A TECHNICAL AND FINANCIAL STUDY OF SOLAR HOME SYSTEM IN BANGLADESH: PROSPECTS, CHALLENGES, CONSTRAINS

A dissertation by

Md. Mahmudul Hasan
ID:151-33-2346
Md. Mehedi Hasan
ID:151-33-2391

Supervised By

Prof. Dr. M. Shamsul Alam
Dean
Faculty of Engineering

Submitted To

Department of Electrical and Electronics Engineering
DAFFODIL INTERNATIONALUNIVERSITY

Certification

This is to certify that this thesis entitled "**A TECHNICAL AND FINANCIAL STUDY OF SOLAR HOME SYSTEM IN BANGLADESH: PROSPECTS, CHALLENGES & CONSTRAINS**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

Signature of Supervisor

5.1.19.

Prof. Dr. M. Shamsul Alam
Dean,Faculty of Engineering.
Daffodil International University

Signature of Candidates

Md. Mahmudul Hasan

Md Mahmudul Hasan
ID:151-33-2346

Md Mehedi Hasan

Md Mehedi Hasan
ID:151-33-2391

ACKNOWLEDGEMENT

First of all, we give thanks to Allah or God. Then we would like to take this opportunity to express our appreciation and gratitude to our thesis supervisor **Prof. Dr. M. Shamsul Alam, Dean , Faculty of Engineering** for being dedicated in supporting, motivating and guiding us through this thesis. This project can't be done without his useful advice and helps. Also thank you very much for giving us opportunity to choose this project.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us in making this project a success. Also thanks for lending us some tools and equipment.

To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this University

Dedicated to
Our parents
&
Respected Teachers

Abstract

Power is one of the most important factors in developing country and for sustainable economy. Like the rest of the countries of the planet, in Bangladesh the demand for power is increasing day by day. The main aim of our research is to find out the irradiation of sun in Dhaka city in the month of September so that the power production by the solar panel can be estimated and, we collect the solar irradiation and the maximum power data in Dhaka for (September)0ne month and analyze the data to get average irradiation and find the relationship between solar irradiation and power and by using this data we can easily understand the electricity production by solar home system and create a standard form of power production of solar home system in 2018.This research is an endeavor to analyze the socio economic impact by using solar Home system and also test the feasibility of maximum power can be generated from the panel. Social and Economic development from SHS and their prospects , challenges and constrains can be estimated by specific method named SWOT analysis. This research is basically for rural area where grid electricity is not available. Our research have done be a remote village named “Monpura” situated in the district of “Bhola. So to be a part of this modern world, electricity is the basic needs... Solar Home system (SHS) is very effective for any remote villages like monpura. Other hand this renewable electricity system not only performs Electrification but also perform social and economic development for any society. By using this Solar Home System (SHS) people can be benefited. Their income has increased, their education status has increased, and they are socially active.

Our research concludes these major findings:

- Introduction to the Solar Home System (SHS), present condition of solar Home System, Future prospect of Solar Home System.
- Solar Home System coverage area have huge amount of positive changes. This positive changes are Economic improvements, Educational improvements, socially upgraded, Family bonding, solved unemployment problems, Women empowerment etc.

TABLE OF CONTENT

CHAPTER 3
METHODOLOGY

CHAPTER 4
DATA ANALYSIS

CHAPTER 5
CONCLUSION

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS

SHS	Solar Home System
IDCOL	Infrastructure Development Company Limited
MW	Mega Watt
BPDB	Bangladesh Power Development Board
NWPGCL	North west zone power generation company limited
PV	Photovoltaic
DC	Direct Current
AC	Alternating current
GDP	Growth Development Product
DPDC	Dhaka Power Distribution Company
DESCO	Dhaka Electric supply Company Limited
GS	Grameen Shakti
IRE	Institute of Renewable Energy.
UV	Ultra violate
NGO	Non Governmental Organization
SREDA	Sustainable and Renewable Energy Development Authority
APSCL	Ashuganj Power Station Company Ltd
EGCB	Electricity Generation Company of Bangladesh
RPCL	Rural Power Company Limited
PPA	Power Purchase Agreement

CHAPTER 1

INTRODUCTION

1.1 Background of study

If we are highly civilized then we need more power. We want electricity to use each and every sector to make the work more easier and efficient .We are now the era of 21st century where most of the technology have established with an enormous amount of success. A most important & significant look in our modern civilization is “energy” of different forms. Many necessary functions can be at a standstill with our energy. So energy is a part of our life. There is various form of energy consumption process like raw energy in falling water, in deposits of coal, oil, gas etc. and also from sun and wind flow which called renewable energy. Only renewable source of energy can be regenerated after a regular time cycle. So with the alarming rate of depletion of the major energy resources worldwide, it has become an urgent necessity to seek for renewable energy resources that will power the future. According to the worldwide market economy, the increasing demand for energy had forced to put a huge price tag on natural combustible sources of energies [1]. It has been predicted that in the near future the demand of energy will grow in such a rate that it will be completely impossible to find out or meet the demand with the resources that we had been using for so long.

In this context we have concentrated our focus on the research of renewable energy and the possibilities of using Solar Home System and the socio-economic growth. Among these renewable energy resources solar energy is one of a kind. Solar energy is one of the most popular forms of renewable energy. Solar Energy is the most efficient form of renewable energy also. The use of solar panel is increasing rapidly all over the world. But worldwide many local area are now isolated from energy. According to the World Energy Council report; 1.267 billion people were without access to electricity globally in 2010,[2] out of which majority of people lived in remote and isolated rural areas.

In Bangladesh, electricity is the most widely used form of energy. Future economic growth significantly depends on the availability of electricity. At present, about 72% of the total population has access to electricity, and electricity supply is not adequately reliable

In the off grid areas of Bangladesh, solar home system (SHS) is getting popular day by day due to its declining price and due to favorable financial packages offered through Infrastructure Development Company Ltd. (IDCOL).It can definitely say that Solar power is an alternative technology that will hopefully lead us away from our petroleum and gas dependents energy sources.

1.2 Energy Scenario of Bangladesh

The History of Bangladesh's Power Sector is one of persistence hard work and success. We have been growing up technologically and also producing Power. The achievements have been driven by a single minded dedication, Public-privet sector collaboration in power sector [5]. The main and the cheapest source of energy in Bangladesh is Natural gas. It is an important source of energy that accounts for 75% of the commercial energy of the country which is likely to be depleted by the year 2020[13].

- In 1990-1991 the installed capacity stood at 2350MW
- In 2016-2017 the installed capacity has increased to over 13500MW
- Today the installed capacity has increased to over 16193MW

In working to achieve its electrification goals, Bangladesh is adopting flexible power solutions alongside traditional grid connectivity with 10% of off-grid power. For this reason the electrification rate have increased –In1990-The rate was 8.5% , In 2009-The rate was 47%, Today-The rate is around 90%-Privet-Public Partnership (Government contribution 56% & Privet contribution 46% of financial support) actually helped to raise the electrification rate. In our country the present Generation is around 10000MWthough our capacity is still 13500MW.But day by day power demand is rapidly expanding for increasing urbanization and the massive amount of industrialization.

Table: 1 Present Installed Generation Capacity (MW) as on 11 September, 2018[5].

Public Sector		Installed Generation Capacity (MW)
BPDB		5266
APSCL		1444
EGCB		839
NWPGCL		1211
RPCL **BPDB-RPCL JV**		77 149
Subtotal		8986 (53%)
Private Sector		
IPPs		4802
SIPPs (BPDB)		99
SIPPs (REB)		251
15 YR. Rental		169
3/5 YR. Rental		1576
Power Import		1160
Subtotal		8057 (47%)
TOTAL		**17,043 ***

Including Captive Power & Renewable Energy Total Installed Capacity (17,043 + 2,800+290) = 20,133 MW.Total Renewable capacity is 290MW and the hydro can only can produced 230MW.Present Government have already taken some future project to increase the electrical capacity . They have made a plan to make the capacity 24000MW within the year of 2021,to make the capacity 30000MW in the year of 2030 and the 60000MW in the year of 2041.

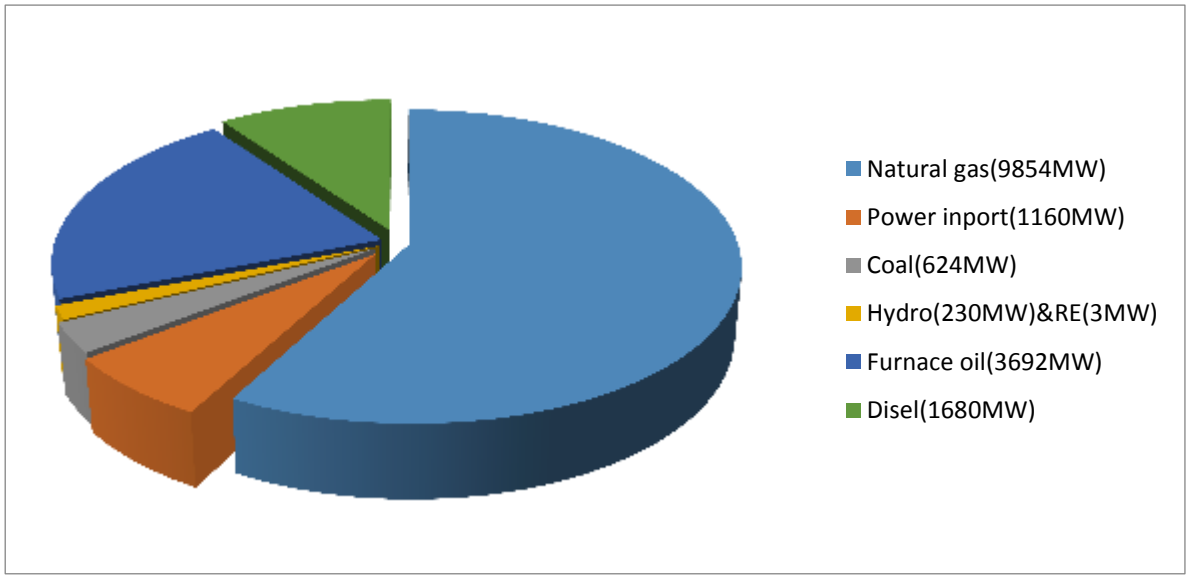


Figure 1.1: Power generation capacity of Bangladesh in the month of September 2018

1.3. Statement of Problems

In our country we are mostly depending on grid electricity to fulfill our energy demand. We all know that our grid electricity. But now a day's Renewable energy is playing an important role to fulfill they energy demand. Having set that, Solar Home system (off-grid, on-grid, Micro grid, mini grid, Roof top) user increasing day by day. It has been using for several years as a rural electrification and also in civilized zone.

At present the on-grid solar power generation capacity amounts to 15MW (Sreda 2018) including one well-publicized solar park with 3MW capacity built on 8 acres of land in Sarishabari in Jamalpur district. To date, the government has approved proposals for establishing 19 on-grid solar power parks(5MW-200MW) submitted by different private companies. Companies has to complete the construction and start power generation within one and a half years from signing the PPA and IA. Unfortunately, none of the companies could complete construction and start power generation till date although the deadlines have passed. It appears that the development of the on-grid solar has so far failed to provide a realistic hope. With such low level of development it would be impractical to believe that the growth of solar power would reach anything near the projected target by 2021.Mainly our focused problems about the solar home system panel problems, impact after using solar home system, social impact, economic impact

The reasons that are restricting expected growth of on-grid solar. One of the major challenges is the difficulty of acquiring land. As per the government rule, no agricultural land can be used for solar power project. Bangladesh is a densely populated fertile agricultural land and non-agricultural unused land is not easily available. A 100MW solar park for example would require about 300 acres of land. It is expected that the efficiency of the solar panel will increase in future through new technological advances thus requiring lesser area for generating per unit of power. But until that happens, acquiring land will be a major problem for rapid expansion of on-grid solar in Bangladesh.

Most of the user in Bangladesh are not properly trained to maintained the solar system or to get the maximum output. Even our Government are now spending a huge amount of money to install mini solar panel on the road light . But after some day it become damage or do not work properly. If we calculate the total money which govt. are investing for it we will see it's

huge. But sometimes for civilized zone its quite not much efficient than a rural electrification. By concerning people we can save a huge amount of electricity which is not much more the generated electricity from the solar in our Dhaka city I think so. By gathering this money which govt. are investing in Dhaka city for sustainable development govt. can create mini or micro grid for rural electrification or alternatives electrification or other renewable energy generation. Sometimes technology is not suitable for all civilized zone. It's a technology and also for sustainable development. Actually there are many problems in this entire sector.

But we will focus our specific problem that includes in our or related with our study.

- People are not using this solar home system properly
- They don't know about anything technical for solar home system
- They have no idea how much power they need from the solar system to run all of their appliance
- They are illiterate people so they can't know about this
- Applying more technology is quite hard for this rural region
- Company who provides solar system are not interested to motivate people properly for their business purposes.
- National policy is not much suitable for rural region for rural electrification.

1.4.Objectives :

- To col1ect solar irradiation and maximum power data in Dhaka for (September) one month and to analyze data to get average irradiation and find the relationship between solar irradiance and power.
- After collecting data we made a per unit calculation for average maximum power and feasibility test for Solar Home System in a rural village.
- To assess the role of SHS on socio-economic development in Bangladesh.
- To identify the socio-economic impact , prospects, challenges & constrains by using a SWOT analysis.
- To introduce Renewable Energy (RE) as an alternative solution for power generation.
- To study solar PV system of Bangladesh and future scope and present condition.

.

1.5 Rationale & scope of the study:

Bangladesh is blessed with year round sunshine (over 300 days per year) and has an enormous potential for solar energy. We have been utilizing solar power wisely and using its experience towards diversifying renewable energy (RE) for maximum use. Bangladesh government has taken a systematic approach towards renewable energy development Community-based solar approach such as solar irrigation pumps; solar mini-grid, arsenic water treatment plants, and solar street lights have the potential of benefitting the community people by ensuring food security, arsenic free pure water, improved socio-economic conditions in off-grid areas of Bangladesh etc. Our study basically will focus on the socio-economic impact having use of solar home system.

1.6 Outline of the study:

Chapter 1 : Introduction

Chapter 2 : Literature Review

Chapter 3 : Methodology

Chapter 4 : Data Analysis

Chapter 5 : Conclusion

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

Renewable energy (sources) or RES capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. The most common definition is that renewable energy is from an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind. The United States currently relies heavily on coal, oil, and natural gas for its energy. Fossil fuels are non-renewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. In contrast, the many types of renewable energy resources-such as wind and solar energy-are constantly replenished and will never run out. Most renewable energy comes either directly or indirectly from the sun. Solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity. The sun's heat also drives the winds, whose energy, is captured with wind turbines. Then, the winds and the sun's heat cause water to evaporate. When this water vapor turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using power.

2.2Classification of Renewable Energy

There are many forms of energy. Most of these renewable energies depend in one way or another on sunlight. Wind and hydroelectric power are the direct result of differential heating of the Earth’s surface which leads to air moving about (wind) and precipitation forming as the air is lifted. Solar energy can be collected by the direct conversion of sunlight using panels or collectors. Some popular kind of renewable energy-

- Solar,
- Biomass,
- Hydropower,
- Wind,
- Geothermal etc

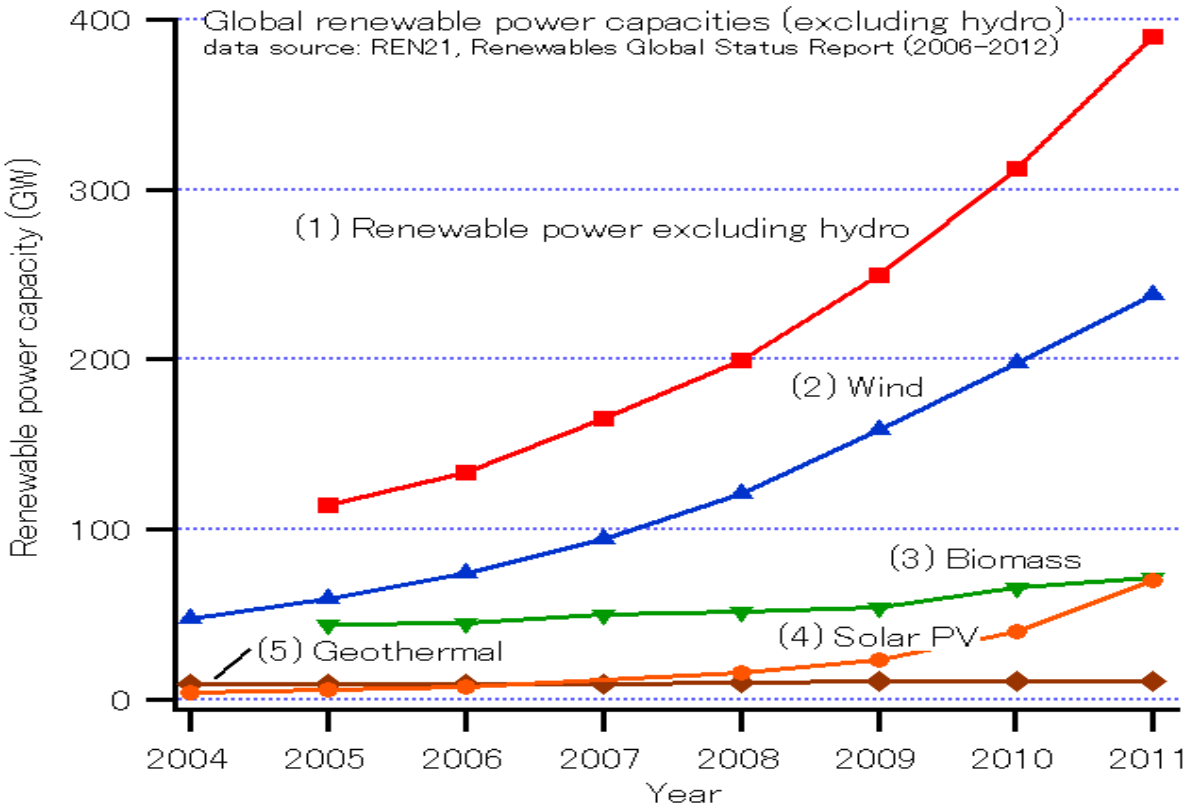


Figure 2.1: Global Renewable energy capacities.

