electricity and further 2.0 billion are severely undersupplied. In Bangladesh about 94.9 million out of 162.22 millions (around 59%) living mostly in rural areas have no access to grid electricity. Per capita electricity consumption of Bangladesh is 136.94 KWh on the other hand world's per capita electricity consumption is 2574.4 KWh.

So, in terms of electricity consumption Bangladesh is one of the poorest countries of the world. However, the government of Bangladesh has a vision to provide electricity for all citizens by the year 2020.

At present, power development board (PDB) in Bangladesh generates around 3,500-4,000MW of electricity against the demand for 5,500-6,000MW every day. Renewable energy sources contribute less than 1.0 percent of the total electricity generation of Bangladesh. The government of Bangladesh has targeted to increase the contribution of the renewable energy sources to 5 percent by the year 2015 and 10 percent by the year 2020 of the total energy consumption. It has targeted to generate around 100 MW of electricity from solar power projects by the year 2013.

Bangladesh has good solar radiation resources, its average daily solar radiation ranges from 4 to 6.5 KWh/m2-day. Solar radiation levels reach maximum at March-April and falls minimum at December- January. Even during the monsoon season, due to the long day hours the daily solar radiation level remains close to the average level. Three major challenges are associated with the providing of grid connected electricity are the shortage of the production of conventional electricity, the remoteness of the rural area and the density of the population. So, small Solar Home System (SHS) has a great potentiality in Bangladesh especially for the off gridded area.

Solar Home Systems (SHSs) has brought lighting facilities and related utilities such as charging mobile phones, watching TV, using computers and internet connection to remote areas in Bangladesh, where people are far from grid electricity. Solar home system has brought significant improvements in the standard of livings of the people by reducing in-door air pollution as well as increase income generating opportunities for women.

In the environmental aspect, a study found that the total CO_2 emission would increase more than 10-fold during 2005-2035 in Bangladesh. Solar Home System (SHS) reduces CO_2 by displacing hydrocarbon-based lighting devices such as kerosene lamps and candles. According to Nieuwlaar and Alsema the use of PV system as a replacement for fossil fuel-based electricity has significant environmental benefits.

This paper would examine the financial viability of solar home systems in Bangladesh with and without environmental benefits in terms of Taka. Section 2 describes SHS and its payment system under NGO provision, section 3 discusses about objectives and

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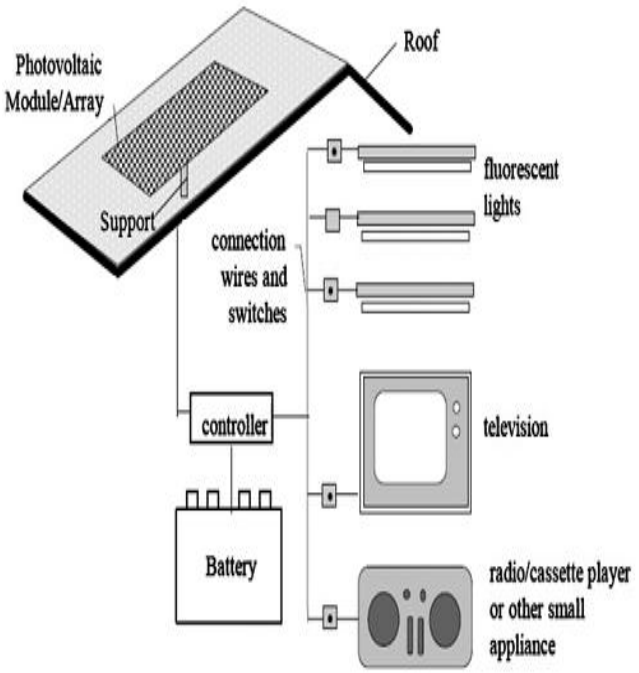
study area, section 4 explains the research methodology, section 5 presents the case studies, section 6 describes precisely all findings from the case studies and at last section 7 illustrates concluding remarks and policy recommendations.

