Performance Analysis of BRAC Solar Energy Program

An Independent Study

Submitted to the Department of Computer Science and Engineering

Of

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By

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DECLARATION

I hereby declare that this report is based on the results established by us. Materials of work found by other researchers are mentioned in the reference. This study, neither in whole nor in part, has been previously submitted for any degree.

Signature of Supervisor

Signature of Authors

ACKNOWLEDGMENTS

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ABSTRACT

Bangladesh is a country, where the people in the remote rural areas have to rely on fuel basically kerosene based lighting to bring minimal lighting services in their homes. The replacement of fuel based lighting can be done in a sustainable way by using the existing and environmentally friendly renewable energy sources like solar PV technology. This sustainable way of lighting many villages in Bangladesh is expected to improve the general living standard of the communities, contributing significantly to health, education. To provide electricity in the rural areas BRAC Solar Energy Program is initiated under BRAC foundation in 1998. In this study I emphasized on the performance of BRAC Solar Energy Program.

TABLE OF CONTENTS

Page

CHAPTER I. INTRODUCTION

CHAPTER II. OVERVIEW ON BRAC SOLAR ENERGY PROGMAR.

CHAPTER III. SOLAR HOME SYSTEM IB BANGLADESH.

CHAPTER IV. STUDY AREA : KAPASIA GAZIPUR

LIST OF FIGURES:

LIST OF TABLES

CHAPTER I

Introduction

1.1 Background

There is an immense potential for the use of solar PV technology in Bangladesh. Photovoltaic is a proven viable option in remote areas. There is a lot of research work done in this field [9][10][11][12][15] Bangladesh is a developing country with a population of 135 million in an area of only 147,570 sq. km. About 85% of the population lives in rural areas. Per capita energy consumption in Bangladesh is one of the lowest in the world [17][18][19].

Bangladesh is continuing its efforts for harnessing its solar power for reaching electricity in its hilly areas and islands where supply of traditional electricity will not be possible in foreseeable future. Although there are good prospects for solar PV system in Bangladesh, potential market development has rather been limited. The Govt., Private sectors and NGOs are taking increasing initiative towards development of the solar energy utilization.

BRAC has started their Solar Energy Program in 1998. This independent study was designed to understand the progress of BRAC solar Energy program towards rural electrification through Solar Energy. Our aim was to analyze the social impact of SHS in rural areas and at the same time to contribute technically to improve the performance of the SHS. In chapter II I discuss the overview of BRAC Solar Energy Program in detail. In chapter III I talk about the components of solar home system in detail. I discuss the field visit at Kapasia Gazipur in chapter IV, here I talk about the social impact, system performance, problems regarding the SHS components in the study area. In chapter V, I suggest some practical steps that can be taken in order to improve the system.

CHAPTER II

2.1: About BRAC:

BRAC is a national private development organization, set up in 1972 by MR. Fazle Hasan Abed. After liberation war of 1971 he began BRAC as a relief organization focused on the resettling the refugees returning from India. This take over BRAC redirected its focus to the issue of property alleviation and empowerment of the poor people in rural areas of Bangladesh. In the year of 1998 the BRAC foundation has started its journey towards rural electrification through Solar system under its Rural Enterprise project (REP). BRAC launched a pilot program with Infrastructure Development Company Limited (IDCOL) a government owned and World Bank financed company. After the successful completion of the first phase, BRAC contracted an agreement with IDCOL as phase II for five years for installing 20,000 Solar Home System within 2007.

2.2: Infrastructure Development Company Limited (IDCOL):

The IDCOL's Solar Programme[2] has the mission of fulfilling basic electricity requirements in the rural areas of Bangladesh and hence, supplementing the government's vision of electrifying the whole of Bangladesh by the year 2020.

In addition to refinancing, IDCOL also provide grants to lower costs of SHS and build institutional capacity of the Partner Organizations (POs'). IDCOL's principal objective is the commercialization of SHS. Therefore, IDCOL has adopted a policy of reducing grant with the progress of the project.

Table 2.1: Phased reduction of the grants

Item	Amount of Grant Available per SHS/household		
	Total	Buy-down grant	Institutional Development Grant
The World Bank funds			
First 20,000 systems	$90	$70	$20
Next 20,000 systems	$70	$55	$15
Next 30,000 systems	$50	$40	$10
GTZ funds			
33,660 systems	€38	€30	€8
KfW funds			
First 30,000 systems	€38	€30	€8
Next 35,000 systems	€36	€30	€6
Next 35,000 systems	€34	€30	€4

(Source: IDCOL's Solar Energy Program)

So far sixteen POs namely: Grameen Shakti, BRAC Foundation, COAST Trust, TMSS, SRIZONY Bangladesh, CMES, IDF, Shubashati, UBOMUS, DORP, BRIDGE, PMUK, Hilful Fuzul, RSF, PDBF and Mukti have signed Participation Agreements (PA) with IDCOL to participate in the solar program. Operational flow diagram of IDCOL's Solar Home Systems Project is shown below.

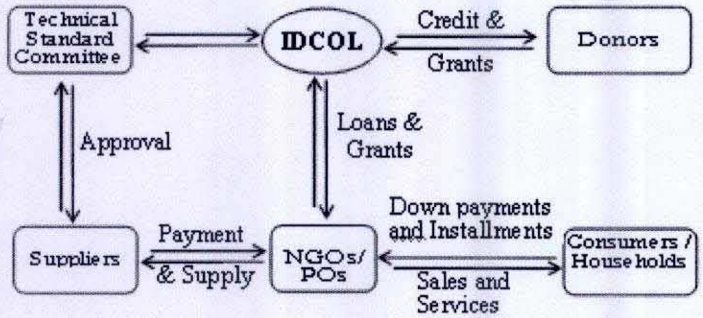


Figure 2.1: Operational flow diagram of IDCOL's Solar Home Systems Project. [3]

Up to July, 2009 the number of installed SHS units by partner organizations (PO) are given in table 2.2[1]. Grameen Shakti is the largest PO by number of SHS installed and BRAC foundation is the second height.

Table 2.2: PO wise installed SHS units under IDCOL's RREDP till July, 2009.[3]

Participating Organization	Number of installed SHS
Grameen Shakti	209,928
BRAC foundation	48,974
RSF	32,138
Srizony Bangladesh	9,194
UBOMUS	6,956
BRIDGE	5,183
COAST trust	3,076
IDF	3,405
CMES	2,762
Shubashati	2,471
HSFKS	5,441
TMSS	1,724
PDBF	1,873
PMUK	578
Others	388
Total	334,091

2.3: BARC Solar Energy Program:

BRAC Solar Energy Program for Sustainable Development was launched in December 1998. An integrated and multipurpose program, its projects spread across the country in a wide variety of settings including households, BRAC and other NGO offices, training centers, schools, health clinics, cyclone shelters, a weather monitoring station, a government rest house and income generating centers such as carpentry, tailoring shops, cloth dyeing and printing shops, leather workshops, restaurants and grocery shops. stand- alone PV systems and wind turbines for solar electricity, Hot Box cookers and biogas plants have been installed in various regions throughout the country. In addition, the program has also installed 2 PV- utility interactive systems and 6 PV-wind turbine hybrid systems pioneering in Bangladesh. Projects with solar thermal micro-hydroelectric generators, biogas electricity and are soon be implemented.

With support from IDCOL/WB/GEF/GTZ/Kfw BRAC Foundation installed capacity **36,631 Solar Home System (May 18, 2008)** Stand alone Solar Home System to provide electricity in rural off-grid areas.

2.3.1: Objective of BRAC Solar Energy Program:

- To change the living and social statues of the rural people.
- To conservation of environment
- Self-dependence
- To meet the demand of the electricity in rural and off grid areas.
- To increase the working hours as well as education hours.
- To change the economy of the society by pursuing modern approach through TV, radio etc.
- To develop awareness about photovoltaic (PV) cell.

Table 2.3: BRAC solar energy program at a glance:

Particulars	Cumulative
No. of region covered	55
No. of area covered	260
No. of PO working	345
No. of sales promotion officer	29
Sales	49000

As BRAC Foundation is already in market ang gained experience, a tentative salse targer is shown in below year-wise from January 2110 to December 2012.

Table 2.4: Proposed tentative sales (month wise) [4]

Month	Year 2010	Year 2011	Year 2012
January	800	1000	1150
February	800	1000	1200
March	800	1000	1200
April	850	1000	1200
May	850	1000	1200
June	850	1100	1200
July	900	1100	1200
Auguat	900	1100	1200
September	950	1100	1250
October	950	1100	1250
November	950	1150	1250
December	1000	1150	1250
Total	10600	12800	14600

As BRAC believes that this project will change the overall socio-economic status of rural people of the project areas by creating new jobs, increasing the education hour and by income generation activities.