2.2.1 Solar energy

Solar power is one of the most popular types of renewable energy. It comes from the sun, which supplies our entire planet with the energy we need to survive. Using solar panels, we can harvest energy directly from sunlight and convert it to electricity that powers our homes and businesses. Solar energy can also be used to produce hot water or charge battery systems.

Figure 2.2: Solar energy collected by solar Panel

2.2.2 Biomass

One last example of renewable energy is biomass. Biomass energy refers to any energy produced from recently living organic matter like plants or animals. Biomass is a renewable resource because plants can be regrown relatively quickly, and they grow using renewable energy from the sun. Fuels like ethanol and biodiesel (both used for cars and trucks) also come from biomass.

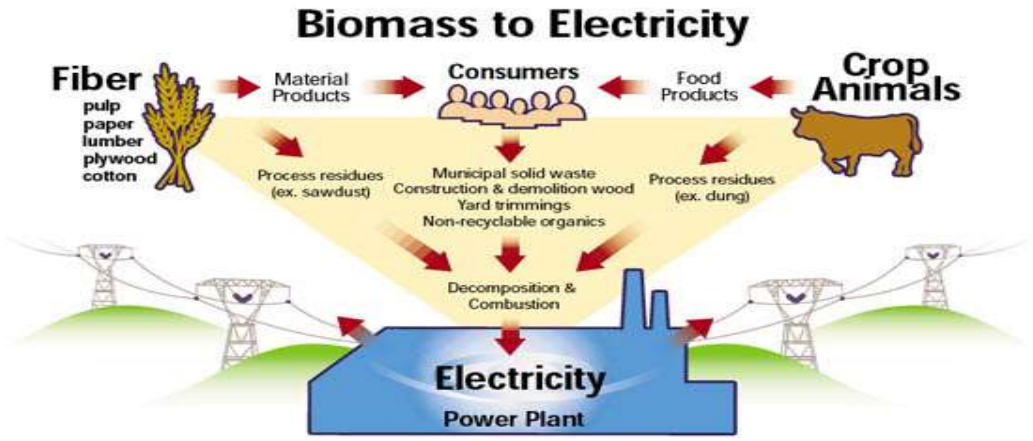


Figure 2.3:Biomass to electricity Generation system

2.2.3 Hydroelectricity

We can produce renewable energy from moving water just like we can from moving air. Energy is generated when moving water runs through a turbine, spinning it to produce electricity. This often happens at large dams or waterfalls, where water drops significantly in elevation. Two important places where hydroelectricity is produced are the Hoover Dam on the Colorado River and at Niagara Falls on the border between New York and Canada.

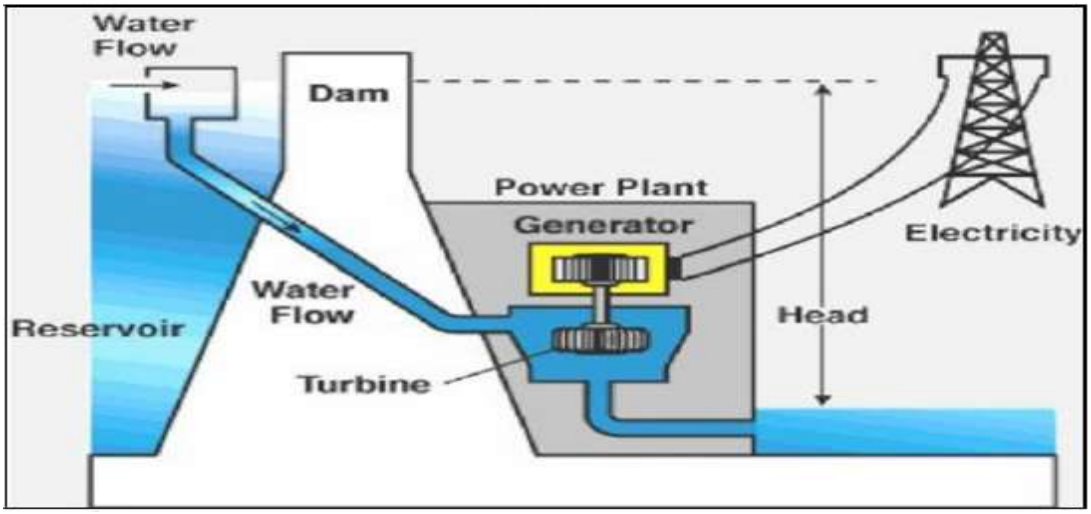


Figure 2.4: Hydroelectricity generation Plant

2.2.4 Wind power

Another type of renewable energy that we interact with every day is the wind. When you feel the wind, you're simply feeling air moving from place to place due to the uneven heating of Earth's surface. We can capture the power of wind using massive turbines, which generate electricity when they spin.

Figure 2.5: Wind power to electricity

2.2.5 Geothermal energy

Earth has a massive energy source contained within it. Heat trapped when our planet formed, combined with heat generated from radioactive decay in rocks deep beneath the crust, results in a massive amount of geothermal heat energy. Sometimes that heat escapes in large amounts all at once, which we see as volcanic eruptions on the surface.

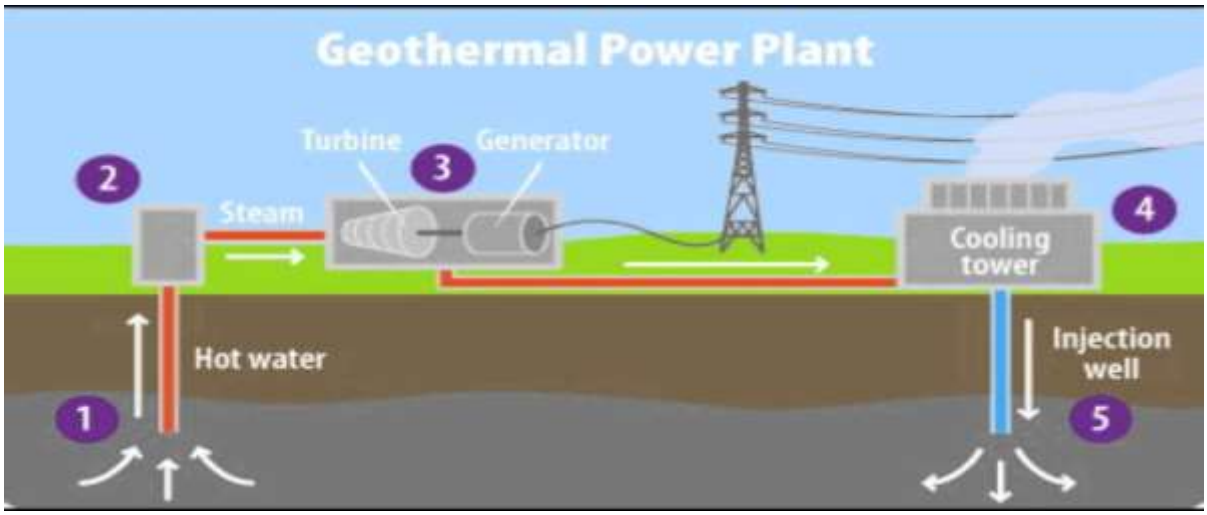


Figure 2.6: Geothermal Energy to electrical Energy plant

We can capture and use geothermal energy by using steam from heated water to spin a turbine. In a geothermal spring system, water is pumped below ground. Once it is heated, it rises back to the surface in the form of steam and spins a turbine to generate electricity.

2.3 Solar System:

Solar system as renewable energy is all about the PV cell. PV cell basically collects solar energy from the sun and converts initially DC electricity. This DC electricity can be stored by battery as a part of solar home system. Solar Panels are becoming more and more popular with every passing day and the main component of these solar panels is the electronic systems called Photovoltaic Cells. Solar energy, radiant light and heat from the sun, is harnessed using a range of ever evolving technologies such as solar heating, solar photovoltaic', solar thermal electricity, solar architecture and artificial photosynthesis.

The first solar cell was constructed by Charles Fritts in the 1880s. The German industrialist Ernst Werner von Siemens was among those who recognized the importance of this discovery. In 1931, the German engineer Bruno Lange developed a photo cell using silver selenite in place of copper oxide, although the prototype selenium cells converted less than 1% of incident light into electricity. Following the work of Russell Ohl in the 1940s, researchers Gerald Pearson, Calvin Fuller and Daryl Chapin created the silicon solar cell in 1954. These early solar cells cost 286 USD/watt and reached efficiencies of 4.5-6%. There is an alarming energy crisis world-wide as fossil fuel reserves decrease and the ageing power plants are going to close in near future. From the aspect of global warming and shortage of natural gas, scientists and engineers are looking for clean, renewable energies. Solar energy is the one of the best options.

2.3.1 Photovoltaic Cell

In the simplest manner, it is a chemical composition that takes the energy from the reflected light and turns that energy. The PV cells, which have a semiconductor feature, create voltage

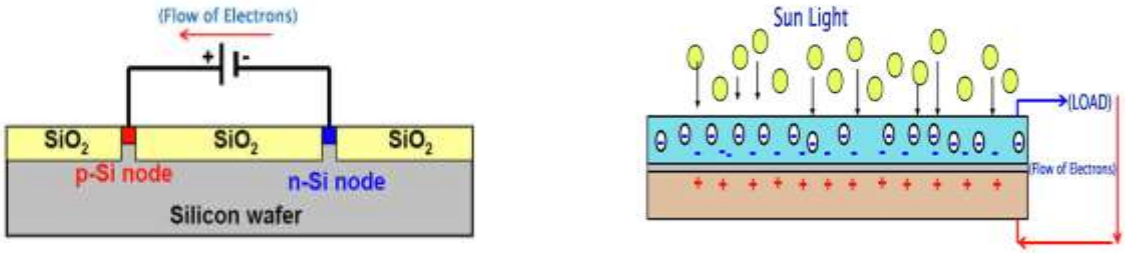


Figure 2.7: Photovoltaic Cell

and current by providing electron movement between (+) and (-) poles as a result of the Photons that hit them. In the picture below, you can see the chemical structure of a PV cell and the electric current flow in detail.

2.3.2 Electricity Production

When sunlight fall on the PV cell photon hit the silicon surface which upper surface contain electron or (-) charge. And the lower portion is (+) charged. So when photon hits the cell then the negative electron go to the N region and Positive charge go to the P region which flow electricity. The cells which are made of semiconductor matter absorb the light that is reflected on them and transform it into electric energy. The major process here is provided by the flow of the extra electrons in the (-) pole to the holes in the (+) pole by means of the photons. During this flow the generation of electricity occurs. In the picture below you can see how the flow process works.

The amount of the **electric energy produced by Photovoltaic cells** is in proportion to the power and the angle of the light that comes to the unit area.

- The light that comes with a right angle provides more power generation
- The light that comes from a higher level provides more power generation

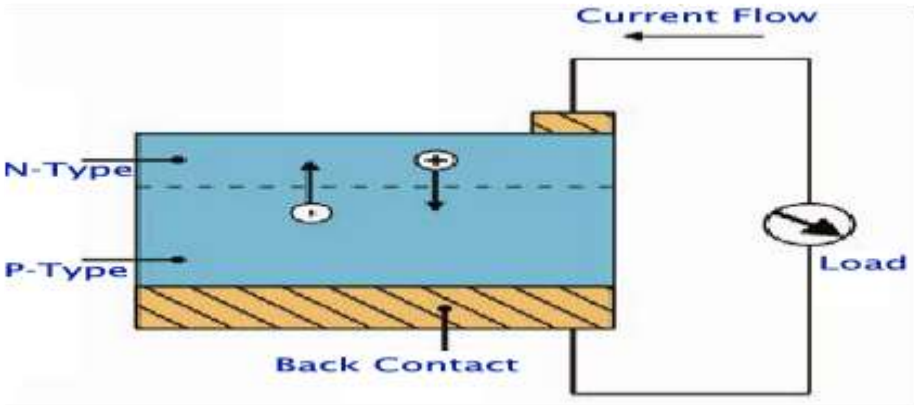


Figure 2.8: Electric energy produced by Photovoltaic cells

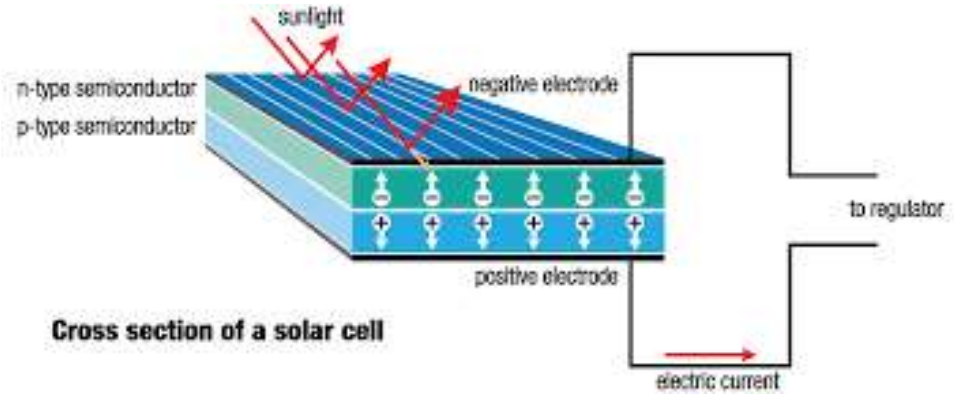


Figure 2.9: Cross section of a solar cell

2.4 Present Scenario of Bangladesh solar Power

Bangladesh is now making the challenge to raise the capacity of electrical power. We have very much scope to make the traditional power plant like by natural gas, coal based, diesel etc. But Government has kept their concentration to the renewable energy like solar, wind and hydro. To raise the GDP rate 7-8% Government have already taken some initiatives and made a master plan to expand the Electricity sector. According to the plan the renewable power will be 2000MW within the year of 2021[9]. But solar energy will be the leading power from all the renewable sources. Commendable progression has been compiled in the renewable energy sector in the last few years. Currently, the total electricity generation from such sources is 404 MW. A 10 kW central AC solar PV system has been installed in one selected market in each of the three Rangamati district's sub-districts. With these systems, the shops of that market have been electrified with normal AC electricity[13].

Table 2: Progress in the solar power in Bangladesh[6]

Methods	MW
Installation of solar home system(4.5)million	150
Installation of Rooftop Photovoltaic(PV) at Government Offices	3
Installation of PVs commercial buildings and shopping centers	1
Installation of PVs by consumers during new electricity connection	11

Up to November 2013, a total of 2,677,896 Solar Home Systems (SHSs) have already been installed. Figure 1 below shows the approximate distribution of SHSs installation division

wise and illuminates that the distribution of the SHSs is highest in Dhaka district and lowest in Sylhet district [17] .