II. Solar Home System (SHS)



Source : World Bank, Technical paper, 1997

Figure 1 : Typical Solar PV System

A typical SHS generally has a 20 to 130 Wp (Watt-peak) photovoltaic module used in this country, a battery charge controller, a rechargeable battery for energy storage and one or more lights (generally fluorescent), an outlet for a television (TV), radio/cassette player, mobile charger or other low power-consuming appliances, switches, interconnecting wires, and mounting hardware (support) just like as figure 01.

Both the panel size and the sunlight accessibility will determine the available amount of electricity produced by a SHS. The highest cost of a solar PV System is the Modules or panel cost and the 2nd highest cost is the battery cost. How long the panel lasts the system also lasts. Generally panel warranty is given for 20 years. So by changing battery (5 years warranty) and others component especially lights, a Solar PV system serves at least for 20 years.

a) Payment System of Solar Home System (SHS) Under NGO Provision

There are three approaches of payment systems are offered by Grameen Shakti (sister concern of Grameen Bank that provides solar photovoltaic system in rural Bangladesh). One can take a connection of solar panel by giving 25% of total cost as down payment and remaining 75% of total cost will be paid in 24 installments in 2 years with 4% flat service rate (Option-1). Another way of having a solar panel connection is given 15% of total cost as down payment and remaining 85% of total cost will be paid in 36 installments in 3 years with 6% flat service rate (Option-2). One can enjoy 4% reduction of total cost in case of cash payment (Option-3).

Monthly installment process is very helpful for rural poor households to have a SHS, for the smallest 20 W solar panel the installment rate is 345 Tk./month (36 installments) and down payment is 1170 Tk.

III. Objective and Study Area

a) Objective

The objectives of the study are to conduct a technical review of some existing solar panels in Sunamganj district. The main objective is to measure financial viability of solar panel system (with and without environmental benefits) in rural area and suggest some policy recommendations for the further dissemination of the system.

b) Study Area

One village named Jhamak and a market place nearby the village are selected for this study. The village is taken from the Chhatak Upazila near Jawar bazaar bus stoppage under the district of Sunamganj. Jawar bazaar bus stoppage is situated about 40 kilometers west from the district head quarter of Sylhet and almost 34 Km south-east from the district head quarter of Sunamganj. Jhamak is about 3 km away from the Jawar Bazaar bus stoppage. The case studies were collected from this village due to its location, number of user of solar home systems and for the socio economic condition of the villagers. Three organizations GS (Grameen Shakti), BRAC (Bangladesh Rural Advancement Committee) and RSF (Rural Service Foundation) provide solar panel in this region.

IV. Methodology

In this paper the information of six Solar PV Systems have been collected from a village named Jhamok; where 52 HHs use SHS among 120 HHs. Information has also been gathered from a market palace nearby the village under the district of Sunamganj.

Among the users (who were interviewed) one micro-enterprises and one HHs use solar lamps for income-generating activities beside daily household usage and the rest four HHs use SHS only for daily household activities.

Standard methods of financial analysis have been followed to analyze the data. Different financial indicators such as Net Present Value (NPV), Simple Pay Back Period (PBP) and Internal Rate of Return (IRR) with

and without considering environmental benefit have been calculated to determine the financial viability of Solar PV System in this paper for the selected cases.

a) Net Present Value (NPV)

NPV is defined as the difference of the present values (PVs) of the total cash inflows (benefits) and the cash outflows (costs). In the case when all future cash flows are incoming and the only outflow of cash is the purchase price, the NPV is simply the present value of future cash inflows minus the purchase price.