CHAPTER III

3.1: Solar Radiation:

Solar radiation is the source of various renewable energies. The solar radiation is 5.4 million Ej/year. 30% of the solar radiation is short wave radiation this portion is directly reflected to space. 47% that is 2.55 million Ej/yr is directly converted to heat in air, earth and ocean. 1260 Ej/yr is used for photosynthesis and approximately 1% for wind, wave convection and current. For 3.1 shows the distribution of solar radiation on earth.

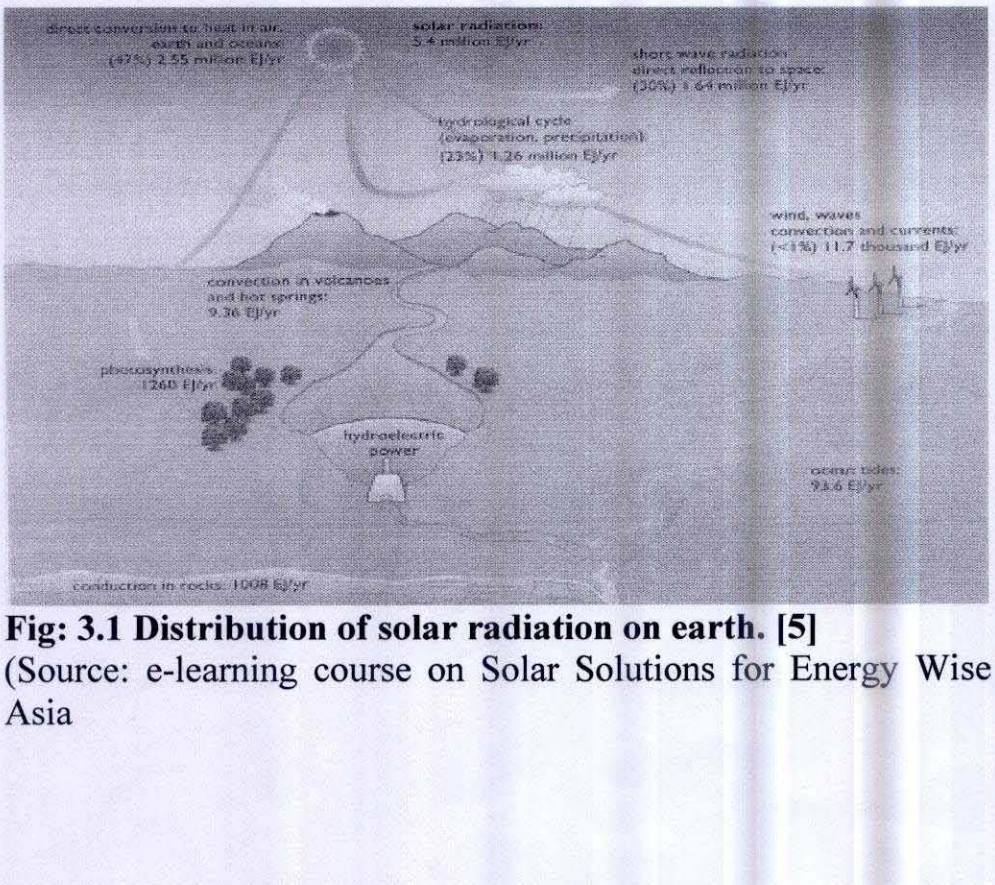


Fig: 3.1 Distribution of solar radiation on earth. [5]
(Source: e-learning course on Solar Solutions for Energy Wise Communities in Asia

3.1.1: Different Collection Process of Solar Radiation as Proposed by Calvin:

Direct conversion of sunlight to electricity is perhaps the neatest and most aesthetically pleasing of all schemes for the exploitation of solar energy. Different collection process of solar radiation [6]is shown is fig 3.2.

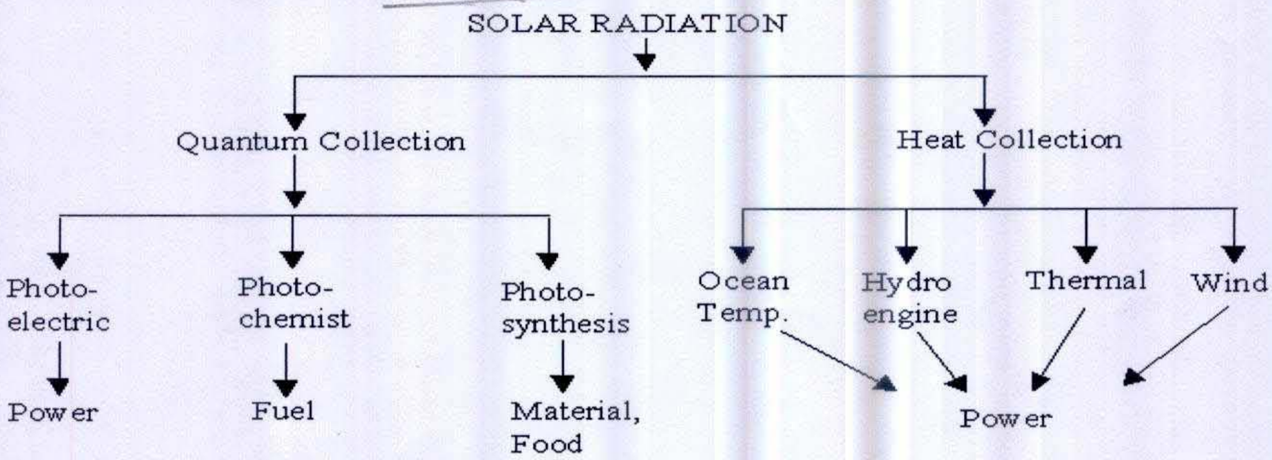


Fig 3.2: Types of solar radiation.

(Source: Prospects of solar PV system in Bangladesh, solar PV system in Bangladesh.)

3.1.2: Solar energy in Bangladesh:

According to recent studies, yearly average insolation availability in Dhaka is 1.73MWh per square meter on a horizontal surface and 1.86MWh per square meter on a tilted surface. Bangladesh with an area of 147,570 sq. km. receives annually from the sun about 900 * 10^18 joules of energy i.e. the availability per sq. meter is 193 W, whereas the consumption per sq. meter is only 0.17 W. This shows what abundance Solar radiations is hitting the places around us. What fraction of it we can hold for our use will depend on the availability of the technologies suited to local conditions. Figure 3.3 shows the solar radiation map in Bangladesh.

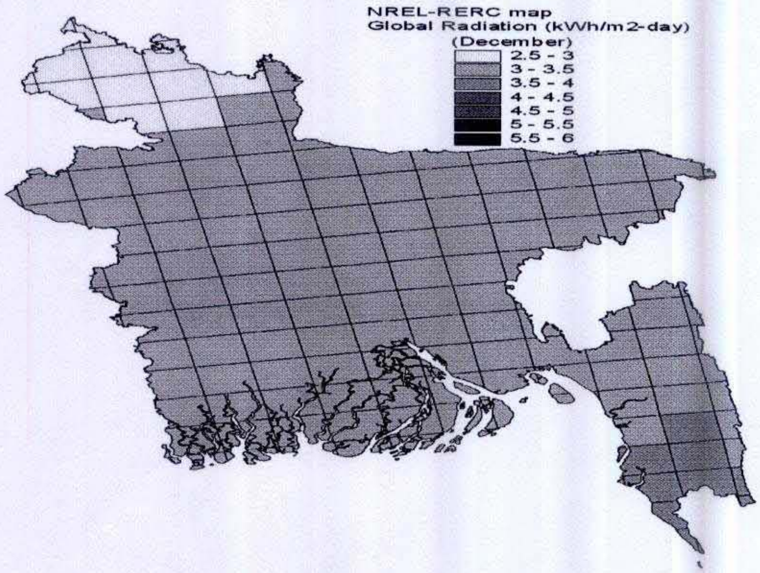


Fig: 3.3 Solar Radiation Map in Bangladesh. [5]

Monthly averaged hourly GHI* (Wh/m2), 2003-2005, Bangladesh [7]

Hours/months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5:30			1	5	17	19	11	7	3			
6:30	3	8	29	66	106	93	86	66	58	46	31	11
7:30	57	93	148	198	252	200	198	180	165	169	157	97
8:30	175	254	318	354	406	321	355	288	303	324	331	237
9:30	300	424	489	521	561	416	438	433	435	473	490	382
10:30	411	573	629	666	681	494	503	514	485	487	580	479
11:30	494	672	712	751	727	532	548	537	485	520	614	498
12:30	518	701	722	764	711	593	570	535	486	488	573	489
13:30	483	646	657	693	641	500	503	482	441	406	510	426
14:30	379	528	541	553	577	451	463	453	385	323	377	309
15:30	236	353	377	402	419	329	372	356	281	208	204	183
16:30	94	175	204	237	257	215	244	231	164	76	57	54
17:30	10	37	55	72	93	93	107	89	45	6	1	2
18:30			2	4	11	17	18	8	1			
Daily average (kWh/m^2-day)	3.16	4.46	4.88	5.28	5.46	4.22	4.42	4.18	3.74	3.53	3.92	3.17

*Global Horizontal Irriadiance

(Source: SWERA Project, RERC, University of Dhaka, Bangladesh)

3.1.3: Pyranometer:

To measure the solar radiation a special type of equipment is used which is known as Pyranometer [8]. A Pyranometer is a type of actionmeter used to measure broadband solar irradiance on surface. It is one type of solar radiation sensor. It measures the solar radiation flux density (in watt per meter square) from a field of view 180 degrees. A typical Pyranometer dose not requires any power to operate.