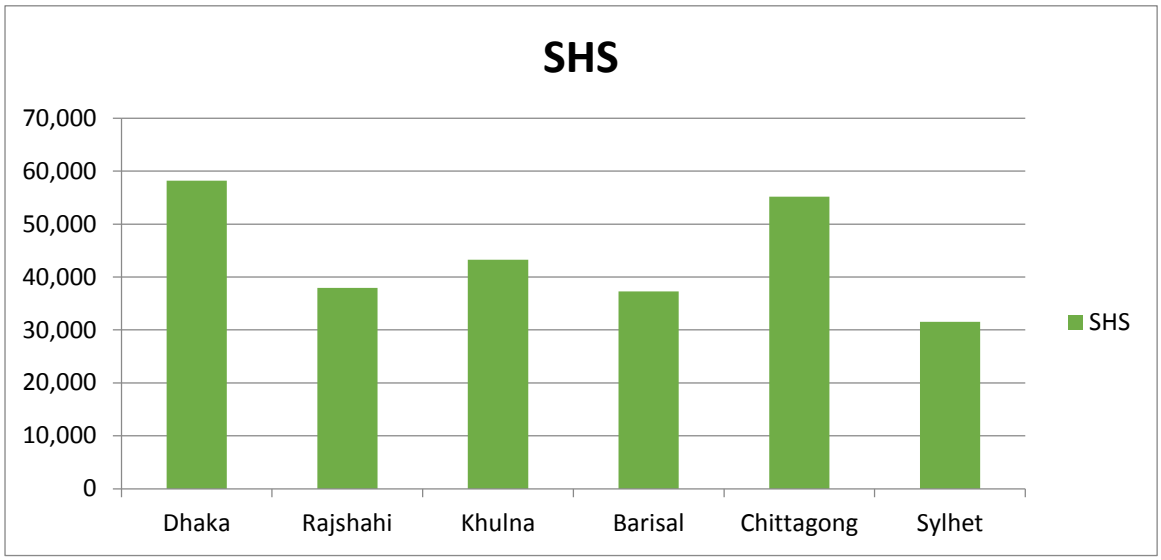


Figure 2.10: The Solar Home System installed in Bangladesh

Solar Thermal Energy Based Recharging Stations for Electric Vehicles is very much needed for the present situation of Bangladesh. The government has now promoting various other renewable energy projects i.e. solar-powered transportation, rooftop solar system, solar cold storage and dryers, battery charging station .When these projects will come to light, then it will greatly influence the socio-economic condition of Bangladesh. Solar mini-grid and solar micro-grid as well as solar smart grid technology has already took the attention of the government of Bangladesh. The solar diesel hybrid technology may also contribute to our energy crisis solution.

2.5 World Solar scenario

Solar PV capacities are now growing in both grid connected and off-Grid. Now the world's 1% of electricity is being fulfilled by solar (2015).By concerning the globalization effect and the enormous amount of energy demand make different country to think alternative power .We know that solar is the most efficient form of renewable energy that we can implement where the solar irradiation occur. Now many developed country have already started a huge amount of solar project. Cumulative Global PV installation up-to 2016 is Chaina-23%, USA-12%, Japan-14%, Germany-13%, Italy-6%, Rest of the world-30%.. Also we have get an idea

about the various future application of solar PV like solar fuels, Solar based oil Production. Oil companies are increasingly producing heavy oil, which accounts for 70% of today's remaining reserves. Heavy oil is abundant, but difficult to extract. The leading method of producing heavy oil is steam injection, a type of thermal enhanced oil recovery (EOR) that injects steam into a reservoir to heat the oil making it easier to pump to the surface. Steam injection can boost well productivity by up to 300%, but is an energy intensive process. Also solar is being used outside the world as water treatment plant. Another risk for investors is the retroactive reduction of Fit, which should be avoided as Much as possible for maintaining investors' confidence. There are also some risk discussed in thesis literature like Regulatory risk and regional conflict. Also we get an idea about the future outlook of the solar PV, Future market places for investors, new financing model for solar energy.

2.6 Solar Home System

Basically solar home system means a single panel in one house where no electricity before.
It's basically for rural electrification. In Bangladesh many people are still out from the electrification. In Small Island, near hill many villages are still not connected to the grid. Solar Home systems are not only used in un-electrified houses or region but also where people cannot get electricity through their regular demand. There many advantages, opportunities, challenges, constraints of Solar Home system.

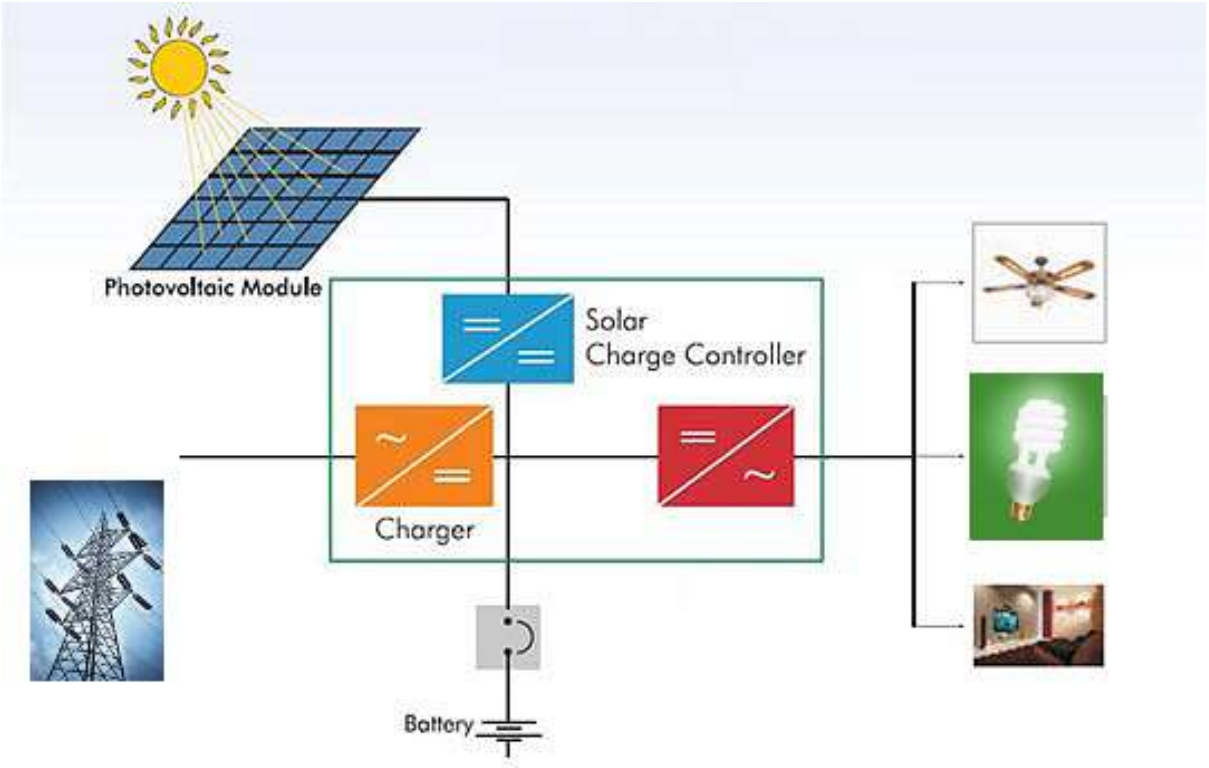


Figure 2.11:Solar Home system Block Diagram

2.6.1 Equipment of Solar Home system:

Solar System basically contains Solar Panel, Battery, Charge controller, Inverter , Dc appliance etc. Basically for rural electrification mainly panel, battery, Charge controller are there. For rural electrification there is only one panel for one house.

2.6.1.1 Battery:

Battery is something which performs to store charge from the panel. A battery is a device that produces electrons through electrochemical reactions, and contains positive (+) and negative

Figure 2.12: Battery with solar panel

(-) terminals. A battery consists of one or more electrochemical cells, which transform stored chemical energy directly into electrical energy. When an external load connects to a battery, electrons cross from the negative to the positive terminal, creating an electrical current. Panel basically generates DC electricity. Then this electricity transmitted by wire to battery. For rural electrification Battery size depends on the total connected load and the panel size [20].

2.6.1.2 Solar Panel:

a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. For extremely rural area like Monpura people uses single solar panel.

Figure 2.13: Solar Panel

There are four types of solar PV cells

1. Single crystalline or mono crystalline.
2. Multi- or poly-crystalline.
3. Thin film.
4. Amorphous silicon

Single crystalline or mono crystalline:

Mon crystalline solar cells have a uniform appearance, and the cells form a distinctive shape – small black squares with notched corners. Solar panels made with these solar cells typically have either a white or black back sheet. These panels conduct electricity more efficiently and perform better in high temperatures and shaded conditions, enabling them to generate more solar power than other panels of the same size [21]

Figure 2.14: mono crystalline

Multi- or poly-crystalline:

These solar cells have a multifaceted, non-uniform, gem-like surface and are typically blue in color. Polycrystalline solar panels are less efficient but are less expensive. There is less silicon waste in the manufacturing process. These are the most prevalent solar panels globally, primarily due to a production boom in China over the last few years [21].

Figure 2.15: Poly crystalline

Thin film:

Thin film silicon panels are generally larger and have a uniform, solid black appearance.

Features: This is a commercially available but newer technology that makes sense where space is not an issue. Thin film solar panels are low cost, easy to produce, flexible, portable, and lightweight. They are expected to be less durable and to have a shorter lifespan [21].

Figure 2.16: Thin film crystalline

Amorphous silicon:

Amorphous silicon is newest in the thin film technology. In this technology amorphous Silicon vapor is deposited on a couple of micro meter thick amorphous films on stainless steel rolls.Compared to the crystalline silicon; this technology uses only 1% of the material.

Figure 2.17: Amorphous Silicon crystalline

2.6.1.3 Charge Controller

For SHS charge controller is very important equipment. Charge controller basically maintain the charge condition. A **charge controller**, **charge regulator** or battery **regulator** limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk [22].

Figure 2.18: Charge controller

2.6.2 Opportunities

There are many opportunities in solar home system. In rural area people are not aware about their social life, education life. After having solar home system they developed by many things like economically, in education, socially updated, up to date, etc.

2.6.3 Constraints of SHS

After observing the data from the people and discussion we had fund many problems. For this problem sometimes they are not interested to install the solar home system (SHS).But SHS program have their aim to electrify the rural area and also make the environment developed.

- We have found that most of the Panel in this village are over the roof top .But the height of tree is even more than panel. So Panel does not get the full Light from the sun. All the time it is under shade. For this reason the panel can't able to collect photon from the sun. Due to this problem battery can't be charge well to perform all day long [14].

- In villages there are lot of Air flow. So that the rubbish particle falls on the panel board. For this reason it can't collect the photon from the sun properly.
- For Solar panel the amount of sunlight is main things. So it's important to set up
  The panel in a proper angle so that the panel can collect maximum photon from the sun. But in this area most of the panels are not placed in proper angle.

- For this above problem battery can't be charge well. Before it getting fully charged the battery is being used and fully discharged .Having set that the battery life goes down. And this problem is the most important problem for any user. Because this cost is very high to replace the battery [14].

2.6.4 Solar Home system Contribution

Still in Bangladesh from the help of Infrastructure Development Company Ltd. (IDCOL) , Around 4.5million of Solar home system have already exist and around 13million people are now getting the advantage from the solar home system .From the IDCOL the Solar home system(SHSs) is being installed 65000 per month[7] . Solar home system is a success story in Bangladesh and day by day its popularity is increasing in the rural areas, especially in the off-grid regions.

Figure 2.19: Solar Home system Contribution

2.6.5 Rooftop system Contribution

In Bangladesh most of the building's rooftop both commercial and privet are not using for

\anything. Having set that, Government has already taken some initiatives to implement the solar rooftop system on that building by the help of some Power distribution company like DPDC, DESCO etc. Most of the Roof-tops in the commercial and residential buildings are lying vacant either fully or partially. The Grid PV system is an independent Solar Power Plant which can provide

Figure 2.20: Rooftop system Contribution

Power to the individual requirement as well as feed power to the local distribution system. It indeed an effective solution in the grid connected urban areas by generating AC [8].

Govt. has identified this one as the potential side to install solar power and has issued directives as a pre-condition to get new electricity connection to install solar panel by the consumers to meet their certain percentage of their load. Govt. is also trying to encourage industries to install solar panels to offset a portion of their energy demand from renewable energy. Estimated solar power capacity addition from this project shall be 20 MW [8].

2.6.6 Mini-grid system contribution:

Providing access the electrical power to the remote area or village is a big challenge for any government or the Electrification Authority. Bangladesh Government in 2007 published a Guideline for Remote Area Power Supply System (RAPSS) to facilitate electricity access to un-served areas. A commercial model has been identified under the guideline to implement the mini grid project through the private sector. But that policy focused on

Figure 2.21: Solar Mini grid System

Conventional, mainly diesel, based power generation. In line with the idea of developing mini grid in remote areas, government has allocated 25 MW to be developed as solar mini grids by the private sector. Each project will be implemented under Distributed Utility concept integrating solar based Generation & Distribution Management. The government will assist by providing necessary fiscal and financial support. Initially 30 remote locations have been identified where grid expansion is not planned for next 15-20 years [9].So far, 11 solar mini-grids with a cumulative capacity of 2.19 MW has been installed and are in operation. 15 more solar mini grid projects are under implementation with a cumulative capacity of 3.17 MW. Majority of these projects are being financed by IDCOL and they have a target to finance 61 more projects in the upcoming years. However BPDB has installed 650kWp solar mini grid project at Shalla, Sunamganj which is the largest solar mini grid project in south Asia [9].

2.7 Future of Solar system in Bangladesh

According to the government plan, renewable sources should provide about 10 percent of the total power generation capacity by 2021, meaning 2400MW power generation from renewable sources. Keeping that mind, Government and also some Privet organization have taken some of the project to make it happen. There are many way to implement the solar system Like –Solar home system, Solar Rooftop, Solar micro and mini grid, solar irrigation. But I think the most efficient way to increase the use of renewable energy and also decrease the consumption rate of grid electricity is the solar home system and the solar irrigation.

There are around 1.34 million diesel operated irrigation pumps (DTW – 3000, STW – 1.2 mil., LLP – 0.14mil) are working for irrigation, which covers 3.4 million hectares of land. Government has a target to install/replace diesel operated pumps by solar pumps which will ensure 150 MW energy generations from irrigation sector.

BR powergen Company Have projected 100MW solar power plant project in Kaizar char, Madarganj, Jamalpur.Which is grid tied Solar PV. Expected date of Completion is june 2020 .Cabinet committee on public purchase has given nod to the proposals on setting up four solar power plants to produce a total of 258 megawatt in different places across the country with a cost Tk 9,158 crore for next 20 years. There are many project of solar PV are still pending to be installed. There are a huge opportunity in Bangladesh to implement the solar PV in various purposes. Like we are not using the solar PV in vacant hilly area , we can also use the solar PV inside the hydro power plant in Kaptai. This project have already projected. The per capita electricity generation and consumption in Bangladesh is still very low. According to

BPDB in the year 2012-13 the per capita electricity generation and consumption are 248.89 kWh and 213.15 kWh.BPDB has planned to implement Solar Park Projects on IPP/PPP basis under the Roadmap of ADB's 500 MW Solar Power Mission such as-

- 40-45 MW Solar Park Project adjacent to Bangabandhu Bridge, Tangail and Sirajgonj area.
- 2-3 MW Solar Park Project adjacent to PGCB Grid Sub-station compound, Ishwardi.
- 1-2 MW Solar Park Project adjacent to PGCB Grid Sub-station compound, lhenaidaha.
- 30 MW p Solar Park Project adjacent to new Dhorola Bridge, Kurigram.

The Renewable Energy Policy envisions that 5% of total energy production will have to be achieved by 2015 and l0% by 2020[13].

2.7.1 Hybrid Solar System:

Photovoltaic (PV), wind hybrid energy model become an effective solution in particular for off-grid system to fulfill the exceeding energy demand. To make the system more stable and flexible many authors are working on it.

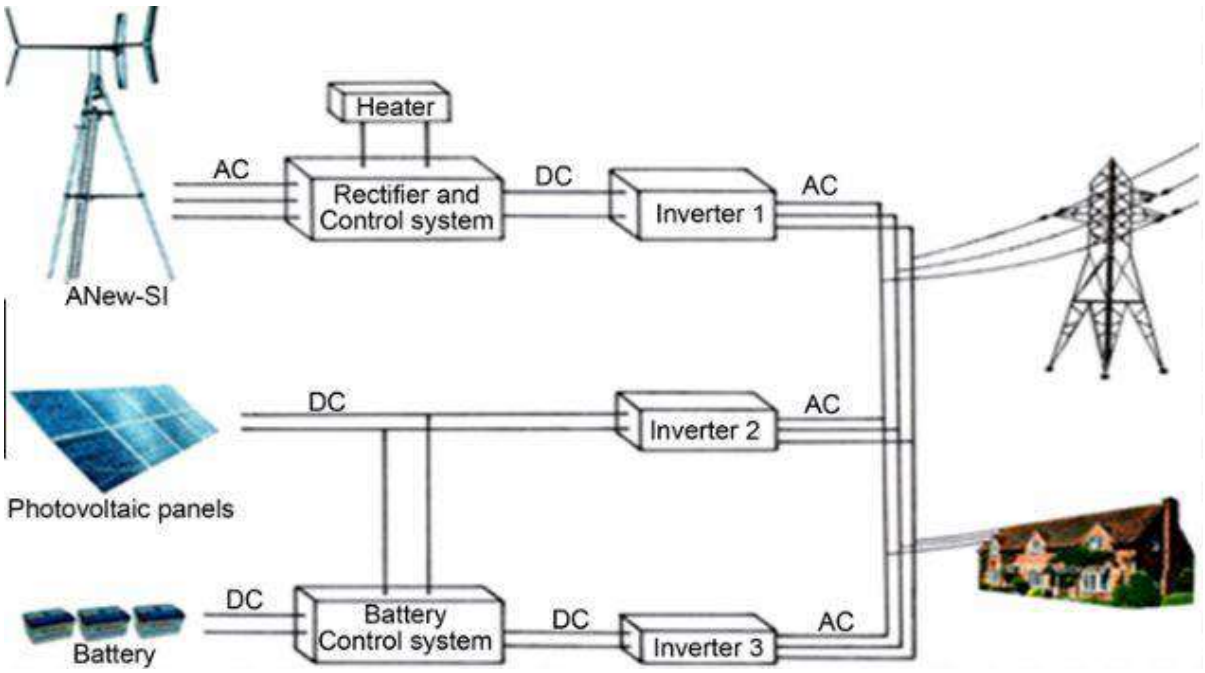


Figure 2.22: The basic diagram of grid-connected PV-wind hybrid system.