NPVs are calculated here at the discount rates of 6%, 9% and 12%, which symbolize typical bank interest rates. Thus we can compare the gains between buying a solar photovoltaic system for some amount of money and saving the same amount in a schedule bank.

b) NPV Calculation in Excel Sheet

- PV(RATE, NPER, PMT, FV,TYPE)

There are five parameters to the present value (PV) function. RATE is the interest rate per period (here year) NPER is the total number of periods, and FV is the future value. PMT (Payment of an annuity) and TYPE are included to handle annuities (a series of equal payments, equally spaced over time). For problems of the type that we are currently solving here, we will set both PMT and TYPE to 0 to find out the present value of 20 years cash flow separately.

- NPV (RATE, VALUE1, VALUE2 …)

Where RATE is per period rate of return (i.e., the discount rate), and VALUE1 is the first cash flow (or range of cash flows), VALUE2 is the second cash flow, and so on. Finally by subtracting cash out flow in initial period (period 0) from the NPV of 20 years one can find out net cash flow in 20 years.

c) Internal Rate of Return (IRR)

The internal rate of return (IRR) on an investment or potential investment is the annualized effective compounded return rate that can be earned on the invested capital. IRR is the discount rate of interest that makes net present value equal to zero. If the IRR becomes 10 percent suppose for buying a SHS with life time 20 years means that to buy a SHS brings enough revenue in 20 years to pay its cost and also grant a return of 10 percent on the invested capital. So, in this case borrowing the required capital at less than 10% and finance it for buying the SHS will be a profitable investment.

d) IRR Calculation in Excel Sheet

- IRR(VALUES,GUESS)

Here, where VALUES is a range of cash flows (including the cost), and GUESS is the optional first guess at the correct interest rate. If the result comes 16%, which means that owner of SHS will earn a compound annual rate of 16% from this investment.

e) Payback Period (PBP)

Payback period in capital budgeting refers to the period of time required for the return on an investment to "repay" the sum of the original investment. For example, a $2000 investment which returned $500 per year would have a four years payback period.

f) PBP in Excel Sheet

- Pay Back Period = I/(R-E)

Where, I= Net investment/Net cash flow at period 0.

R= Return/Average net inflow

E= Expenses/Average net outflow.

R-E= Average net cash flow/year

IRR shows us the actual gain (rate of return) of buying a solar PV system and PBP shows the returning period of the invested capital form the investment in a solar PV system. Here the financial analysis is hold for 20 years because the solar PV System serves at least for 20 years and also the warranty is given for the panel is 20 years.

g) Process of Environmental Benefit analysis:

Environmental benefit was calculated in terms of Taka by using the following information -

1 L Kerosene produces 3.15 Kg CO_2[1] and price of per ton CO_2 is 20 USD[3].

Here, 1ton CO_2 = 1000Kg CO_2 & 1 USD = 69Tk.Environmental benefit (in 20 yrs) for Kerosene= $\frac{\text{Monthly used kerosene} \times 12 \times 20 \times 3.15 \times 20 \times 69}{1000}$ Tk.

Here, in numerator -- Monthly used Kerosene (in liter) ×12 month ×20 years ×3.15 kg ×20 USD × 69 Tk.

And this numerator is divided by 1000kg to convert into ton (because price of per ton CO_2 is 20 USD) thus the environmental benefit is counted in terms of Taka.

h) And for Burning Candle

1 Candle produces 30g CO_2[2] and price of per ton CO_2 is 20 USD[3].

Here, 1ton CO_2 = 1000Kg CO_2; 1 USD = 69Tk. Environmental benefit (in 20 yrs) for Candle= $\frac{\text{Monthly used candles} \quad 12 \quad 20 \quad 30g \quad 20 \quad 69}{1000 \times 1000}$ Tk.

[1] 1 L kerosene emits 3.15 kg CO2 (See, for example, p 67athttp://www.dft.gov.uk/pgr/aviation/environmentalissues/ukairdemandandco2forecasts/airpassdemandfullreport.pdf).

[2] "Burning Candles" by Stubborn Mule on 27 March 2009.

[3] Mondal, M. A. H., 2010. Economic viability of solar home systems.