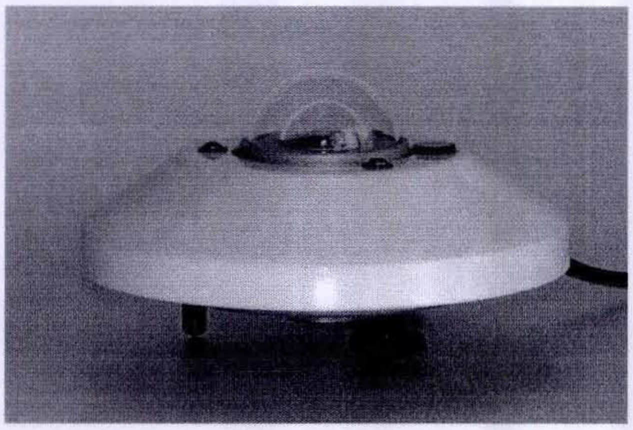


Fig: 3.4 Pyranometer

3.2: Photovoltaic Technology:

The conversion of sunlight into electricity can be achieved with basically simple devices that involve no moving parts, no additional sources of energy and minimal maintenance. These photovoltaic devices are based on the properties of certain materials that supply an electric current capable of performing useful work when these materials are exposed to sunlight. Although the devices are basically simple – containing semiconductor materials to which two metal contacts are made – the fabrication requires sophisticated technological capabilities. Currently, silicon is the most commonly used material. Work on many other materials is being actively pursued. A solar or photovoltaic cell is made from joining two opposite types of silicon {NP junction}. Around the junction is created an electrical field which keeps the positive and negative charges separate.

Solar cells are grouped together to form a solar module and these modules are grouped together to form a solar panel. The power of the modules depends on the efficiency of the solar cells and the amount of sunshine. The maximum power is called peak power and is expressed as peak watt {Wp}. Peak watt of a module is the optimal power given under illumination of 1000 Watt per meter square at a temperature of 25 degree Celsius at the cell junction. Single crystal of monocrystalline Silicon made by slicing electronic quality silicon is rather expensive; but the reliability and output are good (13-15%). Crystalline silicon is obtained through molding blocks or by drawing off chips are less expensive and also less efficient (11-13%) than the single crystal, commercially termed Polycrystalline Silicon. Amorphous silicon, made by depositing silicon on glass is the least expensive, but is at the same time, least efficient of the three (4-6%).

3.3: Solar Home System Components:

A typical solar home system (SHS) includes a 20- to 100-Wp photovoltaic array, a rechargeable battery for energy storage; a battery charge controller; one or more lights (generally fluorescent); an outlet for a television, radio/cassette player, or other low power consuming appliance; switches; interconnecting wires; and mounting hardware. A typical solar home system is given in the Figure 3.5. Both the array size and the sunlight availability will determine the amount of electricity available for daily use.

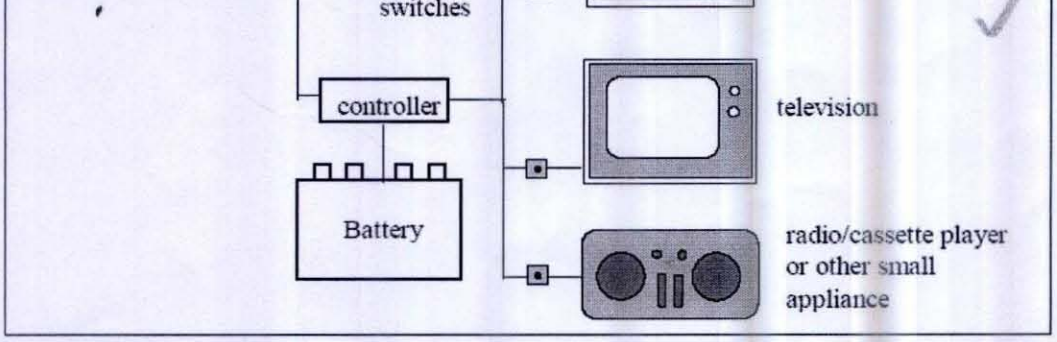


Figure 3.5: Typical Solar Home System Components [9]

(Source: http://www.worldbank.org/astae/pvpdf/pvbest.pdf)

3.3.1: Solar Home System Components provided by BRAC:

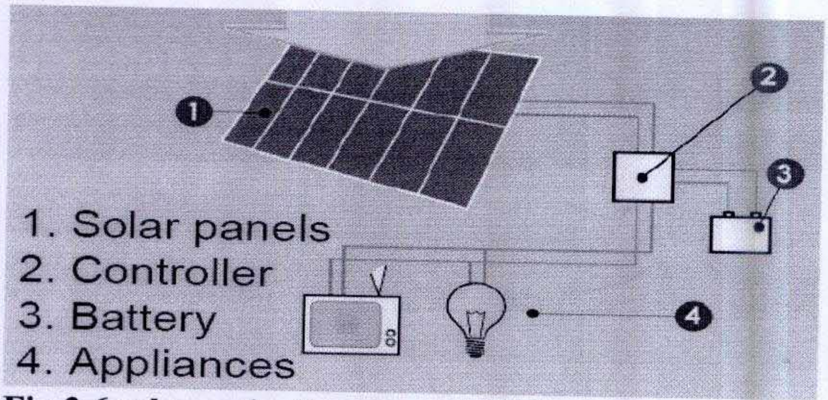


Fig 3.6 schematic diagram of SHS [16]

A. Photovoltaic module (Solar panels):

Photovoltaic converts the sunlight to electricity. Modules are made of silicon cells. Usually the modules consist of 36 solar cells connected in series to give the nominal voltage of 12V direct current (DC). The nominal power of a module is expressed in "watt peak (Wp)" measured under standard test condition of an irradiance 1000 W/m2, temperature 25 degree and a light spectrum of 1.5 AM.

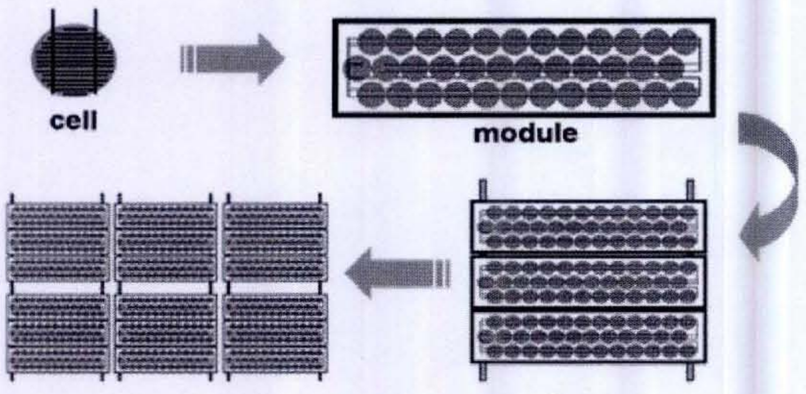


Fig 3.7: photovoltaic module schematic diagram [5]

B. Charge controller:

Charge controller protects battery from over charging and over discharging to ensure maximum life of the battery. When the battery voltage rises to a pre-set level of charging it limits the charging current to stop further charging. Similarly, when the voltage reaches the pre-set level of discharging it disconnects the load from battery and prevents the battery from further discharging. Charge controllers also have visual indication to show the battery status. Some features of charge controller:

1. Low Voltage (Load) Disconnect (LVD)
2. High Voltage (Panel) Disconnect (HVD)
3. Indication of battery charging current
4. Indication of battery voltage
5. Temperature Compensation
6. Adjustable set point
7. Reverse current flow
8. Data logger
9. Computer interface
10. Communication with other equipment and so on.

C. Battery:

The electricity that is produced by PV module during daytime is stored in the battery. Usually lead-acid flooded type batteries are used due to their comparatively low cost and low response to the temperature variation. Different types of batteries are used worldwide. However, batteries with tubular positive plate have longer life than that with flat plates.