2.7.2 Solar tracking system in SHS:

Solar irradiation doesn't same for all day long. But conventional solar Panel doesn't follow the solar irradiation. So these technology needs to be more update so that it can follow the sunlight. This is called solar tracking system. It is very effective for maximum solar power from the panel.

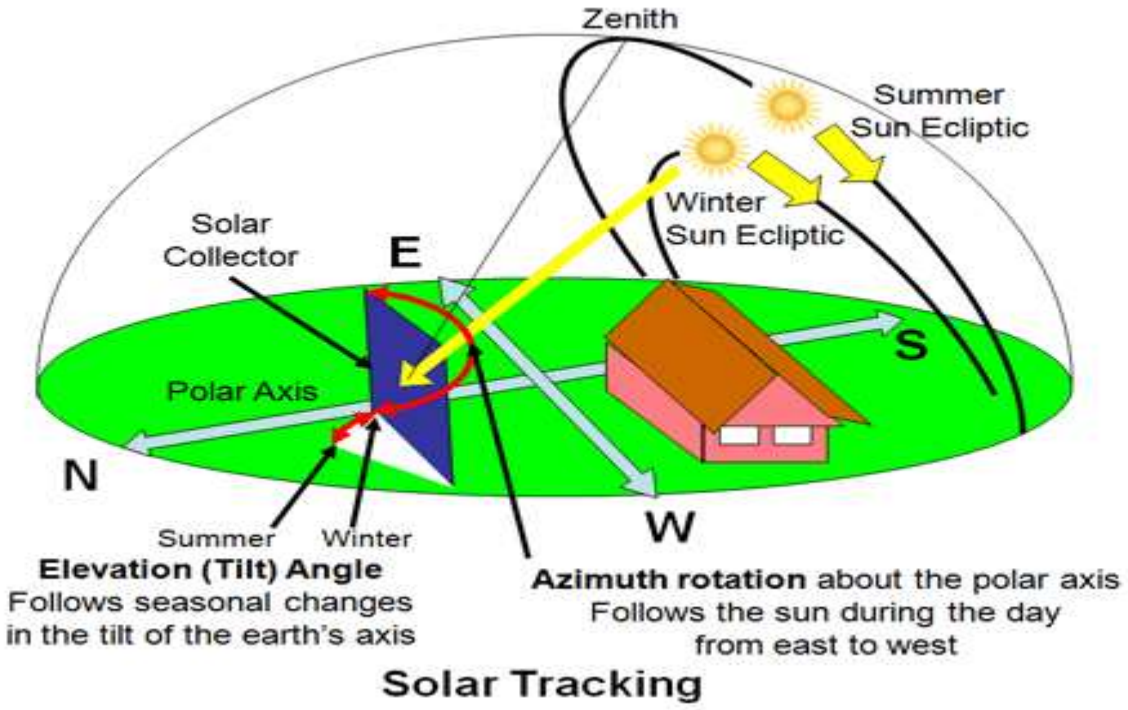


Figure 2.23: Solar Tracking System

2.8 Geographical condition for Bangladesh Solar Irradiation

Solar energy is one of the most potential renewable energy resources in Bangladesh as solar radiation falls on an average of 5kWh/m2 with over 300 sunny days per annum. The Government of Bangladesh has already launched "500MW Solar Power Mission" to promote the use of renewable energy [19].

For solar PV electricity generation sun irradiation rate is very important term. Like there are many countries in Antarctica where most of the time sun doesn't irradiate fully. So we can't use this renewable system in there. But luckily in our country the rate is quite satisfactory.

Dhaka is the largest city and the capital of Bangladesh. It is also one of the largest cities of South Asia, with the population of about 12 million people. It is a very old historic city, with

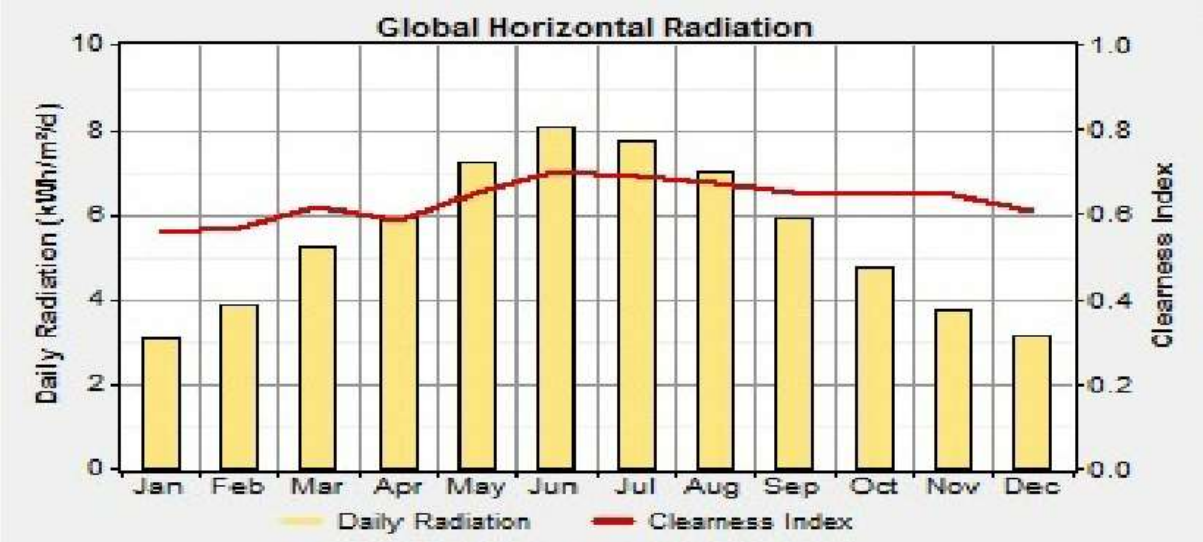


Table 3: Average Solar irradiation of Bangladesh

Plenty of cultural and other types of attractions, which is visited by a great number of tourists every year. The latitude of Dhaka, Bangladesh is **23.777176**, and the longitude is **90.399452**. **Dhaka** is located at *Bangladesh* country in the *Cities* place category with the gps coordinates of **23° 46' 37.8336'' N** and **90° 23' 58.0272'' E**[3]. Bangladesh have a great potential to use solar irradiation as a solar power to produce electricity.

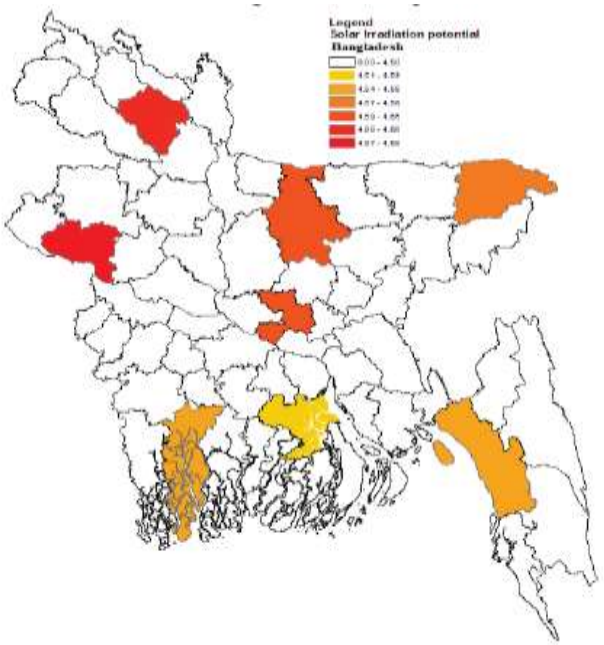


Figure 2.24: Solar irradiation potential of Bangladesh

2.9 Economic view of Energy:

Energy is something that helps us to do our day to day work; sometimes it helps us to make us comfortable, sometimes it gives us better living. Energy is directly related to the economy. As well as Electrical can converted into many other form of energy easily and effectively. So that economy can be affected easily by energy.

2.10 Socio-economic impact in rural area by using Solar Energy:

After having solar electrification in remote area or rural villages in Bangladesh their total socio-economic development somewhere depends on the Solar Electrification. People can make them more social and self-supportive than before. They can create a huge concentration about their child education; they can start a small business. This rural electrification can make people more aware about their living, birth control, family relationship. They can connect themselves to outside of the world so that they are more social than before which also create interest for education. Overall socio-economy directly or indirectly depends on the electrification. They can use mobile phone or television so that they can get an information from outside of the world for agricultural information, Health information, and some for entertainment purposes. It has proved that renewable energy can make the change to change some social issue. We saw that there was a lot of change in socio-economy, Education like- Children were studying at night and they were mush aware about education , Increased small businesses like- weaving, kitchen-gardening, small service industry , productive works like rice-mill, water pumps, a straw chopper, poultry farm, improved cultural vision, the relation between the villagers increased, villagers are now passing more time the society people and the family , almost all the household in the village heavily relied on the biomass (firewood, animal residues, agricultural crops residue) for heating, cooking, and lighting purpose. The adverse impact of which are degradation of natural forests, susceptible to indoor air pollution leading to a health problem. [15].

2.11 Micro financing for rural SHS Installation:

In rural area people are not likely to buy a panel with some necessary equipment with one down payment. To make the solar Home system more reliable microfinance is more important. Many organization are trying to give that opportunity to the village people. Microfinance basically a short term loan for any socio-economic purposes .For rural community. Grameen Bank gives people a short term loan for development . Grameen Shakti (GS) is one of the sub organization which is funded by Grameen Bank for solar Home System (SHS).Given Loan is recovered from regular monthly or weekly installments .It actually help people to install a SHS and inspire them a lot . Infrastructure Development Company Limited (IDCOL) actually work on renewable energy projects in Bangladesh. IDCOL play a important role in executing renewable energy projects in Bangladesh[16]. Then SHS program in Bangladesh established by REREDD-Rural electrification and Renewable Energy Development Project by help of GOB as a non-bank financial institute. First IDCOL has targeted 50000 SWHS program and achieved it within the year 2008.Then IDCOL revised it's target for installing 200000 SHS by the year 2009 with the help of World Bank(WB).After the end of the year 2009 , in 2010 IDCOL had crossed the target by achieving the 210000 SHS program with few wind, biomass and mini-hydro projects .The total estimated cost was around $70 million. The total project was completed by some specific group and operation like –Microfinance Institute (MFIs), technical standard committee, suppliers etc.[16]. Still now SHS program have around 438000 SHSs by the help of the major contributor GS which is a partner organization of IDCOL. Total capacity from the SHS is now 15.5 MW and the daily power generation capacity is now 62 MW-hr.. This is a great success of SHSs. Because the people of rural area had never dreamed it before that they would able to do the same thing like the digital world. SHSs program basically worked in two ways that who had no electricity connection and who want to reduce grid electricity consumption .People who couldn't think a night without darkness now they are more confident and self-dependent. They are now studying, they are using solar power to install small business like tailoring shops etc. So Overall This program have created a new era for the rural people to participate the socio-economic development This SHS program is not only for solar electricity it also contributing women empowerment , self indepency, Literate rate, Family planning etc. By electrification of this off grid area by SHS has created lots of job, which have also contributed for unemployment problem for any society[16]

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this section, we will discuss the process of data collection method and research tools. We will collect the data for our research in two different ways. One is primary Data which we have collected form our solar lab. Another hand we have collected the secondary data from rural village where solar home system have established.

3.2 Site Selection for primary data

A study area is a place where we collect data for our necessary work. Our study area has established in Daffodil International University Administrative Building rooftop. It is situated Dhaka 1215, Bangladesh. Different types of solar panel have installed their such as 45W, 60W and 100W. We study the performance analysis the power of 60W & 100Woff grid solar panel.

Figure 3.1: Study Area for primary

3.3 Satellite View

Figure 3.2: Satellite View

3.4 Site selection for Secondary data

Basically we have finished our survey in a small region of the district Bhola,Upozilla-Monpura, Bangladesh. People were using fossil fuel like-oil to light up. But now they are in the blessings of Solar Home System. Now they are using the solar power and store it to their regular usage. We have surveyed about the SHS and got some great result. We have tried to survey all the matters and factors after having SHS installation. Having set that we made some analysis with an individual methodology named SWOT analysis. We have surveyed also to make sure that their life style and their social condition have increased then before.

Figure 3.3: Survey area of Monpura, Bangladesh

3.5 System Design

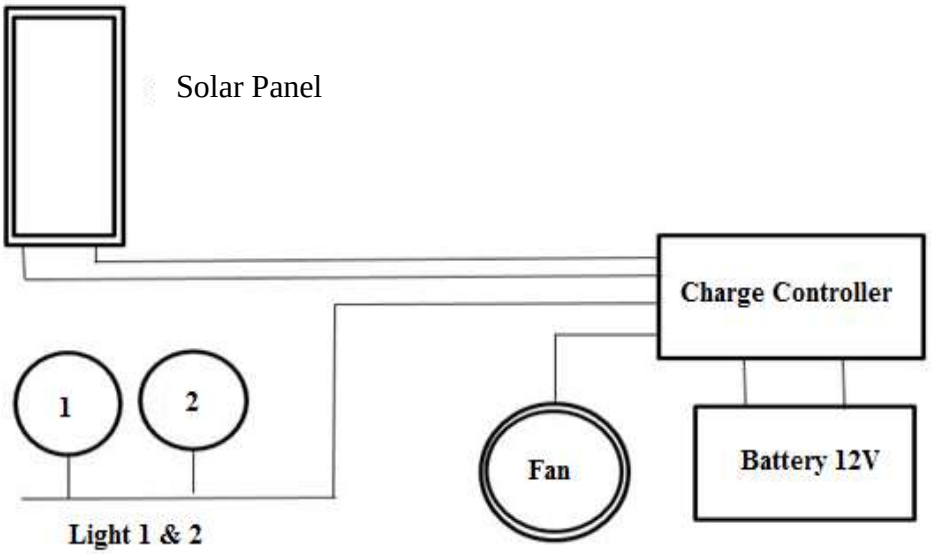


Figure 3.4: System Design (45W)

3.6 Research Machineries & Tools

Some tools have been used to collect data such as I-V 400w, temperature sensor, 60W & 100W solar panel, irradiation sensor (HT304N).

3.6.1 100W Solar Panel

The cells of the solar made in Germany. To measure power in Standard Test Condition (STC) cell temperature is 25°C. These solar cells made in Germany and the efficiency of the 100W panel is 14%.

3.6.1(a) Electrical Specifications

Maximum power: 100W

Open circuit voltage: 21.42V

Short circuit current: 4.63A

Voltage at maximum power: 17.10V

Current at maximum power: 3.63A

Module dimension: 580*550*35mm

Module weight: 4.16KGS±3%

Figure 3.5: 100W Solar Panel

3.6.2 I-V 400W

I-V 400w enables to measure of the I-V characteristic of the main characteristic parameters both of a single module and of a whole photovoltaic system up to a maximum of 1000V and 10A. The obtained data are then treated to anticipate the I-V characteristic under standard test conditions (STC) and comparing with rated data. Irradiation and temperature sensor plays a tremendous role for extrapolation of the I-V characteristic under the standard test conditions. Open circuit voltage and short circuit current can measure through the device. With a mobile device, HTANALYSIS™ helps to determine and understand problems may have the in-PV Installations.