V. Case Studies

Case 1 : In this HH only 2 hurricanes (4L Kerosene / month) is replaced by a 2 lamps Solar panel (20W)

Table 1.1 : Basic Information of case 1

Name of panel Owner: Mosabbir Ali	**Name of the respondent:** Amena Begum
Age of HH head: 33 years	**House hold members:** 4
Education of the HH head : Class 5	**Occupation**: Service at abroad
Purpose: Lighting and Charging mobile	**Add**: Jhamok, Chhatak, Sunamganj.
Panel Size & Battery capacity: 20W & 30AH	**Offers**: Provide 2 lamps and a charge connection for mobile
Installed by: GS	**Installation Date**: Feb. 2010
Amount of first payment: 2205 Tk.	**Purchasing pattern:** 15% down payment & 85% in 36 installments.
Monthly amount of installment: 345Tk	**Increased Income:** 0Tk./month
Monthly Previous income: 5000 Tk/ month	**Monthly new income**: 5000 Tk/ month.
No. of mobile (Before installation): 1	**No. of mobile (After installation)** : 1
No. of TV(Before installation): 0	**No. of TV (After installation):** 0

Source : Author

This house hold (HH) just replaced 2 hurricanes by 2 lamps of the smallest 20W solar panel. So, only 4 Liter kerosene saved after the panel installation. Before solar panel installation the HH charged mobile in neighbor's home free of any cost. Thus this HH saves only kerosene cost by the installation of solar home system (SHS).

The findings of the financial analysis (of 20 years) are as follows:

Table 1.2 : Output of Financial Analysis for Case 1

Indicators	Values
Simple Payback Periods(years)	19.27 years
Simple payback period without Environmental benefit (yr)	27.36 years
NPV (6%)	3047.19881Tk
NPV (9%)	57.9443303Tk
NPV (12%)	-2056.7738Tk
IRR (%)	9

Source : Author

So, in this case PBP shows very high and NPVs remains positive till 9% interest rate. So, at 9% bank interest rate, this money (13600 Tk.) becomes indifferent to keep in a bank or to invest for buying a panel. But if we compare the light quality of SHS with hurricane and other daily life comfortableness such as charging mobile at home then it should be more viable and profitable to buy a solar home system.

Case 2 : Two Hurricanes and a wick replaced by a 40W panel and saved 75Tk. for charging mobile & 5 L kerosene cost/month

Table 2.1 : Basic Information of case 2

Name of panel Owner: Ashik Mia	**Age of HH head**: 32 years
Education: Class 6	**Occupation**: Service at middle east
House hold members: 5	**Add:** Jhamok, Chhatak, Sunamganj.
Panel Size & Battery capacity:40W & 60AH	**Offers**: 3 lights, connection for charging mobile and TV.
Installed by: GS	**Installation Date**: Sep. 2008
Amount of first payment: 5000 Tk.	**Purchasing pattern:** 15% down payment & 85% in 36 installments.
Monthly amount of installment: 600Tk	**Increased Income:** 0Tk./month
Monthly Previous income: 7000Tk	**Monthly new income**: 7000Tk.
No. of mobile (Before installation): 1	**No. of mobile (After installation)** : 1
No. of TV(Before installation): 0	**No. of TV (After installation):** 0

Source : Author

This HH replaced 2 Hurricanes and 1 wick by a 40W solar panel. The HH saves 5L kerosene and 75Tk. charging cost for mobile per month by the help of SHS.

Financial analysis of solar panel for this HH is as follows (considering 20 years cash flows):

Table 2.2 : output of financial analysis for case 2

Indicators	Values
Simple Payback Periods(years)	22.77 years
Simple payback period without Environmental benefit (yr)	30 years
NPV (6%)	3066.97 Tk
NPV (9%)	-1956.59 Tk
NPV (12%)	-5510.19 Tk
IRR (%)	8

Source : Author

This HH replaced little amount of kerosene and a minimum charging cost for mobile by a comparatively larger size solar panel (40W). And also has no impact on income level from the panel installation. On the other hand this HH never has any expenditure for enjoying TV. For these reasons NPV comes negative at 9% and 12% interest rate, IRR is 8% and payback period shows very high (more than 20 years). In spite of under use of the panel the investment still shows positive NPV at 6% interest rate. If we consider the environmental benefit, comfortableness under brighter light, safety and future chance of enjoying a black and white TV, the viability in favor of this investment goes up.