Fig: 3.8 Internal diagram of Solar Battery. (source: Author)

C. Appliances:

The appliances of solar home system are

- 12 V, 7 Watt DC CFL 12
- 12 V, 1 Watt, LED lamp
- 20 watt Black and White TV
- DC fan
- Radio
- All DC components

3.4: Solar Photovoltaic Installations:

Key solar PV installations of the country are listed below -

A. Bangladesh Power Development Board (BPDB) installed the first solar photovoltaic installations in Bangladesh In 1981. 55 solar powered signalling lights were installed on 11 towers of the East-West Power Inter connector in Aricha. Still the solar panels are operating satisfactorily.

B. In 1983, Bangladesh Inland Water Transport Authority (BIWTA) installed 125 solar-powered beacon lights in different parts of Bangladesh to identify the marine routes at night.

C. In 1988, Bangladesh Atomic Energy Commission (BAEC) carried out Solar Photovoltaic Pilot project at Sandwip Island, where a solar-powered beacon light was installed on top of a watch tower, solar-powered refrigerators in a veterinary hospital for storing life saving vaccines, solar light and microphone in the local mosque. But all of these systems were destroyed in the 1991 cyclone. Currently BAEC is operating two pumps, one at Moulovibazar and the other one at Savar to supply water for irrigation. There is no storage battery in these systems, so the pumps turn off automatically at sunset.

D. On June 1996, Grameen Shakti (GS) came into existence as a renewable energy company. The main program of GS is its Solar Photovoltaic Program. Under this program GS sells Solar Home System (SHS) in credit and cash. Grameen Shakti has already opened 50 unit offices through which Grameen Shakti will research on marketing policy. This network allows Grameen Shakti to quickly disseminate and commercialize any improvement in the technology. Since the systems are expensive for the rural people Grameen Shakti has introduced a soft financing system for the customer. GS has linked this technology to some income generating activities as well. The sales progress of SHS up to June 2002 is shown in Table 3.1.

E. On June 1997, Rural Electrification Board (REB) has implemented the largest solar PV electrification project for rural households and commercial enterprises at a remote island in Narsingdi district with assistance from the French Government. This pilot project served about 900 households of the island community. The total installed capacity is 62 kWp, divided among three battery charging stations and stand-alone solar home systems. The PV systems are owned by REB and the users paid a monthly fee.

F. Local Government Engineering Department (LGED), having a decentralized organizational structure with strong implementation capability at the grass-root level, has been playing a pioneering role among government agencies in introducing and disseminating renewable energy in Bangladesh. Within the overall framework of SEMP (Sustainable Environmental Management Programme) sponsored by UNDP, LGED has embarked on a program on Sustainable Rural Energy (SRE) on October 1998, for Rural Energy Technologies demonstration and transfer. Already a number of Solar Photovoltaic (SPV) installations are operating successfully in different parts of the country demonstrating innovative application of the technology for improving the quality of life in the off grid rural Bangladesh.

G. Numerous solar PV has been installed by private parties, NGOs (BRAC), Government Bodies (including Bangladesh Railway, Bangladesh Telephone and Telegraph Board, Bangladesh Army) and Educational Institutions (BUET, Dhaka University, BITs). [10]

CHAPTER IV

4.1 Study Area Background: Kapasia Gazipur.

4.1.1 Geography

Gazipur district is situated between 23053/ and 24021/ North latitudes and between 90009/ and 90022/ East longitudes. It is bordered on the North by Mymensingh district, on the East by Norshingdi district, on the South by Dhaka and Narayanganj district and on the West by Manikganj district. This district comprises of six *upazilas* with a total area of 1741 square kilometers including riverine area. It is 1.18% of total area of the country. Kapasia has an area of 354.98 square kilometers. Map of the Gazipur district is given in the Figure 4.1

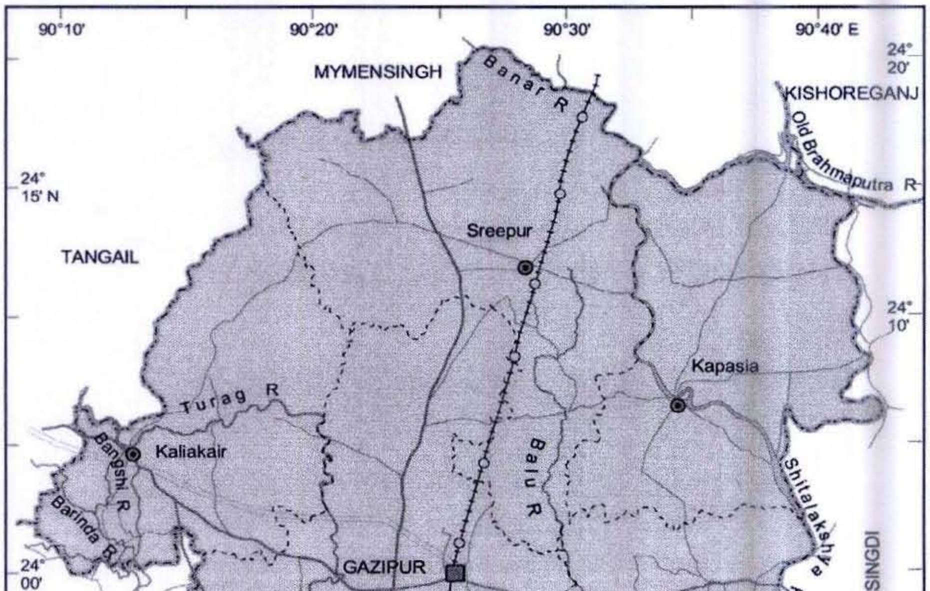


Figure 4.1: Map of Gazipur District [11]

(Source: http://banglapedia.search.com.bd/Maps)

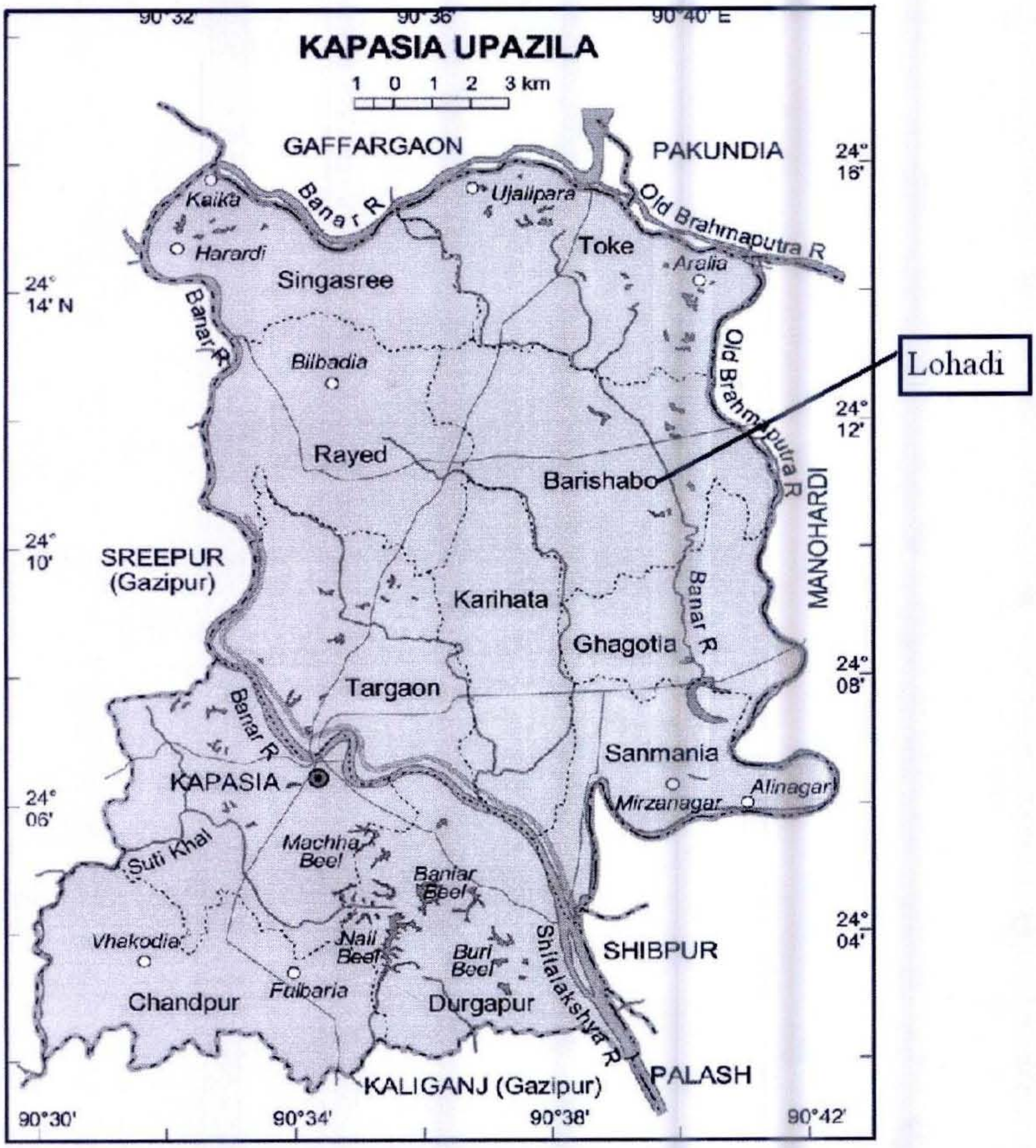


Figure 4.2: Tentative Locations of the Study Village [14]