Figure 3.6: I-V 400 W Photovoltaic Panel Analyzer

3.6.2.1 Electrical Specifications

Table-4: range, resolution and accuracy

Parameter	**Range (V)**	**Accuracy**
VDC Voltage @ OPC	5.0 - 999.9	±1.0%
IDC Current @ OPC	0.10 -10.00	±1.0%
Max Power @ OPC (Vmpp>30V,	50 -9999	±1.0%

Impp>2A)		
VDC Voltage (@ STC and OPC)	5.0 -999.9	±4.0%
IDC Current (@ STC and OPC)	0.10 -10.00	±4.0%
Max Power @ STC (Vmpp>30V, Impp>2A)	50 -9999	±5.0%
Irradiance (with reference cell)	50 -1400	±1.0%
Temperature of module (with auxiliary PT1000 probe)	-20.0 -100.0	±1.0%

3.6.2.2 General Specifications

DISPLAY AND MEMORY:

Features: 128x128pxl custom LCD with backlight

Memory capacity: 256kbytes

Saved data: 249 curves (I-V curve test), 999 IVCK

POWER SUPPLY:

SOLAR I-V internal power supply: 6x1.5V alkaline batteries type LR6, AA, AM3, and MN 1500

Autonomy of SOLAR I-V: > 249 curve (I-V curve test), 999 IVCK test

Approx 120 hours (yield test)

SOLAR-02 power supply: 4x1.5V alkaline batteries type AAA LR03

SOLAR-02 max recording time (@ IP=5s): approx 1.5h

OUTPUT INTERFACE

PC communication port: optical/USB

Interface with SOLAR-02: wireless RF communication (max distance 1m)

MECHANICAL FEATURES

Dimensions (L x W x H): 235 x 165 x 75mm

Weight (batteries included): 1.2kg

ENVIRONMENTAL CONDITIONS:

Reference temperature: -20°C - 5°C

Working temperature: 0° - 40°C

Working humidity: <80%HR

Storage temperature (batt. not included): -10 - 60°C

Storage humidity: <80%HR

GENERAL REFERENCE STANDARDS:

Safety: IEC/EN61010-1

Safety of measurement accessories: IEC/EN61010-031

I-V curve measurement: IEC/EN60891 (I-V curve test)

IEC/EN60904-5 (Temperature measurement)

Insulation: double insulation

Pollution degree: 2

Overvoltage category: CAT II 1000V DC, CAT III 300V AC to ground

Max 1000V among inputs P1, P2, C1, c2

Max altitude of use: 2000m

3.6.2.3 Temperature Sensor

It senses temperature from the solar cell and sends data to the I-V 400w.

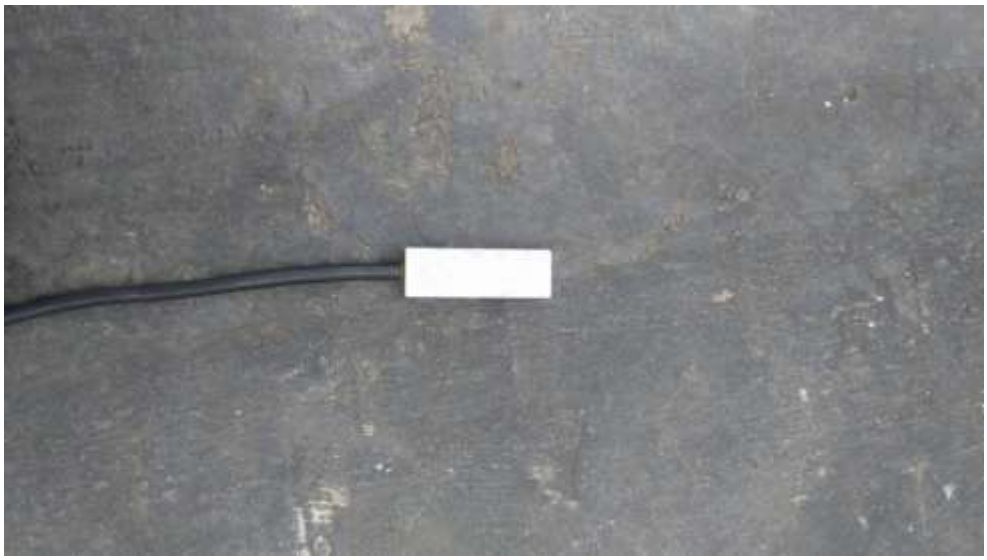


Figure 3.7: Temperature Sensor

3.6.2.4 Irradiation Sensor (HT304N)

This device (Fig. 35) can able to measure as MONO PANELS or MULTI PANELS. It is a passive sensor and does not necessary any power supply.

Figure 3.8: Irradiation Sensor

3.6.2.5 Technical Specifications

Table-5: range & accuracy

Parameter	**Range [W/m^2]**	**Accuracy**
Irradiation	50 - 1400	±3.0% of readings

3.5.2.6 General Specifications

Available reference cells: MONO Crystalline and MULTI Crystalline Silicon

Guidelines

Safety: IEC/EN 61010-1

Technical literature: IEC/EN 61187

Calibration: IEC/EN 60904-2

Mechanical protection: IP65 in compliance with IEC/EN 60529

Pollution degree: 2

Mechanical characteristics

Dimensions (LxWxH): 120x85x40 mm

Weight: 260g

Environmental conditions

Working temperature: -20°C - 50°C

Storage temperature: -20°C - 60°C

3.7 Flow Chart

A flowchart is a type of diagram that represents a workflow or process. The flowchart displays the steps as boxes of numerous kinds and their order by connecting the boxes with arrows. We used flowcharts in analyzing, documenting or managing a process or program in various fields.

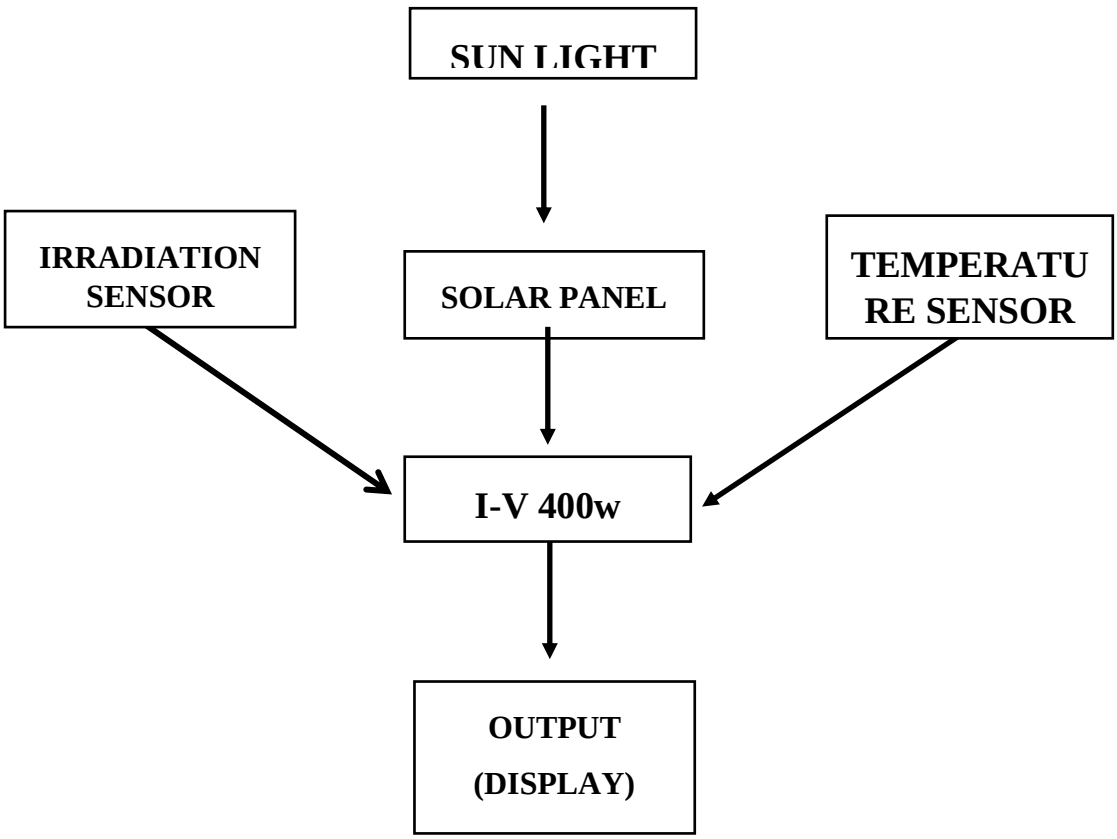


Figure 3.9: Flow Chart

3.8 I-V 400 W Calibration

Before starting the measurement, we must have to calibrate I-V 400 W. For I-V 400 W calibration parameters has given below Table-4

Table-5: I-V 400 W Calibration.

For 60 W panel

Pmax	60 W
Voc	21.50 V
Vmpp	17.50 V
Isc	3.76 A
Impp	3.45 A
Toll-	1.0 W
Toll+	1.0 W
Alpha	0.033 %/°C
Beta	-0.34 %/°C
Gamma	-0.42 %/°C
Noct	45 °C
Tech.	STD
Rs	1 Ω
Degr	0.0 %/yr

For 100 w panel

Pmax	100 W
Voc	22.68 V
Vmpp	19.12 V
Isc	5.60 A
Impp	5.23 A
Toll-	1.0 W
Toll+	1.0 W
Alpha	0.033 %/°C
Beta	-0.34 %/°C
Gamma	-0.42 %/°C
Noct	45 °C
Tech.	STD
Rs	1 Ω
Degr	0.0 %/yr

3.9 Data Measurement Technique

In May, we collected data from sunrise to sunset (time 5.14 to 18.35) and used I-V 400w photovoltaic panel analyzer to measure data. Firstly, setting up irradiation and temperature sensor connect with I-V 400 W photovoltaic panel analyzer. Secondly, 45 W solar panel output cables connected with I-V 400 W. The measured data was in Standard Test Condition (STD) form then which we converted these data into Operational Condition (OPC) form.

Figure 3.10: Data Measuring

Table- 5: Data Sample

SL	Time (Sunrise to sunset)	Irradiance (W/m^2)	Voltage (V)	Current (I)	Vmpp(V)	Impp(I)	Fill Factor	Pmax (W)	Efficiency (%)
1	5.23	0	0	0	0	0	0	0	0
2	6.23	121	20	0.27	11.5	0.19	0.4	2.185	5.66%
3	7.23	141	20	0.35	17	0.14	0.34	2.38	5.29%
4	8.23	481	20.6	1.15	18.2	0.85	0.65	15.47	10.08%
5	9.23	467	20.5	0.95	17.9	0.79	0.75	14.14	9.49%
6	10.23	633	19.8	1.62	7.1	1.41	0.31	10.01	4.96%
7	11.23	888	20.1	2.01	18.2	0.76	0.34	13.83	4.88%
8	12.23	455	19.1	0.92	6.9	0.94	0.37	6.486	4.47%
9	13.23	622	20.1	1.69	7.6	1.39	0.31	10.56	5.32%
10	14.23	530	20	1.24	7.6	1.12	0.34	8.512	5.03%
11	15.23	190	19.4	0.46	14.1	0.46	0.73	6.486	10.70%
12	16.23	251	19.9	0.43	18.9	0.16	0.35	3.024	3.78%
13	17.23	47	17.7	0.11	6.1	0.09	0.28	0.549	3.66%
14	18.27	0	0	0	0	0	0	0	0

Table-5 represents parameter-wise data of a single day (May 3, 2018) starting from sunrise to sunset. Where,

Voc = Open Circuit Voltage of Solar Panel

Isc = Short Circuit Current of Solar Panel

Vmpp = Maximum Voltage of Solar Panel

Impp = maximum Current of Solar Panel

Fill factor = (Impp*Vmpp)/(Isc*Vsc)

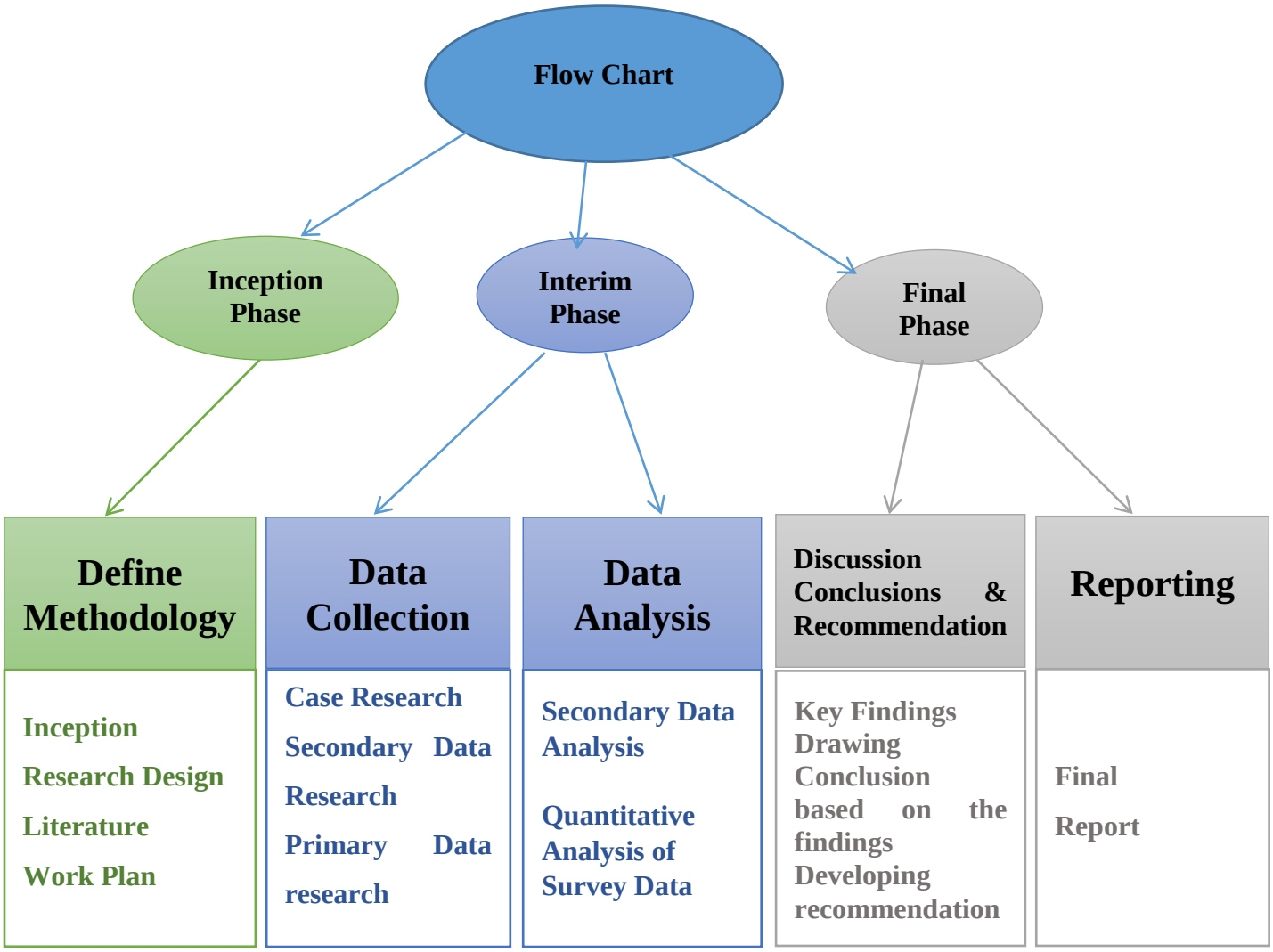
Pmax = Maximum Power

Efficiency = Ratio of output & input power

The research is done by the help of both primary and secondary data. Basically the primary data collected from the internet, from the literature, interviewing with the solar home system user. General information regarding the SHS dissemination program and socio-economic impacts of solar electricity are collected from secondary source and interviews with local experts. Primary data of the study are collected through an extensive household survey and the off-grid solar home system solar panel method using questionnaire. Secondary sources are also used to support the survey data. Basically we have tried to do score analysis.

To observe those problem we had to collect data from the area of implementation such as The size of panel(PV cell Panel),And battery size ,Number of Load, Number of Electrical Gadget, Future Demands, Monthly Income Of the village people .We have analyzed the data after communicating with the local people. We discussed with the people about their economical and family condition so that we can suggest them to install the proper size of the panel .Then we made some particular data series to evaluate the panel size, battery size and other accessories .The particular series are –No of family members & Education level vs. Panel size, Battery Size vs. panel size, Income vs. demand, number of people vs. income. After having all the data observation we can find the proper size of panel and battery needed .

Methodology flow chart:



3.10 SWOT analysis:

SWOT analysis is a framework used to evaluate a company's competitive position by identifying its strengths, weaknesses, opportunities and threats. Specifically, SWOT analysis is a foundational assessment model that measures what an organization can and cannot do, and its potential opportunities and threat. Basically it used for purposes but in our study we used it to find out the socio-economic impact for using Solar Home System.

We have made some questionnaires by using this SWOT analysis for our study so that we can find out our desired result. Our secondary data has processed by using this method and questionnaires.

SWOT analysis

	Indicators	Research question
Strength	-Environment -Manpower -Micro-financing	How environment can be the strength of SHS? How manpower can affect in SHS? Micro-Financing is really helpful for SHS installation or not? How Peoples co-operation effect on it?
Weakness	-efficiency -Reliability National and International Regulation -Returns/Reward -Motivation	How effective this specific SHS comparison to the Maximum efficiency SHS? How effective this specific SHS comparison to other Conventional energy sources? What responses can be expected from the SHS user? What national and international regulation or policy Might arise to the SHS? What kind of returns/reward should give to the consumer to improve the SHS efficiency?
Opportunities	-Education -Financial sufficiency -Women Empowerment -Eco-Friendly Environment	What opportunities are available to improve the education level? What are the real or potential risks with the opportunities? What are the factors of the region that connected with the social factor? How women are contributing their family or society?
Threats	-service/support -increase financial ability -Technology -Co-Operation -national policy	How illiterate people are challenges for this study? Is panel efficiency is really satisfying or not? Consumer can really get proper and full support /service from the installation company? SHS is really helpful to increase people's financial ability? What would be required to develop the necessary for installing and maintaining the technology for SHS? How it would be done to make connectivity between policy maker and consumers for SHS?