Case 3 : HH's Panel capacity is 75 W and provides 6 lamps, a TV connection & a charging facility for mobile. Thus simultaneously saves cost for lighting, entertainment and charging mobile

Table 3.1 : Basic information of case 3

Name of panel Owner: Rahamat Ali	**Name of the respondent**: Mrs. Rahamat Ali
Age of HH head: 35 years	**Occupation**: Earning from abroad.
Education: class 5	**Add.**: Jhamok, Chhatak, Sunamganj
House hold members: 7	**Offers**: 6 tube lights, Connection for mobile & TV.
Panel Size & Battery capacity: 75W & 100AH	**Installation Date**: may,2003
Installed by: RSF	**Purchasing pattern:** Cash payment
Cash price of the panel: 36000	**Purpose:** lighting in home, Charging mobile & watching TV.
Monthly Previous income: 55000Tk.	**Monthly new income**: 55000Tk.
No. of mobile (Before installation): 1	**No. of mobile (After installation)** : 2
No. of TV(Before installation): 1	**No. of TV (After installation):** 1

Source : Author

This HH replaced 2 hurricanes and 1 wick, a TV battery and charging cost for mobile by 75W solar panel. The HH also saved 7.5 L kerosene cost/month by 5 solar tube lights. These all are the components of cash inflows and the cash outflows are the purchasing price and maintenance cost of the solar home system.The financial analysis of SHS for this HH is as follows:

Table 3.2 : Output of 20 years financial analysis for case 3

Indicators	Values
Simple Payback Periods(years)	9.67 years
Simple payback period without Environmental benefit (yr)	10.85 years
NPV (6%)	28304.3602
NPV (9%)	16364.895
NPV (12%)	7918.9903
IRR (%)	16

Source : Author

The HH bought SHS in cash payment of 36000 Tk. in 2003. They bought a comparatively larger panel considering the number of their family members. The household does not involve any income generating activities by using solar lamps. After all the results show that the investment decision was financially feasible because NPV come positive at all three interest rates.

Case 4 : This HH Shares only one lamp of three lamps and bears ⅓ cost of the 40w solar panel. By placing the only tube middle of the two rooms saves considerable amount of kerosene. (Save only kerosene).

Table 4.1 : Basic Information of case 4

Name of panel Owner: Shekh kalam Ali	**Age**: 45 years
Education: illiterate	**Occupation**: Agriculture.
House hold members: 5	**Add.**: Jhamok, Chhatak, Sunamganj.
Panel Size & Battery capacity: 40W,60AH	**Offers**: 1 tube light.(⅓ share of 40W panel)
Installed by: GS	**Installation Date**: August. 2008
Amount of first payment: 1700 Tk.	**Purchasing pattern:** 15% down payment & 85% in 36 installments.
Monthly amount of installment: 200Tk	**Purpose:** lighting, Charging mobile.
Monthly Previous income: 3000Tk.	**Monthly new income**: 3000Tk.
No. of mobile (Before installation): 0	**No. of mobile (After installation)** : 1
No. of TV(Before installation): 0	**No. of TV (After installation):** 0

Source : Author

Mr. Ali just uses one light and bears ⅓ cost of a 40W panel. Before installation of solar panel his family used 1 hurricane and 1 wick. He meets up this necessity by setting the only solar tube in the middle of his two rooms. Thus he replaced 7 liters kerosene (per month) only by a tube light. So, his cash inflow rises dramatically and cash outflow remains smaller.