(Source: http://banglapedia.search.com.bd/Maps/MK_0078.GIF)

4.2 Key Statistic of the Study Area:

Kapasia has an area of 354.98 square kilometers. Kapasia has 11 unions and 231 villages, among these 231 villages only two villages are urban rest 229 are rural. The total population of Kapasia is 3, 85,580 and the literacy rate is 56%. 70% of the people of Kapasia are residing abroad. For this reason Kapasia is economically strong compared to most of the rural areas of Bangladesh. 20% of the people are service holder and small businessmen such as service holder, teachers, grocery shop owner, poultry firm etc. 10% of the population live on farming, this section of people are not able to afford Solar Some System. Key statistic of Kapasia Thana is given in the following Table 4.1

Table 4.1: Kapasia Thana at a Glance for the Year 2009

SL. No.	ITEM	STATISTICS
01	NO. OF UNION	11
02	NO. OF VILLAGE	231
03	TOTAL NO. OF POPULATION	3,85,580
04	NO. FO PRIMARY SCHOOL	225
05	LITERACY RATE	56%
06	NO. OF HOSPITAL	02
07	NO. OF BANK	09
08	NO OF BAZAR	55
09	ROAD IN KM (PACCA)	90
10	ROAD IN KM (KACHA)	238
11	NO. OF NGO WORKING	08
12	VGD CARD HOLDER	550
13	TOTAL AGRICULTURE LAND	64,960
14	NO. OF POND	2,260
15	TOTAL WATER BODY	825
16	NO. OF CHILDREN (0-15 YEARS)	75,821

(source: BRAC, Kapasia Unit, Kapasia, Gazipur.)

Kapasia has a large number of villages which do not have grid connection. From the survey it was clear that most of the population of the study area can afford SHS as they are economically sound. To increase the literacy rate solar home system can play an impotent role here.

For selecting a location for solar project BRAC has some criteria [12] they are:

- Grid connection will not reach by the next 5 years.
- High population density.
- Economically more or less sound.
- Number of markets and Bazar.

Kapasia fulfill all the condition mentioned above so it was selected as a project area since 1998.

4.3 Collection of Information

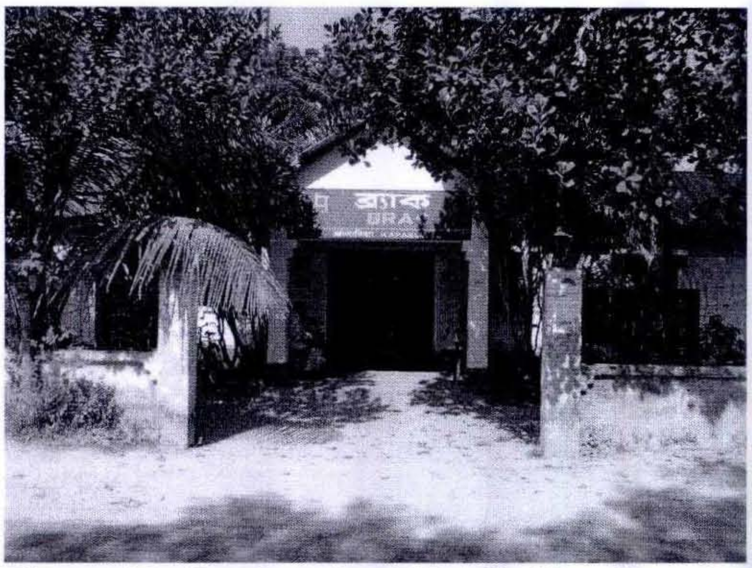


Figure 4.3: Jamiratchor BRAC office Kapasia Gazipur.

Information was mainly collected by means of questionnaire survey at the households and rural market level. To explore the real portrayal view of technical, social and economic aspects, the survey was carried out in those households having the solar home systems. The names of the owner and installation year of SHS were collected only for the selected village from register book of BRAC, Kapasia Unit, Kapasia Gazipur. To find out the real views of SHS the survey was carried out from the village Lohadi under Barishabo union in Gazipur district servicing the SHS by BRAC. Figure 4.3 shows the Jamiratchor BRAC office.

4.4: Types of Solar home system:

Four type of solar home system are provided by BRAC [15]. They mainly vary in size, capacity and price but their operating time constant. Table 4.2 gives a clear view about the appliances and components of solar home system for all the available solar home system.

Table 4.2: Description of Solar PV Systems Provided by BRAC at Kapasia:

Solar PV Module	Appliances	Components	Operating Time	Price (TK)
20 Wp	Two lamps of 8 watt	One module of 20 watt. One deep discharge battery of 47 Ah. Two charge controller. Two lamps of 8 watt. One structure, other accessories and installation.	4 hour per day.	10,500
40 Wp	Three lamps of 8 watt & one Black and White TV	One module of 40 watt. One deep discharge battery of 70 Ah. One charge controller. Three lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	18,200
50 Wp	Four lamps of 8 watt & one Black and White TV	One module of 50 watt. One deep discharge battery of 80 Ah. One charge controller. Four lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	22,500
60/65 Wp	Five lamps of 8 watt & one Black and White TV	One module of 60/65 watt. One deep discharge battery of 80 Ah. One charge controller. Five lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	28,600
75 Wp	Six lamps of 8 watt & one Black and White TV	One module of 75 watt. One deep discharge battery of 98 Ah or 100 Ah. One charge controller. Six lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	31,400

4.4.1: Components Importer Companies:

BRAC imports the components from different companies the following table provides a list of companies and their products:

Table 4.3: Importers of SHS components:

Product	Company
Solar panel	1. Moserbaer – India 2. Blue Tech – China 3. Kyocera - Japan 4. sun link PV
Battery	1. Rahimafrooz – Bangladesh 2. RIMOS –Bangladesh
Charge controller	1. Easy –Bangladesh 2. Innovative – Bangladesh.

(Source: kamrujaman, PO, Engineer, solar)

The variation of price of the component is more or less similar but package price mentioned in table 4.2 remain same. There are some extra components available like mobile phone charger produced by Easy the price range it 200 to 250 taka. It is not included in the package the user has to bye it separately if required.

4.4.2 System Used by the Customer by Size

50 Wp solar home systems were most common in the study area which can run three lamps and one black and white TV system. Larger capacity systems (75Wp) were used by comparatively larger family (higher income group) it was also a popular size. Chart 4.1 shows the using patterns of different systems.

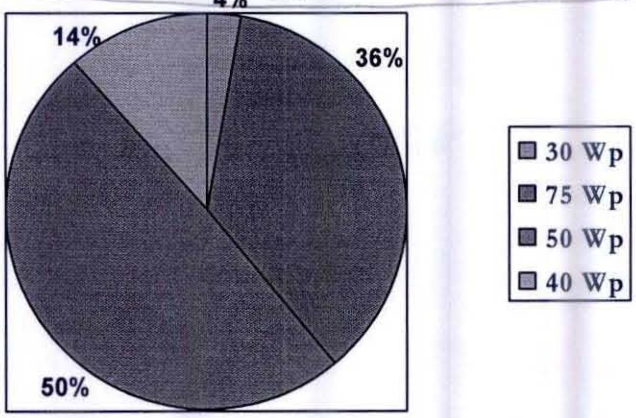


Chart 4.1: System Used by the Customer by Size

4.5 Conventional Energy Sources in the Study Area:

1. Candles: Some of the people in this area were using candles for lighting. Mainly business people were using candles for emergency lighting and students were using candles before examination, at least 2 hours in the night. The average price of a candle in this area was 2 Taka.

2. Small Kerosene Wick Lamps: Also few families were using wick lamp among the study village. It provides poor quality light and produce smoke and smell, also represents a constant fire hazards. The kerosene consumption of the wick lamp is low. The average price of small kerosene wick lamp was about 5 Taka.