CHAPTER 4

DATA ANALYSIS

4.1. Introduction

Our study is basically data analysis based. Our work have divided into two part. One part is seems to be technical and the other part of our study is basically survey based. Every study should have proper data.

4.2. Data Analysis:

Our work basically depends on two segments. Firstly we measured the technical data from the panel to measure the irradiance of the sun, power of the panel to get an idea how much maximum power can be generated from the panel. Our intention was to analyze the maximum possible power output and also per unit cost. Secondly we surveyed a rural area which is covered by solar home system to analysis the socio-economic impact and also determined the constrains and challenges. Our survey basically done by a analysis called SWOT analysis.

4.3Technical Data analysis:

To determine the technical data we used our small solar lab. In our solar lab there are 3 panel available 100W, 60W and 45W. These three panels are basically off-grid. Basically solar Home system is off-grid. We have determined the data for the month of September-2018.We have determined the irradiance and the possible average power from the panel. We used the specific meter and also the specific method which we have already described above.

4.4 Irradiation pattern and performance testing:

Villagers are using solar Home system to make them more capable socially and economically .But most importantly cannot take care of this panel. They have no idea how it work. How much maximum power can be collect from those panels? What type of maintenance is necessary to make the system more reliable? To know this we have performed the test for one month named irradiance pattern and performance testing in our small solar lab.

4.4.1. Monthly average irradiance for September-2018 for 60W panel:

We have analyzed 1 month's data to measure the maximum efficiency we can get from the panel. We have analyzed the irradiance and the power in our small solar lab. We have analyzed 60W panel irradiance pattern and power. For the month of September, maximum irradiance measured on 7th September 472.14 w/m^2 and also the 17th and 28th September accordingly 406.92 w/m^2 and 405 w/m^2. Also lowest irradiance measured on 13th September 81.42 w/m^2 .

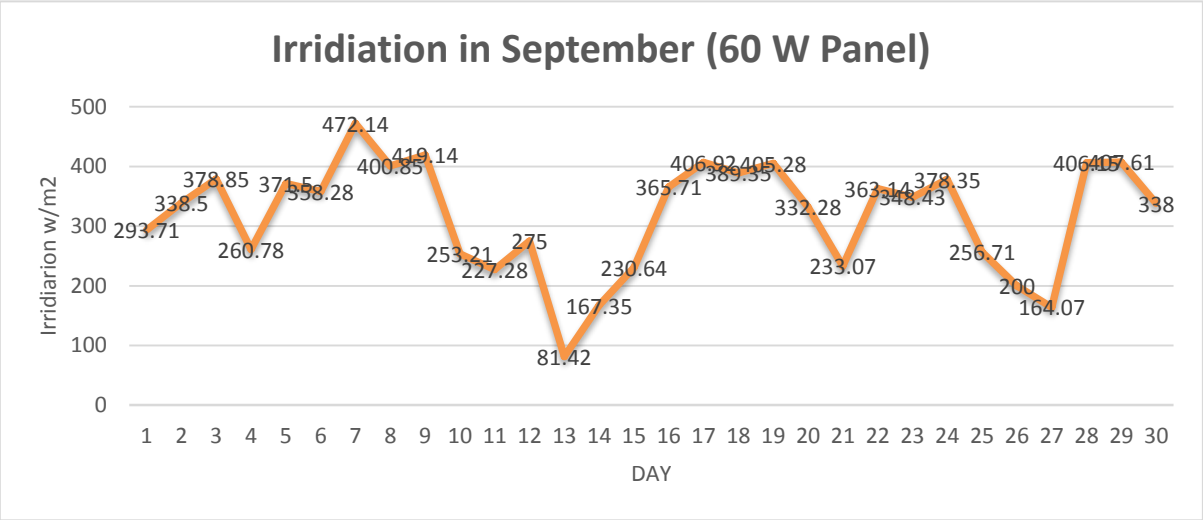


Figure 4.1: Irradiation in September of a 60W Solar Panel

This measurement shows some average irradiance data per day. Basically September month Mostly sunny and rarely cloudy for the city of Dhaka. But sometimes the irradiance is too low just because of cloudy day.

4.4.2. Average maximum power for September-2018 for 60W panel:

We have collected month irradiance, current voltage, and power for 60Wpanel. Then we plotted a graph for maximum power for day to day basis. So that we can get an idea for any solar system how much maximum power can be generated by the panel? We can see that there is a huge power variation for day to day basis. Panel output power basically depends on the irradiation. We can see from the graph showed in below that the maximum power is 19.27 w at the day of 29.And lowest average power 3.48 at the day of 13.

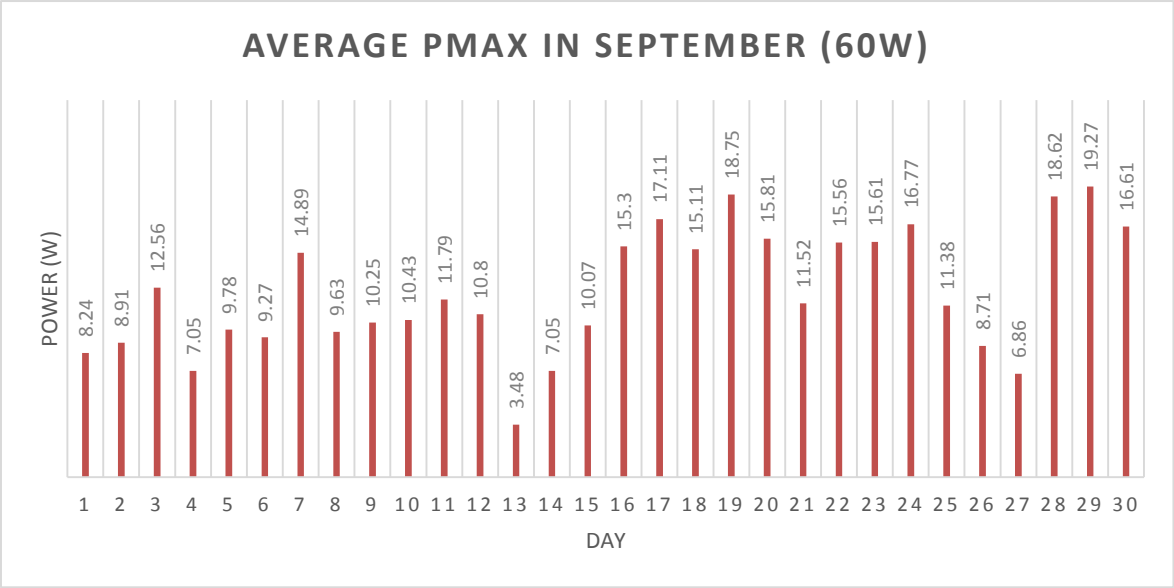


Figure 4.2: Average maximum power per day septemnber-2018, 60W panel

4.4.3Monthly average irradiance for September-2018 for 100W panel:

We have also repeated previous process for 100W panel. We can see that maximum irradiance we get from the 20th day which is 430.5 w/m^2 . Also 426.14 w/m2 for day 2 , 416.64 w/m2 for day 18, 405.84w/m2 for day 28. We have also get some lowest irradiance at the day 13 which is 76.14 w/m2 and also the day 2y which is 127.53 w/m2.

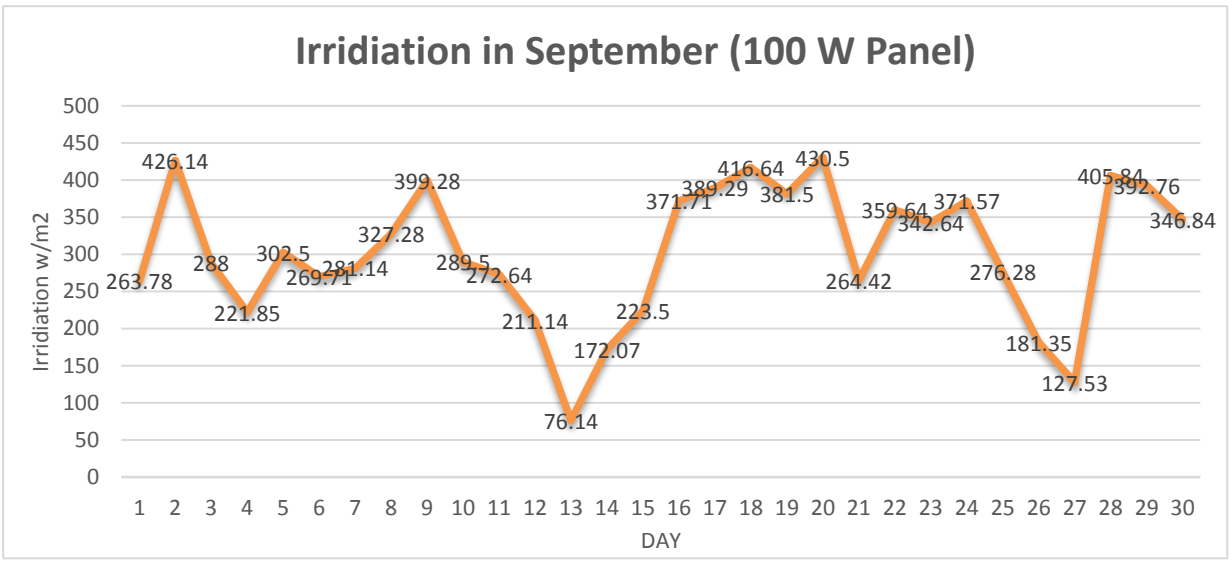


Figure 4.3: Irradiation in September (100 W Panel)

4.4.4.Average maximum power per day september-2018 for 100W panel:

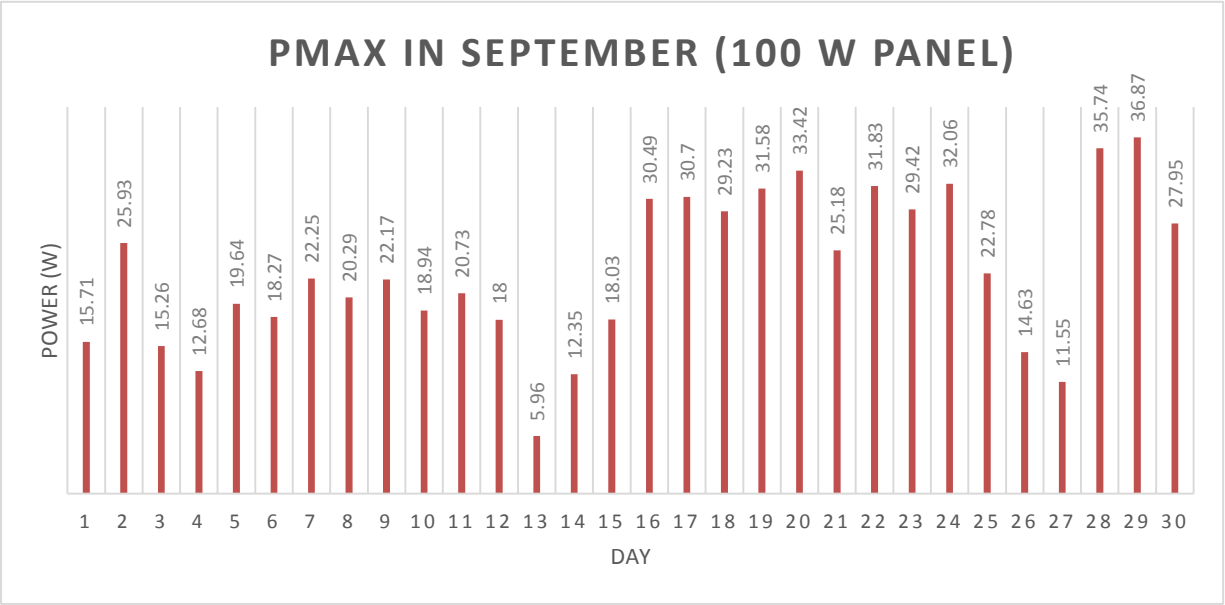


Figure 4.4: Pmax in september (100 w panel)

4.5. Power variation for sunny and cloudy day:

In September most of the day was sunny. So they gave most power. Actually in Bangladesh environment is very helpful for solar power. This sunny environment is our opportunities for us .Basically power of solar panel depends on irradiation from the sun. We have just analyzed the one month data to get an idea that the variation of power.

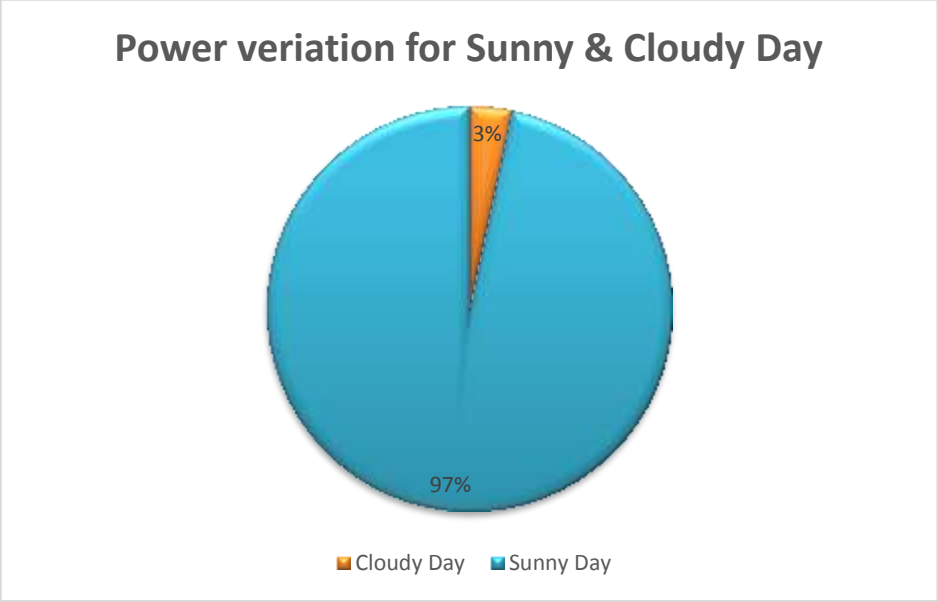


Figure 4.5: Power variation for Sunny & Cloudy Day

4.6 Final findings from solar lab:

For 60w panel

Average Power Generation per day = 11.38*14 = 159.32Wh

Average Power Generation per month =159.32*30 = 4779.6Wh

Average Power Generation per year =4779.62*12= 57355.2Wh

Average Power Generation after 20 years(Wh) =57355.2*20= 1147104Wh

Average Power Generation after 20 years(KWh) =1147104/1000=1147.10KWh

Approximate panel & battery cost for 60w pane l=12500 tk

Maintenance cost for 60W panel :

Cleaning and distilled water cost for battery per year =500 tk.

For 20 year (life time of panel) =(500*20)

=10000 tk.

Charge controller cost =500 tk. (approximately)

But charge controller life time is not so long . Charge controller can be transferred for every three year.

For 20 year life time we need approximately 5 charge controller

Total cost for charge controller =(5*500)

=2500 tk.

Total Cost for battery, panel & maintenance & charge controller =(12500+10000+2500)

=25000 tk.

Cost per unit for 100 W Panel = 25000/1147.10

=21.79 tk

We can see that the per unit cost per kwh solar renewable energy is 21.79tk (approximately). In our solar lab we have calculated the total power unit cost for renewable energy.

4.7 From SWOT analysis:

Our technical data was measured or determined by the specific method. According we have chosen another specific method named SWOT analysis for social and economic data analysis. This method will give us specific output so that we can predict or analyze the possibility, challenges and constrains as well.

4.8 Strength of SHS:

In our survey area there were some strength at that time. Strength is something which is the main or initial part for all of this. We found some strength like Suitable Environment, Micro Financing, manpower etc. Suppose we have such weather where irradiance is too low so that we cannot install the solar Home system. Suppose we irradiance but we don't have manpower so we can't get any positive result.

Strength :

- Suitable Environment-Irradiance is high so that solar power can be converted to electrical energy.
- Manpower – In this particular village there are huge number of consumer or family member so that there is a huge possibility to improve their social and economic status.
- Micro financing- People in village like monpura they are living a very simple life.So micro financing is the most important part for them.

4.8.1 Suitable environment:

We have collected the value of irradiation in the year of 1985 to 2018.We have seen that in 1985-1991 irradiation was 3.96kWh/m2/day and then it was randomly increasing till the year of 1992.Then the year of 2000 again irradiance started to decreased. In the year 2008 again irradiance rate increased to 4.55 kWh/m2/day.

Table: Different Year Irradiation of September Month

Year	Month	Irradiance kWh/m^2/day
1985-1991	September	3.96
1987-1989	September	4.5
1992	September	5.38
2000-2003	September	3.76
2003-2005	September	3.78
2008	September	4.55
2009	September	4
2010	September	3.97
2018	September	8.91

Then again started decreasing in year of 2009 Which is 4 kWh/m2/day and the year of 2010 irradiance rate is 3.97 kWh/m2/day .Then we that irradiance rate increased enormously .In 2018 irradiance rate is 8.91 kWh/m2/day.