The findings of the financial analysis are as follows:

Table 4.2 : Output of 20 years financial analysis for case 4

Indicators	Values
Simple Payback Periods(years)	2.31 years
Simple payback period without Environmental benefit (yr)	2.59 years
NPV (6%)	36788.55Tk.
NPV (9%)	27832.6Tk.
NPV (12%)	21488.83Tk.
IRR (%)	52

Source : Author

Here PBP remains around two and half years. And also NPVs and IRR come high. His monthly installment is 230 Tk. And his Monthly kerosene cost was 360 Tk. (price of 7 Liters Kerosene). The financial analysis becomes financially viable for Mr. Ali mainly because he uses ⅓ capacity and shares ⅓ cost of a 40 W Panel with his neighbor.

Case 5 : 20w panel is used by a mobile servicing shop. Before the dissemination of solar panel a car battery was used to charge mobile in business purpose

Table 5.1 : Basic Information of case 5

Name of panel Owner: Sujon Mia	**Age**: 30
Education: class 8	**Occupation**: Mainly mobile technician
Shop pattern: Mobile servicing	**Add.**: Jhamok, Chhatak, Sunamganj.
Panel Size & Battery capacity: 20W & 30AH	**Offers**: 2 CFLs and a connection for charging mobile.
Installed by: BRAC	**Installation Date**: May,2009.
Amount of first payment: 2205 Tk.	**Purchasing pattern:** 15% down payment & 85% in 36 installments.
Monthly amount of installment: 345Tk.	**Purpose:** Lighting for shop, Charging mobile.
Monthly Previous income: 4000Tk.	**Monthly new income**: 4000Tk.
Extended duration of business: 0 hr/day	**Increased Income:** 00Tk./month
No. of mobile (Before installation): 1	**No. of mobile (After installation)** : 1

Source : Author

Before solar panel installation Mr. Sujon burned two candles daily in his shop. He also used a big car battery (7500 Tk.) to charge mobile in business purposes. This was a monopoly business before the solar panel dissemination. He earned almost 2400 Tk. per month from charging mobile at the rate of 5 Tk per

hour charging and every day charged 16-18 mobiles. After dissemination of solar panel his income from this sector almost becomes zero but income from mobile servicing as a technician rises as the number of mobile user rises rapidly. Under the brighter light he also introduces shoe business in a small scale. So, his monthly income remains unchanged approximately equal to 4000Tk. Now he replaced candle cost (10Tk. /day), battery cost (7500 Tk/3years) and charging cost of the battery (320Tk. /month) by 20w solar panel.

The financial analysis for him becomes as follows:

Table 5.2 : Output of 20 years financial analysis for case 5

Indicators	Values
Simple Payback Periods(years)	0.80 years
Simple payback period without Environmental benefit (yr)	0.81years
NPV (6%)	87786.5Tk.
NPV (9%)	68265.8Tk.
NPV (12%)	54472.62Tk.
IRR (%)	119

Source : Author

His monthly cost was 620 Tk. (300 for candle and 320 for charging battery) for the lighting & battery charging purposes. Now it becomes zero. And monthly installment rate for 3 years is 333Tk for SHS. Thus he saves 287 Tk. per month even in the installment period after 3 years he will save almost 620 Tk. per month.

Under these circumstances, though his income remains unchanged his NPVs and IRR come very high and payback period (PBP) remains less than 1 year in the analysis of 20 years cash flows.