3. Hurricane (Kerosene Lamps with Chimney): For domestic lighting this type of lamp was the most widely used form. This type of lamp was more preferable than candles and wick lamp because it produces more light. One kerosene lamp with glass chimney cost was about 120 to 200 Taka.

4. Torches: This type of flash light was widely used for communication to the outdoors or for intermittent indoor use, usually powered by 2 or 3 dry cell batteries, which was not in any way rechargeable.

5. Car battery: For entertainment purpose some people used to use car battery. To watch a black and white TV for about one hour they had to recharge a car battery twice a month and to do that they had to spend about 200 taka (app.) per month.

4.6: Energy requirement of the study area:

From self observation and by intervening with the respondents the time period of the using of light and for entertainment appliances was found. The using time of TV, radio, cassette was mostly same in all of the families. The period of daily energy consumption and typical energy requirement for lighting and entertainment are given in the Table 1.5 and Table 1.6 respectively.

Table 4.5: The Period of Daily Energy Consumption for Lighting and Entertainment

Consumption	Morning	Afternoon	Evening	Night
Lighting	-	-	6pm-7pm	7pm-10pm
TV			3:30pm-7pm	7pm-9pm
Radio	7am-8am			

Table4.6: Daily Typical Energy Requirement for Lighting and Entertainment

Appliance	Power (W)	Duration (Hour)	Energy (Wh)
Lamp 1 (reading And bed room)	6	5	30
Lamp 2 (bed room)	6	4	24
Lamp 3 (bed room)	6	2	12
Radio	10	1	10
TV(Black and white)	20	4	80

From Table 4.4 we can see that the average daily electricity requirement for one house hold is 156 Wh.

4.7: Case study: Household

4.7.1: Household 1:

Fig: 4.4: Author with SHS user.

Name of the Respondent : Md. Ainuddin.

Address : Village- Lohadi, Post Office- Gazipur, Union-Barishabo, District- Gazipur

Age : 50 Years

Education : Class 5
Occupation : Tailor
Monthly income : 5000 Taka
Family Members : 5 Number of person.
Previous kerosene consumption per month: 6 Liters

Mr. Ainuddin replaced four kerosene lamps and one car battery with solar home system. He is using the 75 Watt solar home system he is the most recent user and he din not have any complain with the system.

Average cost for lighting and entertainment of this family:

Initial cost:
Car battery : 2500 taka
Three kerosene lamp: 50*3 = 450 taka

Monthly expense:
Charging the car battery : 60 taka
Transportation cost for charging the battery: 20 taka
Kerosene cost :6*46=276 taka
[per litter kerosene cost=46 taka]

Mr. Ainuddin had to replace the kerosene lamp (Hurricane) every 4 years and he had to replace the Chimney every 6 months. The life time of the car battery was approximately 3 years.

From the above analysis and from his personal opinion we can say that solar home system is a best solution and he is also being benefited financially as he can work extra one or two hours. Now his grandchildren get more time to study.

4.7.2: Household 2:

Name of the Respondent	: Md. Shahidul Islam.
Address	: Village- Lohadi, Post Office- Gazipur, Union-Barishabo, District- Gazipur
Age	: 45 Years
Family Members	: 5 Number of person.
Capacity of the SHS	: 75 Watt

Previous kerosene consumption per month: 5/6 Liters

Md. Shahidul Islam has also replaced three hurricane lamp and one car battery with 75 Wp solar home system through which he can run 6 light 10 Watt each and

1 black and white TV. He was using the system for about 2 years and left with few monthly installment of the cost. During these two years he had to change one lamp only and on the components on the SHS was working fine. He was also satisfied with the service of the BRAC employee.

4.7.3: Household 3:

Name of the Respondent : Md. Shoriuddin.

Address : C/O Md. Shamer Ali Village- Lohadi, Post Office- Gazipur, Union-Barishabo, District- Gazipur

Age : 50 Years

Family Members : 6 Nos.

Capacity of the SHS : 50 Watt.

Previous kerosene consumption per month: 5 Liters

In this household they replaced two Kerosene lamp and one car battery by solar home systems. This family bought the Solar Home System on 22 December 2002. The system capacity is 50 watt. In these 7 years they had to change the charge controller once. This is the only household we found who were using a DC fan. They were very satisfied with the overall performance of the system and they were also planning to buy another SHS.

4.8: Case study: Grocery shop lighting:

4.8.1: Grocery shop 1:

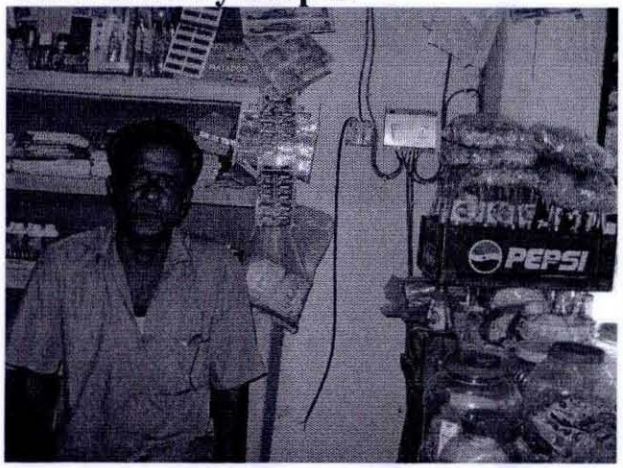


Fig: 4.5: SHS user in a Grocery Shop. (Source: Author)

Name: Md. Idrish Ali.

Address: Jolpai Tola Bazar
Village- Lohadi, Union- Barishabo,
District- Gazipur

Age: 48
Occupation: Business
Monthly more income: 450 Taka
Monthly bill from another lamp: 150 Taka

Md. Idrish Ali installed the solar home system to run his business. He was using a 75 Wp SHS for one and half years. He said that he earns additional 15 to 20 Taka more per day after the installation of SHS, because working time was extended two hours more. He was having some problem with the battery.

4.8.2: Grocery shop 2:

Name: Tara Mia Kholifa.

Address: Jolpai Tola Bazar
Village- Lohadi, Union- Barishabo,
District- Gazipur
Age: 45
Education: Class 6.
Occupation: Business
Monthly more income: 400 Taka
Monthly bill from another lamp: 150 Taka

Tara Mia Kholifa was the oldest solar some user in the study area. He installed a 30 Wp solar home system in the year 1998. Except the solar panel he had replaced all the components once.

4.9: Social Impact in the Study Area

1: Lighting Facilities before and after SHS

For household lighting facilities 80% of the respondents were using kerosene lamps and for torch light and radio they were using dry cell batteries. 95% of the respondents were using car battery for watching TV in the study area.

After the installation of solar home system nobody was using car battery for watching TV. Charging a car battery was expensive and time consuming. The use of Kerosene was also reduced. The reduction of Kerosene was the main impact of the solar home system that results less pollution, less darkness, less hassle. The use of dry cell batteries was still common in use at night for torch lights to facilitate communication.

2: SHS for Income Generation

Few income generation activities were created after installation of solar home systems in the study area. But the people who were engaged with business using traditional fuel, now switch to solar light that results the more development of their business than before. Two tailoring machines were bought to earn some money by two household respondents out of total surveyed households. For this case two women were involved with income generation activities. Grocery shop owners who were using kerosene lamps for their business, two hours working activity was extended now due to SHS. For the tailoring and other grocery shop owners who were using kerosene pressure lamp, the working activity hour was extended one hour due to introduction of solar light.

3 Increment of daily working hour:

Most of the resources of energy before solar some system were expensive this is way people tried to finish most of their daily activities before sunset. Students were not able to study long time at night. Three household respondents made their opinion that their children's performance of study was better than previous. On the other hand, all respondents remarked that their evening working hours were extended. After the installation of solar some system people of the study area get more time for watching TV or listening to broadcast information and entertainment by the radio.

Table 4.7: Number of Hours/day for Social Activities before and after SHS

Activities	Before SHS (Hours/Day)	After SHS (Hours/Day)
Children study	1/2	3/4
Swing	0	1/2
Watching TV	1/2	3/4
Listening radio	1/2	2/3

4: Environmental benefits

Replacement of kerosene lamps for lighting saves about 70 litres/year of kerosene per lamp, equivalent to about 0.19 tonnes/year CO_2. This survey in Kapasia suggested that households were using about 2 kerosene lamps on average. Thus for the 9,680 SHS installed to date, the total saving of greenhouse gases is about over 650 tonnes/year CO_2.

Previously dry cell batteries were used to power radios and music players. The disposal of the spent batteries is a problem, since they are often simply thrown into the streets. Radios and, to a limited extent, other equipment can now be powered by the SHS, which reduces the problem of disposal.[13]

4.10: Problems associated with SHS components:

A. Solar panel:

- Shading problem was the most common problem associated with the solar panel. The maximum power output of the module is decreased due to shadow. Another common problem was placement problem. Due to the wrong placement of the panel user were not getting the maximum power output as expected.

fig 4.6: solar panel (source Author)

- It was found that some of the respondents did not clean the surfaces of the panels, so a thick layer of dust accumulated causing a drop in power out put of the system.