In 2018 irradiance rate is maximum and which is almost doubled than the year of 2008. This is terrifying. In 2008 to 2018 our environment changed has occurred enormously. Earth temperature increased.

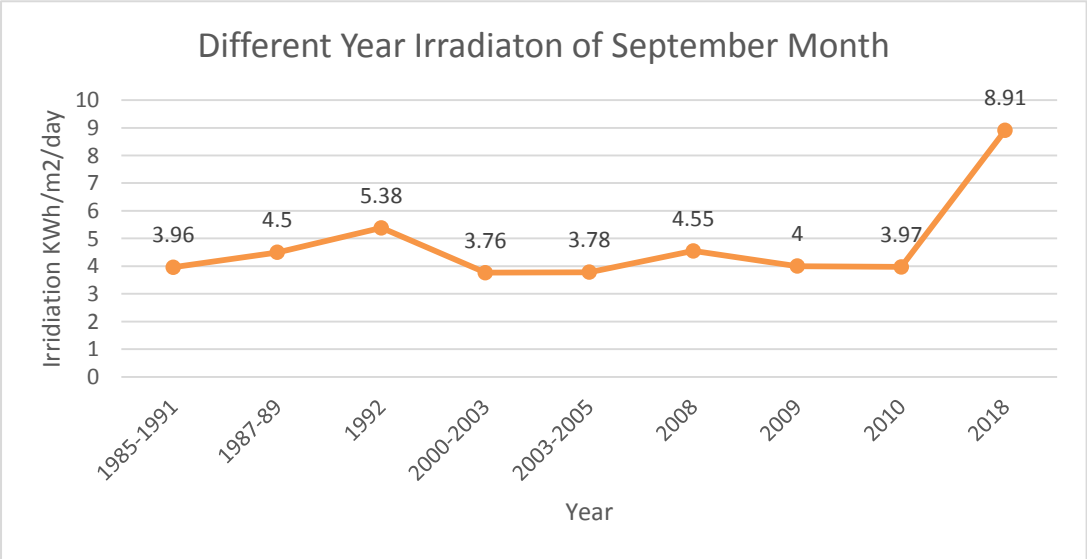


Figure 4.6: Different Year Irradiation of September Month

4.8.2 Manpower:

In this village manpower is the most important part. For any society manpower can contribute a lot for society. So for this region manpower is the most important part. For vast amount of man power can make a difference for changing the development of society socially or economically.

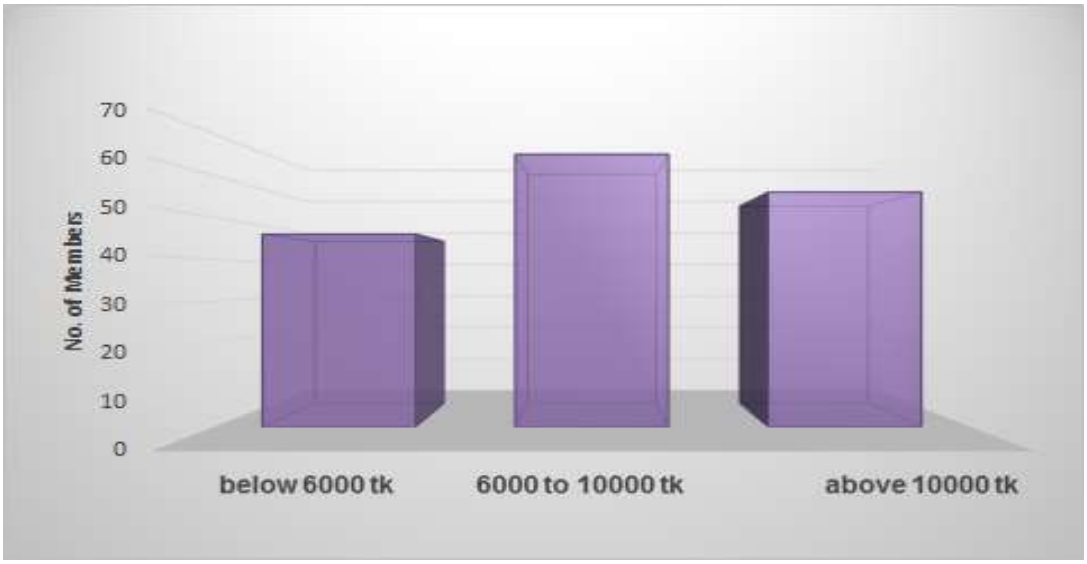


Figure 4.7: Total manpower on the basis specific income based family

4.8.3 Micro-Financing:

Micro financing is the most important part for thesis renewable electrification for any rural area. To make the solar Home system more reliable microfinance is more important. Many organization are trying to give that opportunity to the village people. Microfinance basically a short term loan for any socio-economic purposes .For rural community like monpura we have found that all the family have funded by an organization . This fund should be repayment with some small interest. For this reason people can easily installed solar Home system.

4.9 Weakness of SHS :

Weakness of the solar home system for this region is something that which affect the actually development. It it can be removed then maximum output can be gained. There are many weaknesses we have found in this specific Solar Home system region.

- efficiency
- Reliability

- National and International Regulation
- Returns/Reward
- Motivation
- Low synchronization of load, pane land battery size

4.9.1 Higher installation & per unit cost:

We have found that cost of panel & other appliance was not so reliable. For this higher cost of the total SHS the total cost have increased. So per unit cost have increased .We have calculated the per unit cost for our surveyed area "Monpura"

For 60w panel

Final findings for solar lab

Average power consumed per day		= 120Wh
Average power consumed per month	=120*30	= 3600Wh
Average power consumed per year	=3600*12	= 43200Wh
Average power consumed after 20 years(Wh)	=43200*20	= 864000Wh
Average power consumed after 20 years(KWh)	=864000/1000	=864KWh
Approximate panel & 2 battery cost for 60w panel		=42000 tk

Maintenance cost for 100W panel :

Cleaning and distilled water cost for battery per year	=500 tk.
For 20 year (life time of panel)	=(500*20)
	=10000 tk.

Charge controller cost =500 tk. (approximately)

But charge controller life time is not so long . Charge controller can be transferred for every three year.

For 20 year life time we need approximately 5 charge controller

Total cost for charge controller	=(5*500)
	=2500 tk

Total Cost for battery, panel & maintenance & charge controller =(42000+10000+2500)

=54500 tk.

Cost per unit for 60 W Panel = 54500/864

=63.08tk (approximately)

We see that the cost per unit is very high for this SHS.

4.9.2 Monetization from Government:

Government monetization is most important for any issue. Accordingly for electrification Govt. have a important role. Because they have a huge amount of experts and also they have fund and importantly they are committed to the people. So we have ssen that govt agencies are not much careful for this region .

4.9.3 Lack of awareness:

People of this region are not much educated. So that, they are not aware about Solar Home system. They don't know the maintenance process . They are not care about the maximum power. They don't know about the economy related to the energy.

4.10 Opportunity:

We found that after having SHS in this rural area, many factors have already changed positively and also have the opportunity for future social development.

- Education
- Financial sufficiency
- Women Empowerment
- Eco-Friendly Environment

4.10.1.Family Income before and after:

For any society economy is very important issue. We have plotted a graph which represents the income before SHS installation and after installation. We can see from the graph that after installing the SHS income has increased rapidly. Though we have separated into 3 different regions according to their income. Most of the people are farmer, shopkeeper, and fisherman in the range of first region. So after having SHS other family member also participated to contribute family income

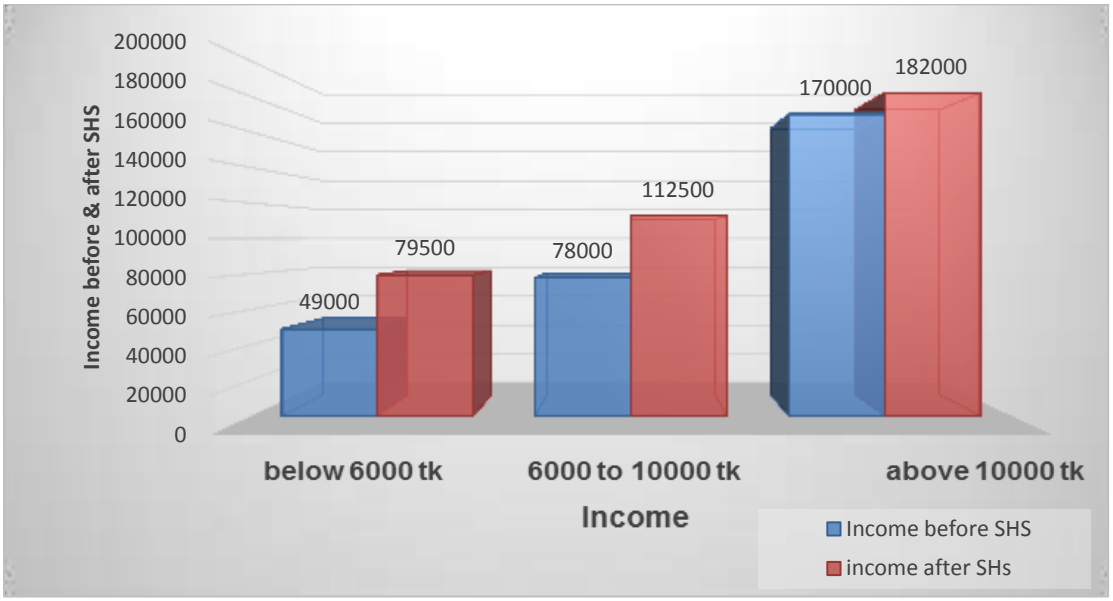


Figure 4.8: Family income before & after SHS

4.10.2 Villager's occupation and their income:

Table: Occupation for villagers who have income under 6000Tk

Income before using SHS	Income after using SHS	Occupation
6000	10000	Shopkeeper
4000	10000	Doctor
4000	10000	Doctor
6000	8000	Farmer
6000	10000	Farmer
6000	9000	Fisherman
6000	10000	Shopkeeper
5000	2500	Farmer
6000	10000	Farmer

Table: Occupation for villagers who have income is 6000Tk-10000Tk

Income before using SHS	Income after using SHS	Occupation
10000	8000	Shopkeeper
7000	7000	Farmer
10000	11000	Shopkeeper
8000	8500	Farmer
7000	7000	Farmer
8000	11000	Shopkeeper
10000	30000	Farmer
8000	15000	Fisherman
10000	15000	Farmer

Table: Occupation for villagers who have income is above 10000Tk

Income before using SHS	Income after using SHS	Occupation
15000	12000	Employee (daughter)
20000	12000	Farmer
15000	10000	Shopkeeper
15000	10000	Shopkeeper
18000	35000	Farmer
20000	25000	Farmer
15000	30000	Fisherman, Farmer
12000	8000	Shopkeeper
40000	40000	Driver

4.10.3 Student number before and after:

We have also plotted our collected data from the survey as no. of student after and before SHS implementation. This is the most crucial point for this study. Because the social improvement indirectly and also directly depends on the maximum number of educated people. We can see from the fig in every family whether their income is less or high no. of students have increased rapidly. This is the most positive part for this study. Mostly the lower class people who have the income level 6000 taka or below 6000 taka, massive amount of students number increased. But for the middle class people who have their income level 6000-10000 taka, it doesn't create much difference than other.

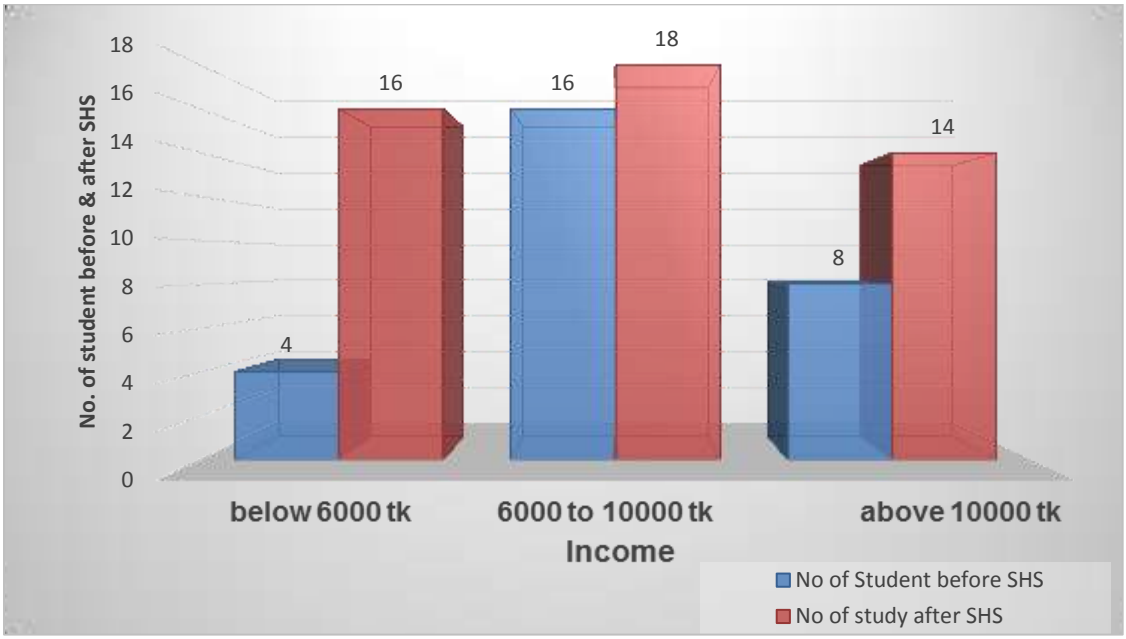


Figure 4.9: Number of students in the family before & after SHS

4.10.4 Study before and after:

Education is most important part for any society to improve their overall condition. We can see from the fig that study hour has increased enormously. People of this area basically were using kerosene to light up their house. So that it was tough to maintain their study for so long . After having SHS they can easily light up their house so that they can study more .

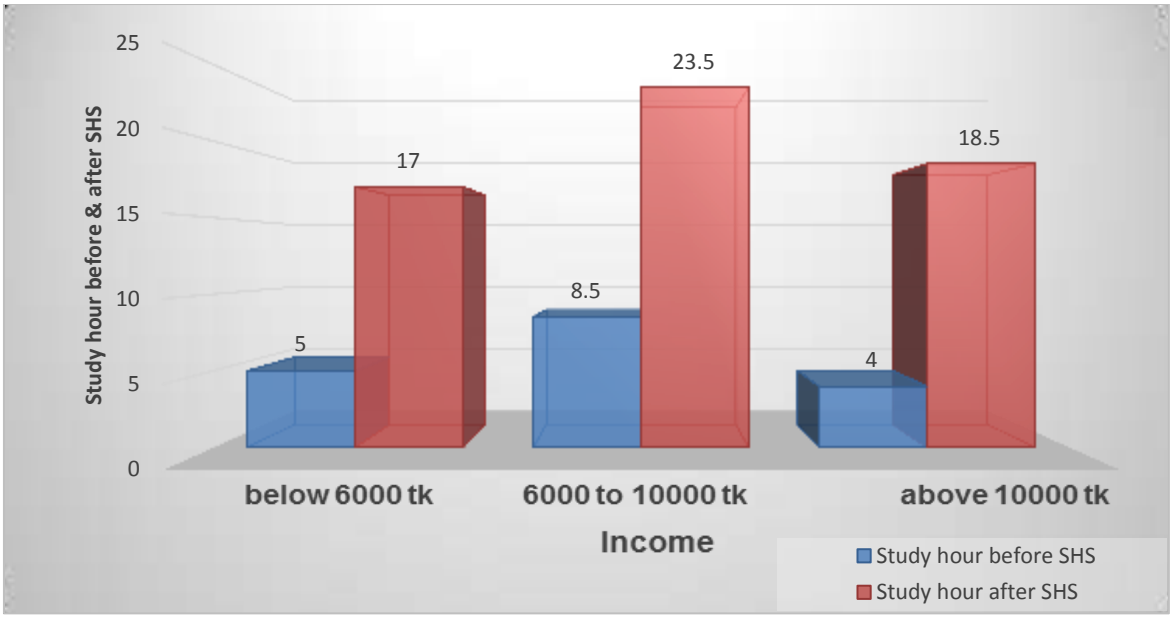


Figure 4.10: Study hour before & after SHS

4.10.5 Using rate of Kerosene before and after:

Before having Solar Home system villagers were using kerosene as a primary energy source. They were using kerosene for lighting up their house or room. We have differentiated the uses of kerosene before and after and before SHS installation. People who have their income under or equal to 6000tk, they were using average 6L of kerosene over a month. After SHS the uses rate slightly decreased to 1L or sometimes 0L.