Case 6 : Husband & wife of this HH run a grocery shop at their home. And besides the saving of kerosene, HH income rises significantly

Table 6.1 : Basic Information of case 06

Name of panel Owner: Shah Alam	**Age of HH head**: 35 years
Education: class 1	**Occupation**: Grocery shop
House hold members: 7	**Add.**: Jhamok, Chhatak, Sunamganj
Panel Size & Battery capacity: 50W & 80AH	**Offers**: 4 tube lights, Connection for mobile & TV .
Installed by: GS	**Installation Date**: Dec.2007
Amount of first payment: 6260 Tk.	**Purchasing pattern:** 15% down payment & 85% in 36 installments.
Monthly amount of installment: 747Tk	**Purpose:** lighting in home & shop, Charging mobile.
Monthly Previous income: 5500Tk.	**Monthly new income**: 7500-8000Tk.
Number of increased daily customer: 30	**Amount of increased income**: 2400 Tk/month
No. of mobile (Before installation): 0	**No. of mobile (After installation)** : 1
No. of TV(Before installation): 0	**No. of TV (After installation):** 0

Source : Author

Before installation 50W panel Shah Alam's family used 2 hurricanes and 2 wicks by burning 15 liter kerosene per month for lighting their grocery shop and home. Now this necessity is replaced by the solar panel.

On the other hand the HH's income rises by 2400Tk. /month for the extension of business hours (from 10 pm to 12 pm). After 10 pm Mr. Alam uses dim light as business purposes. This ensures his battery's long life time.

Financial analysis for Solar panel of this HH is as follows (considering 20 years cash flow):

Table 6.2 : Output of 20 years financial analysis for case 6

Indicators	Values
Simple Payback Periods(years)	0.913 years
Simple payback period without Environmental benefit (yr)	0.935 years
NPV (6%)	380293.4 Tk.
NPV (9%)	297179.5 Tk.
NPV (12%)	238296.2 Tk.
IRR (%)	121

Source : Author

NPVs, IRR are very high and PBP is less than 1 year because this HH extended their business hours by the help of solar lamps (CFL & Dim lights) at night thus their income increases by 2400 Tk. per month. Also they replaced considerable amount of kerosene by the solar lamps. Thus the investment becomes financially incredibly viable.

VI. Description of the Finding from the Case Studies

- Case Studies at a Glance

Table 7.1 : Summary of the 20 years financial analysis (with environmental benefit) for all case studies

Indicator	Case 01	Case 02	Case 03	Case 04	Case 05	Case 06
Simple payback period	19.27 years	22.77 years	9.67 years	2.31 years	0.80 years	0.91 years
NPV (6%) in Tk.	3047.2	3066.97	28304.36	36788.55	87786.5	380293.4
NPV (9%) in Tk.	57.94	-1956.59	16364.90	27832.6	68265.8	297179.5
NPV (12%) in Tk.	-2056.77	-5510.19	7918.99	21488.83	54472.62	238296.2
IRR	9%	8%	16%	52%	119%	121%
Environmental Benefit in Tk.	4173	5216	7825	7303	596	15650

Source : Author

Table 7.2 : Summary of the 20 years financial analysis (without environmental benefit)

Indicator	Case 01	Case 02	Case 03	Case 04	Case 05	Case 06
Simple payback period	27.36 years	30 years	10.85 years	2.59 years	.81years	0.94 years
NPV (6%) in Tk.	653.93	593.92	23816.98	32600.31	87444.61	371318.6
NPV (9%) in Tk.	-1846.78	-3918.79	12793.53	24499.31	67993.70	290036.8
NPV (12%) in Tk.	-3615.32	-7118.26	4996.72	18761.36	54249.97	232451.7
IRR	7%	6%	15%	47%	119%	119%

Source : Author

a) Net Present Values (NPVs)

According to the Table 7.1 and 7.2 all NPVs at 6% interest rate show positive values. So, for all cases to buy a solar home system for 20 years is financially viable at 6% interest rate. Case 1 and 2 use SHS system only for lighting purposes thus for these two cases NPV becomes negative at 9% and 12% interest rates. Case 3 uses SHS for lighting as well as for entertaining TV by substituting car battery with solar energy. For this case NPVs remain positive at all three interest rates. In case of share consumption (case 4) also represents higher level of NPVs. Microenterprises and HH that uses solar home system for income generating activities bears highest level of NPVs (cases 5 and 6).