B. Battery Related Problems:

The batteries used for SHS in study area were suitable to use for the requirement of energy. But for mismanagement they face problems with battery performance most often.

The common problems according to the respondents are:

- Battery charging was not adequate.
- Battery becomes hot due to the near end of life.

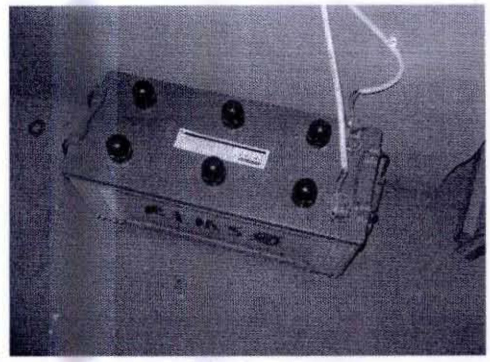


Fig 4.7: Battery (source Author)

C. charge controller:

Charge controller is the only component which the users had to change most frequently. The main problems regarding charge controller is that when ever it is connected to the panel it shows the battery is fully charged, even if the battery is not charged.

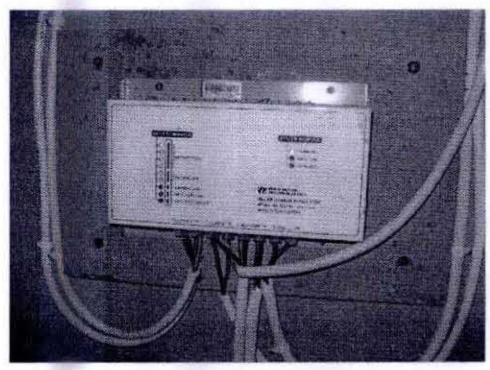


Fig 4.8: charge controller (source Author)

D. Appliances:

Regarding the quality of light, most of the users were satisfied with the quality of light emitted through the luminaries provide. On the other hand, some of the users were experiencing blackening on either one or two ends of the light.

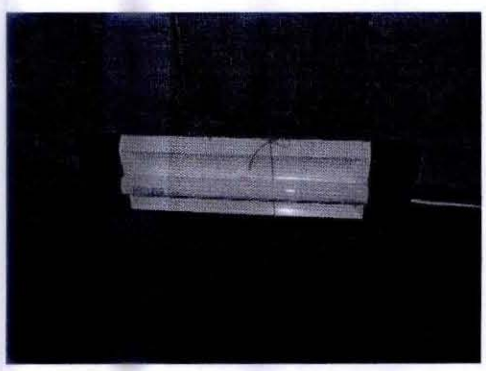


Fig 4.9: Tube light (source Author)

Except the light all the other appliances like Radio, mobile charger, black and white TV, CD player etc. were working well.

4.10.1 Service and Maintenance:

All interviewees reported that there were regular inspection and maintenance procedure provided by BRAC on their own sites. Md. Nazrul Islam, BRAC, Unit Manager, Kapasia, reported that their technicians used to visit every customer house every month to collect the monthly installment and check the system properly. Charge free service and maintenance were getting the users up to their loan period from both NGOs.

4.11: Conclusion: Feedback of the SHS user of the study area:

Although kapasia is a rural area but compared to others Kapasia is economically sound, they can easily afford two batteries to utilize the extra sunshine. This problem can be easily solved by a simple controller with relay.

CFL is an energy saving device but the initial price is slight higher than the conventional tube light they are using at present, CFL has less warranty this is why the are not using CFL but using cfl the will be benefited in the long run

CHAPTER V

5.1: Introduction:

Bangladesh is an energy deficit country. Load-shedding and power failure is a major problem of our country. The conventional source of energy is not sufficient to meet the present demand. Table 5.1 shows the existing generation, demand and shortage of electricity according to a PDB (Power Development Board) survey on 17^{th} August 2008.

Table 5.1: The existing generation, demand and shortage of electricity

Generation of electricity	Required electricity	Average load–shading
3411MW	4350MW	803MW

From this survey we can see that Bangladesh is going through an enormous shortage of electricity. Solar can be a suitable solution to reduce this crisis. Solar is the most important source of electricity in Bangladesh not only in the rural area but in the urban area as well. The solar home system is being popular in the rural and off-grid areas. BRAC Foundation has already installed 49,000 solar Home systems. The BRAC Solar Energy Program has started a project with a vision to bring light in the lives of 36,000 households in three years. But this project doses not include the poorer sections of the rural population who continue to live in darkness. A small solar power plant can be implemented which will be able to serve more people in the rural area. In cities, where the power supply is insufficient, fluctuating and failure is a regular event, the slam Solar Power plant can be a good power source of electricity if installed on the roof-tops of the building. In the cities this small power plant can be connected to the grid then it can be named as grid-connected Solar PV system.

Grid-connected Solar PV power systems are being installed in cities in different countries of the world. Government policies are being framed to encourage and popularize this system by providing necessary regulations and incentives in many developed and developing countries. From the gradual decrease of prices and increased rate of installation of the systems in the cities all over the world it can be easily comprehended that this system will become an important source of electricity in a very short time in the urban areas.

Roof-top grid-connected Solar PV systems are also being installed in our neighboring countries like India, Thailand and Indonesia. The future of PV-grid electricity in Bangladesh is also very bright as we have bright sun light throughout the year.

5.2: Grid-connected PV power system:

During sunny days the DC power generated by the PV modules in the system can be converted to AC by power conditioning unit (inverter) and fed into the local loads. In this power system excess solar power will be supplied to the power line, and any shortfall will made up with grid electricity. During nonsun hours, residence loads will be supplied by utility grid alone. In Roof-top Grid-connected PV systems, we will install PV arrays on the roof-tops of buildings.

5.2.1: System Design and Development:

A block diagram of the system is shown in Fig.1. In this design the following factors have been taken into consideration. Figure 5.1 shows a schematic diagram of the grid-connected Solar PV system.

- Grid interfacing circuitry matching,
- Effects of voltage fluctuation, harmonic distortion and stability
- Over current, over voltage protection and power failure
- Power conditioning and flickering
- Safety, bi-directional metering for power tariff

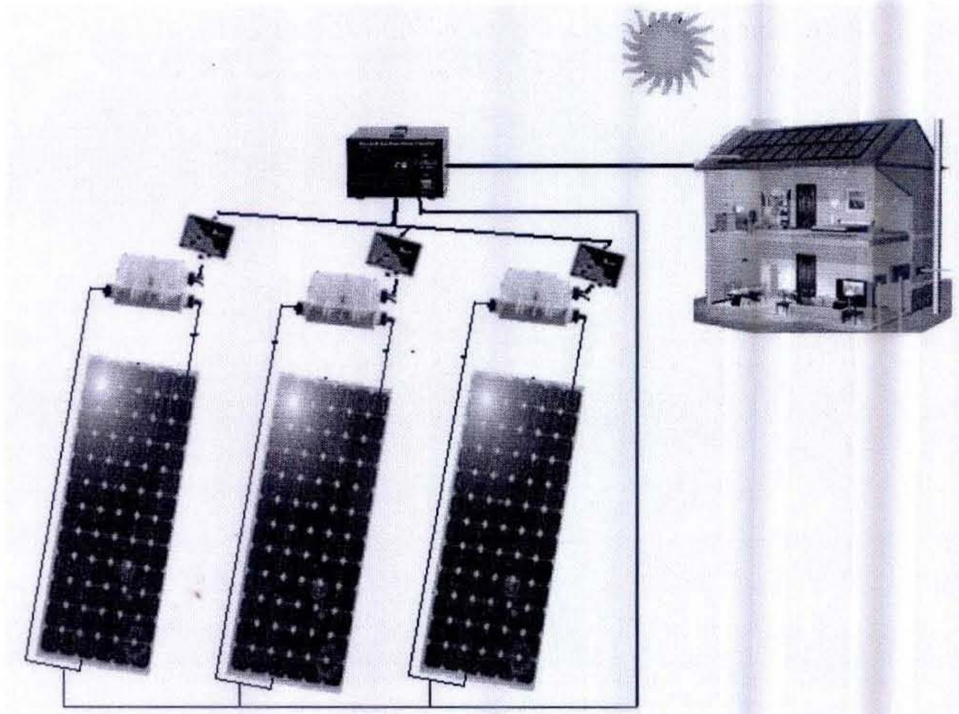


Fig.5.1 Solar PV power system with micro inverter

5.2.2: Roof-top Grid Connected PV system Components:

PV Array: 20 PV panels will be connected in series giving a DC output of 140-400V according to intensity of incident radiation.