From the above studies it is clear that who use solar energy for business and income generating purposes and who can purchase SHS by sharing reveals relatively higher level of NPVs than who use SHS only for lighting purposes.

b) Internal Rate of Return (IRR)

IRR and NPV are positively related. Table 7.1 and 7.2 shows case 5 and 6 (microenterprises) have the highest level of NPVs as well as IRR and cases 1, 2 and 3 have relatively lower level of IRR due to the use of SHS only for daily HH activities. Case 4 shows comparatively higher level of IRR due to share consumption (shares only one 1 lamp of 3 lamps solar panel with his neighbor) thus reveals more financial viability in terms of IRR.

c) Pay Back Period (PBP)

PBP has negative relationship with NPV and IRR. Higher level of NPV and IRR mean lower level of PBP. From Table 7.1 and 7.2 we find that 3 cases have PBP less than 5 years and 3 cases have PBP more than 5 years. In case of share consumption and using SHS in microenterprises (cases 4, 5, & 6) indicates lower level of PBP on the other hand using SHS only for HH daily activities (cases 1, 2 & 3) indicates higher level of PBP.

d) Environmental Benefit

Environmental benefit is calculated by considering only the amount of kerosene and candles used before the panel installation. The higher amount of replacement of kerosene and candles with Solar PV system means higher level of environmental benefit. The information of burning 1 liter kerosene produces 3.15 kg CO_2, 1 candle produce 30g CO_2 and 1 ton CO_2 equal to 20 USD are used to calculate environmental benefit of 20 years.

Case 6 shows highest level of environmental benefits because this HH substitute huge amount of kerosene (15 liters of kerosene per month) by SHS that were used for HH lighting and running grocery shop from the evening to mid night.

The other microenterprise (mobile servicing center, case 5) demonstrates less amount of environmental benefit in terms of Taka due to substitution of candles (60 candles per month) with

solar lamp as burning candle produce less CO_2 than burning kerosene.

Environmental benefits for the other cases (1, 2, 3 & 4) measure from the kerosene that the HHs used for lighting purposes before solar lamps installation in terms of Taka.

VII. Conclusion & Policy Recommendations

From environmental point of view, Solar PV System generates and supplies with one of the cleanest forms of electrical energy, eliminating the process any type of CO_2 emissions that pose a great threat to our atmosphere. Especially when Kerosene or other types of crude oil burns to produce light or energy, significant emission of Green House gases occurs in the process. Therefore, Solar PV System is one of the new forms of Green Energy that has a far-going positive effect in environmental sustainability.

However, as far as this paper concerns, from financial point of view, in rural areas Microenterprises (MEs) and Households (HHs) who use Solar lamps in income generating activities beside daily HH usage stand out for relatively higher levels of NPV, IRR and lower level of PBP. Again, sharing one Solar PV System by two HHs or MEs is financially more viable. Yet, sharing one Solar PV System is not recognized officially by the service providers. Monthly installments are collected only from one authorized person. Therefore, owing to some management problems sharing of SHS has not yet been possible in large scale in the rural areas.

Nevertheless, the micro-installment system, adopted by the solar service providers, designed especially for rural areas has opened a window of opportunity for the Rural Electrification program to succeed, paving a way for the greater success of the Millennium Development Goals (MDG). Still, for the electrification program to reach out even to the poorest people in rural areas the following action plans can be recommended:

- Govt. should provide some sort of subsidy may be equal to the environmental benefits (calculated in terms of Taka in this study) that received our society from SHS for 20 years.
- Government should reduce the amount of subsidy given to the different stage of production and supply of grid electricity.
- The Solar PV System service providers should make arrangement to sell a single PV panel jointly in the name of more than one users and collect due payments separately from each of them then the number of Solar PV users would rise and the system can be expanded even to the root level.

In future the financial viability of mass installment of SHS in grid connected urban areas may be considered as research agenda.

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