Orientation and tilt angle: Orientation is south-facing and tilt angle is 45N. Area will be covered by PV array is about 11m2.

Inverter: Inverter that 'inverts' the above DC power from the panels into AC power of 1.1kW/220V/50Hz. The characteristics of the output signal should match the voltage, frequency and power quality limits in the supply network.

Load: Appliances in the residence that are fed from the inverter, or, alternatively, from the grid.

Meters: They register the energy being used from the local supply network or fed into local supply network.

Local Supply Network: The single-phase network of local supply line. The supply network acts both as a sink for energy or as a backup for low local generation periods.

Micro-inverter: Micro-inverters are attached to every single solar panel in the system and each one is capable of converting direct current from its solar panel into usable electricity – independent of other panels on the string. This means that even if one panel gets shaded a little bit by dust, bird poop, or a tree, the other panels are still capable of feeding usable electricity into our home or business. In addition to more uptime, micro-inverters allow system owners to monitor the energy output of each individual panel.

The overall efficiency of the system depends on the efficiency of the PV array and the efficiency of the inverter. The efficiency of the inverter varies with the load level. High efficiency of the inverter can be obtained by running the inverter near full loads.

5.2.3: Specifications of the system:

PV string:

1. No of PV panel in series-20
2. Open-Circuit Voltage (VOC): 20V/panel
3. Short-Circuit Current (ISC): 4A/panel
4. Power Output: 75 Watt/panel
5. Total output of the string: 1.5kWatt

Inverter:

1. Maximum input current: 10A
2. DC input voltage: 139-400V
3. Max. Input power: 1.21kW

4. Nominal output power: 1kW
5. Output AC voltage: 220V, 50HZ

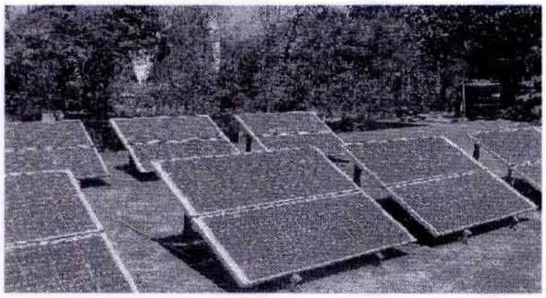


Fig.5.2 PV array of Grid-connected PV system [7]

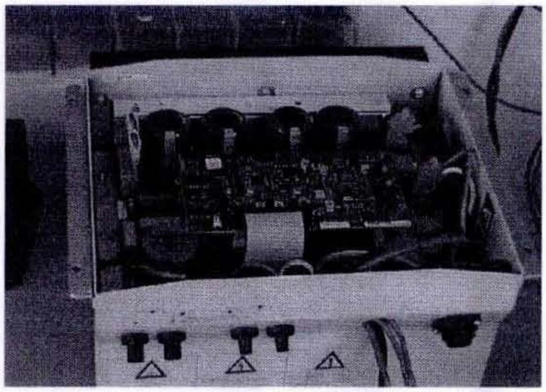


Fig.5.3 Grid-connected Inverter[7]

5.3: Overall coat of the system:

75 watt 20 solar panel = 20*20000=400000 taka

System Size (kW)	System Prize (Taka)	Annual Energy Generation
1.1 kW	**6,60,000**	**401.5 kW**

The cost of unit of electricity produced by this system would depend on the overall system efficiency, the resource availability, the lifetime of the system and the interest rate.

The above estimation will be made by considering an average demand of 3000kWh for a four-member family. We think a system of 2kW power for a single house-hold can produce surplus energy that can be fed to the national grid.

5.4: Small Solar Power Plant:

The Small Solar Power Plant is a modified version for the rural and off-grid areas. In this case the basic difference is we do not need the DC to AC converter. All the wiring connection and appliances will be exactly the same as the existing Solar Home system. Here we need to connect the meter to trace the use of different family. Figure 5.6 shows a schematic diagram of the small solar power plant.

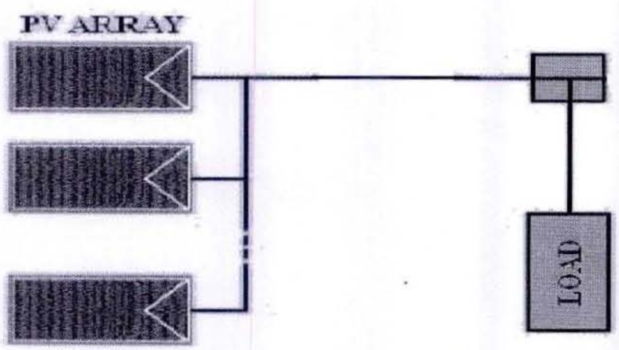


Fig: 5.4 Small Solar Power Plant.

5.5: Impact of the system:

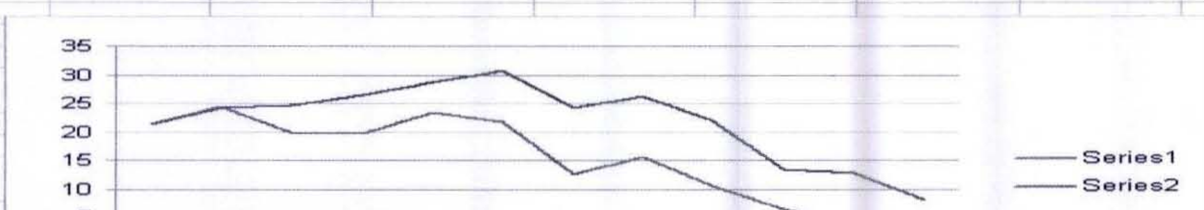
- The power produced by the roof-top grid-connected PV system can be used to supply local loads, with the excess energy fed into the local grid for use by other customers. At night, the local loads are simply supplied by the grid power. If the PV system is large enough, it can supply more energy into the grid than is used by local loads. Instead of receiving a bill every month from the utility supply office, the owner of the system would then be able to earn money by generating surplus electricity.
- The Small Solar Power Plant can provide light to the poorer people in the rural area. There are sections of the rural people who cloud not affords a solar home system. But they use candles or at least one kerosene lamp. If one Small solar power plant if available in the near by area they can get connection for one light and pay a very small amount of money per month.

The power produced by the roof-top grid-connected PV system can be used to supply local loads, with the excess energy fed into the local grid for use by other customers. At night, the local loads are simply supplied by the grid power. If the PV system is large enough, it can supply more energy into the grid than is used by local loads. Instead of receiving a bill every month from the utility supply office, the owner of the system would then be able to earn money by generating surplus electricity.

5.6: Experiment under BRAC Solar:

For utilizing the extra sunlight per day, at first we have to make sure that the battery takes five hours or not. At the same time we have to analyze some technique to decrease the charging time. For doing these we have done some experiments under BRAC Solar, at Niketan, Dhaka. Here we have used a 50 watt solar panel and 80Ah battery, a charge controller and two tube lights. The experimental data are given below:

Time	Initial Voc/V	Isc/A	Power/W	Adjusted Voc	Isc	Power
11:15am	13.8	1.55	21.39	13.8	1.55	21.39
11:45am	14	1.74	24.36	13.9	1.74	24.186
12:15pm	13.8	1.44	19.872	13.44	1.83	24.5952
12:45pm	13.14	1.5	19.71	13.12	2.01	26.3712
1:15pm	13.29	1.76	23.3904	13.48	2.13	28.7124
1:45pm	13.39	1.62	21.6918	13.52	2.27	30.6904
2:15pm	13.18	0.96	12.6528	13.11	1.84	24.1224
2:45pm	13.18	1.19	15.6842	13.1	2	26.2
3:15pm	12.93	0.82	10.6026	13.06	1.68	21.9408
3:45pm	12.8	0.51	6.528	12.85	1.05	13.4925
4:15pm	12.88	0.3	3.864	13.01	0.99	12.8799
4:45pm	13.19	0.22	2.9018	13.23	0.62	8.2026



In this experiment, at first we select an initial fixed position and take all these data after that we move the solar panel by tracking the sun and take the same sets of data. From the data we see that at fixed position the power is: 170.5017 and for adjusted position the power is 247.9871. from this data we can say if we track the sun then we could charge the battery faster and utilize the sun light.

CHAPTER VI

6.1 CONCLUSION

At present Bangladesh is going through severe electricity crisis. In this situation, the solar home system can be a good alternative small-scale power source because it does not require any fuel. It is observed from the preliminary economic analysis that the system would be financially feasible if subsidy is given and net-metering regulation is framed by the government. Moreover, the impact of the system on the environment friendly issue should be considered as the system does not pollute the environment at all.