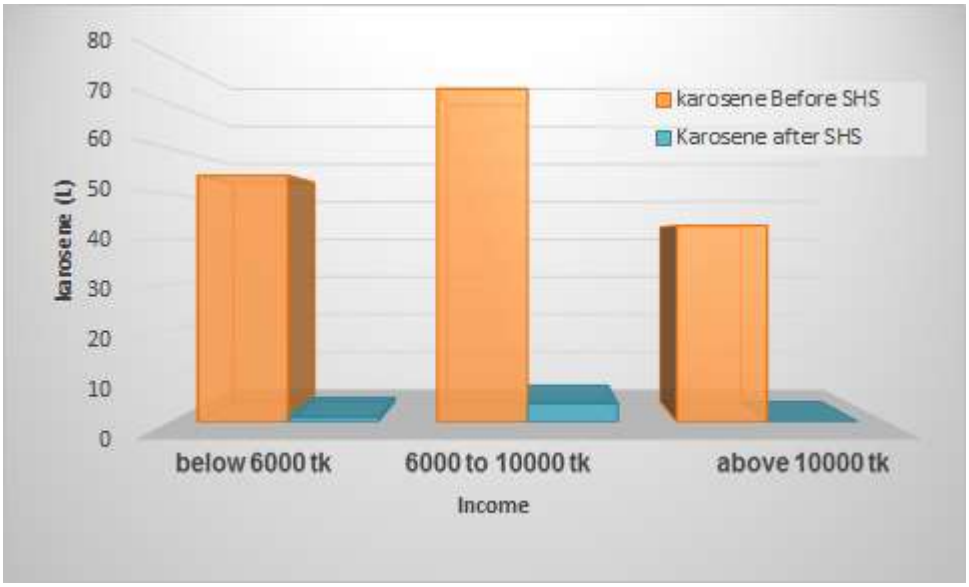


Figure 4.11: Using rate of Kerosene before and after

How much they were spending for buying fossil fuel now decreased. It also good for environment. But alternatively some people have also been less benefited who was shopkeeper.

4.11 Threats:

We found there are many threats for SHS. Which can affect the future development of the SHS. Threats are

- Panel efficiency
- service/support
- Technology
- Co-Operation
- Wastage of Equipment

4.11.1Technology used:

We found that technology is the threat for this region. They spend their money only for panel battery, and electronic appliance. Firstly they are not aware about the technology and other hand they don't have the capability to install.

4.11.2 Wastage of equipment:

Those electrical equipment which are expired of date and act like wastage are throw like garbage which very harmful for social environment.

4.11.3 Lack of Service and support:

Service and support are not enough for those rural area. The companies rolling actively at the panel setup time but after that they never came back for future services. This effect act as negative side and in future people lose their curiosity about solar free energy.

4.12 Final Findings:

We have analyzed our study by two ways. We have analyzed the irradiance pattern for Bangladesh solar electricity generation and also the socio-economic impact by using solar electricity in a rural village. We have collected irradiation rate for correspondingly 60w and

100W panel and also plotted day today basis. We have also calculated the power from the panel and plotted to identify the power variation.

4.13 Asymmetric combination of load, panel and battery size:

The combination of whole setup of SHS is not balanced in proper way at those rural area. For better efficiency its very important to select recommended battery and charge controller for those suitable panel. The panel have to be choose as load basis for decreasing the energy loss.

4.13.1. Panel size and their appliance load:

We have separated into 3 region where one region income is >=6000 taka, other one is 6000-10000 taka, and above 10000 tk. This fig shows the Total panel size (W) for individual income and total load for individual load (w). We can see that Total panel size for individual income region is much higher than the load size. We have identified the weakness about the panel size, load and battery capacity. They are not properly collaborated. That means most of the power is being wasted all the time because People are not concern about it. Even it can be possible if the people who supply the SHS equipment are helpful. Even most of the organization just wants to make the region electrified but they don't make the consumer more aware to maintenance and installation.

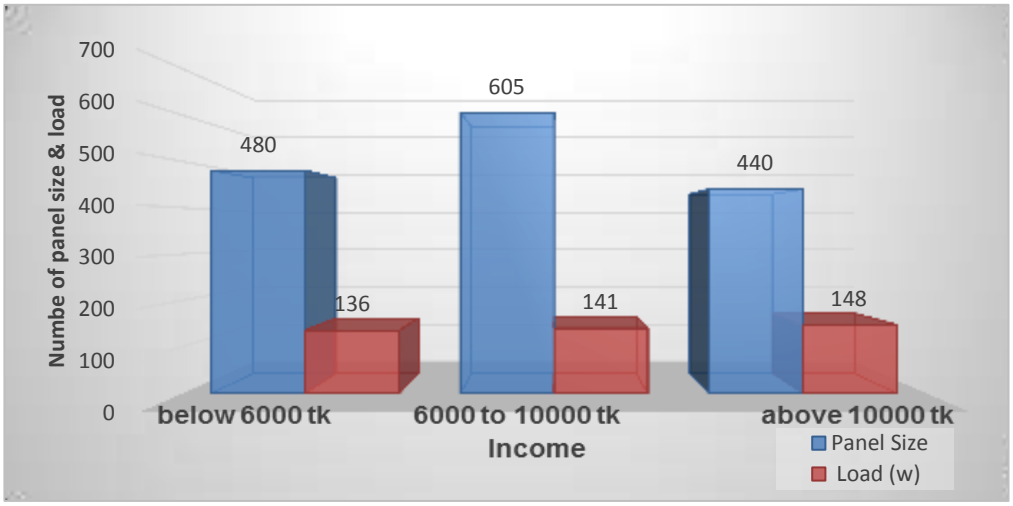


Figure 4.7: Number of panel size & load vs. Monthly income

4.13.2Number of family member and panel size

We have plotted a graph No. of family member & panel-size Vs. Monthly income. We have divided into three region according to their income. We see that which family income have 6000-10000 tk said as middle class people for specific region have the highest panel size and also the no. of member is high. The lowest panel size of the panel who have the income level

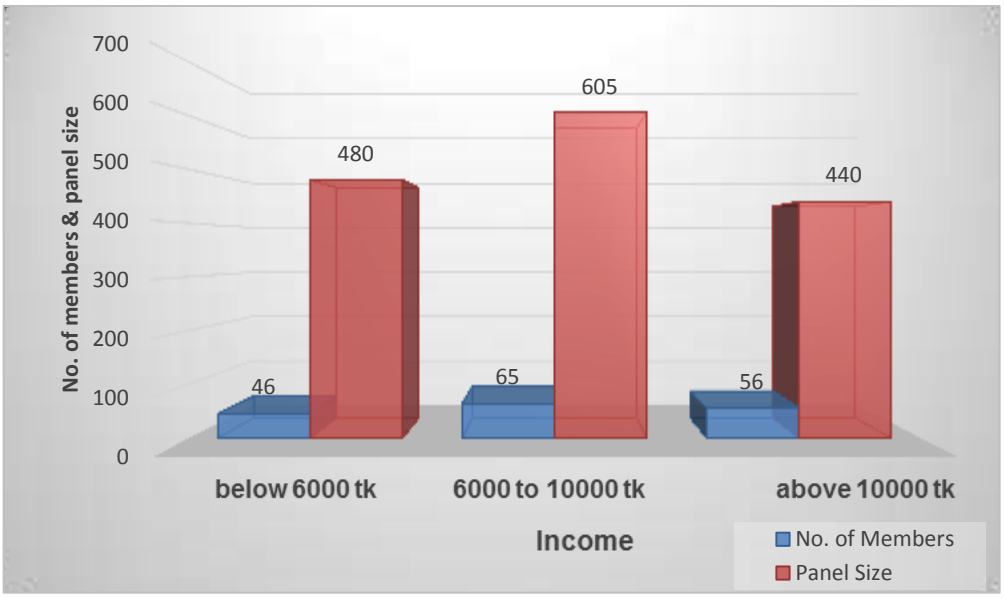


Figure 4.12: No.of Family members &panel-size vs Monthly income

4.14 Improved Social Factor:

Solar home system in a rural village like Monpura plays an important role. SHS is not only electrified them but also developed various factors related to the society. These social factors have increased their day to day life. SHS for rural electrification is like an investment. People have benefited by many ways.

4.15 Income increased:

This is the most important part for any society. We have seen the monthly income before and after using SHS. And we found that most of the family income has increased. Villager's occupation was not so big. Most of the people are farmer, Fisherman, shopkeeper etc. So when they were using SHS, they can spend more time with family. They are doing some extra work so that they can earn more money. Some villagers are doing tailor in night so that they can earn more money. Some people started a small business in house at night.

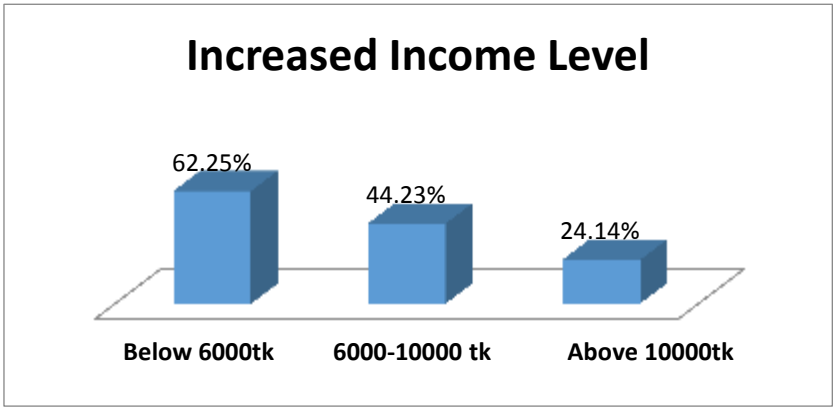


Figure 4.13: Increased income level

4.16 Education Level Increased:

Any developed region education is more important. We have seen the surveyed process data that education level increased than before. SHS users are now getting more time at night. So they are more aware than before. Student number increased rapidly after using SHS. Some people are using TV and they can connect themselves with outside of the world. This makes them more aware for education. When they haven't any solar Home System they got sleep early at night. Night was too long for them. But after having SHS people are sending their children into school because they have a great environment for studying at night.

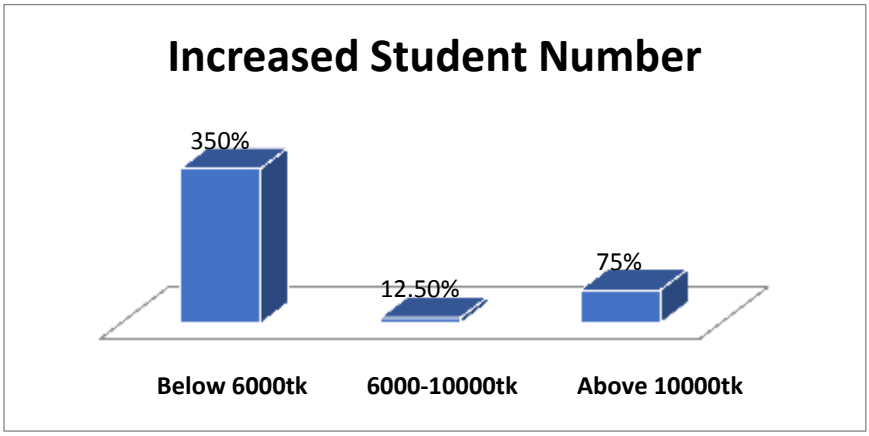


Figure 4.14: Increased student level

4.17 Environment Friendly:

Before using the Solar Home system people were using kerosene to lighting them up. Burning Kerosene was not environmental friendly . After using Solar Home System people do not need to burn it. Solar system have no wastage and also clean

4.18 Summery:

We have analyzed the technical data and survey data for our study. We have seen that per unit cost for our solar panel from our solar lab is less than the SHS in our survey area. We have found some opportunity and possibility for solar Home system by using SWOT method. We have seen that there are many development can be possible if government monetization, Technology used increased.

CHAPTER 5

CONCLUSION

5.1 Introduction

In this present era momentum, progress, ability, social factors indirectly or directly depends on energy. People need power. People are now making more power and also more electrified zone. For any civilized zone energy can effect on their economy, growth rate, education, socialism and also can contribute sustainable development. But for uncivilized zone it can effect satisfactory changes. A countries Sustainable Development Goal (SDG) directly depends on how much people are doing well and how people are educated and also the economy rate.

Our study was about the socio-economic impact for Solar Home system (SHS) implementation and also the feasibility test for solar panel. Our Study showed that after

The SHS role on social development is more dramatic compared to facilitate on economic development. Clear household lighting and fresh air improve education, health, facilitates in access to information, communication, entertainment, and increase perception on safety. These factors bring radical changes in the traditional social life of rural people. Although the use of SHS electric appliance is rather limited, lifestyle has significantly improved due to the availability of solar electricity. Household members quote households work condition improves due to electric lighting and avoidance of kerosene-related work. Solar electric lighting extends evening hours of household activity. Watching TV, productive activities and the studying of school going children are common activities benefited from the extended evening time. SHS electricity also improves household conditions for education as it provides clear light and fresh air, as well as longer studying hours for children. In case of health benefit, it is also found that SHS owned households get improved indoor air, availability of information on health issues as well as reduced accidents related to kerosene use. SHS-Household gets information, education and entertainment for using TV, Radio and mobile phone. Due to widespread ownership of mobile phones, electricity from SHS is becoming an essential factor for telecommunication in remote rural areas, where it constitutes the source of

power to charge the cell phone batteries. Increased perception of safety and social activity due to social gatherings for watching TV and listening radio are also observed in SHS owned households.

5.2. Future scope of this work:

We have tried to show some socio-economic positive effect of SHS and also showed the panel maximum efficiency in our solar mini lab

Our work have a huge possibility of future scope-

- Irradiance and power from solar panel will be measured for minimum one year so that the cost per unit will be more precious.
- Technology used in SHS can be more efficient and have a chance for vast amount social development.

5.2.1. Enhancing productive use of Solar Home System:

It is found from the household survey that insignificant income generating activities are Promoted by the use of SHS. Solar light is used mainly for household lighting; Application of SHS is very limited to providing light for productive activities, like sewing, handicraft making, poultry farming etc. Moreover, due to lack of knowledge and proper training, these applications are not flourished to the remarkable extents. Depending on the demand of household, it is very much essential to disseminate the solar led household appliances for increasing household productivity. Using solar water heating, solar drier, solar lanterns, solar water Desalination, solar blending machine, solar sewing machine, solar driven small machines for power looms, solar water pump, solar rice grinding machine can be popularized for increasing household productivity. At the same time proper training and Marketing facilities is necessary for increasing household income generating activities.

The SHS dissemination organizations should include training for the low income Household in their program on how to use the SHS in various productive ways. More Studies are also essential for using solar power appliances in socio-economic context of Bangladesh.

5.2.2. Enhancing socio-economic condition:

People are only using Solar Home system for household lighting, fan, and sometimes TV. But to improve this social condition need more power and also need more collaboration for government and also the organization that basically perform for micro-financing. Lack of electricity, village community health center cannot use refrigerator and other electricity

driven medical equipment. Every community clinic and union health center could be electrified with SHS and thereby the community people can get health facilities, using SHS refrigeration of vaccines and operation in rural health clinics. Now-a-days information is power. To decrease digital divide government provides computer with internet facilities in the education institutions. But children of rural poor families, who study in the education institution of remote village, cannot use computer & internet in their institution. Providing SHS in those institutions to run computer and internet, the marginalized poor student could be dragged in the main stream of development. In survey it is revealed that TV watching and listening of Radio are most frequently conducted throughout the evening hours by household members. To increase benefits from TV and Radio educational TV and radio program could be implemented. As most of the household use mobile phone, more messages awareness program can be provide through it. People of rural remote village become helpless during disaster period. Electrification by SHS in the cyclone Centre or flood Centre provides better management of affected people as it is possible to vaccine preservation, water preservation, cooking, heating and communication public health information through TV, radio and mobile phone. In remote area of Bangladesh, people do not feel safety at night due to sufficient light. Village street lighting can be possible by using SHS, which increases safety of rural people at night. It can help to improve low and order situation in remote village and thereby ensure good governance.

5.3. Promoting Mini-grid or Hybrid system:

Now a day for rural electrification -Hybrid solar PV and wind generation system become very attractive solution in particular for stand-alone applications to fulfill the exceeding energy demand. To make the system more stable and flexible many authors are working on it. There are many limitation of Hybrid solar PV wind system. They are working on fuel flexibility, intensity, emission, efficiency, Reliability.

Government or SDG ministry should think the way of hybrid system or mini grid system for rural electrification. There are many village in our country where still grid connection is not available. Sometimes only one renewable source like solar is not much efficient like mini grid or hybrid system.

REFERENCE

[1] "Sustainable Energy - Wikipedia, the Free Encyclopedia." Main Page - Wikipedia, the Free Encyclopedia. Web. 12 Apr. 2010. .

[2] World Energy Council, "World-Energy-Scenarios: Composing Energy Futures to 2050," https://www.worldenergy.org/publications/ 2013/world-energy-scenarios-composing-energy-futures-to-2050/(Accessed 12 October 2015)

[3] S.Mojumder K M. Rabbi1,Indrajit Nandi, A. S Saleh3, F. Faisal: Prediction of Solar Irradiation in Bangladesh Using Artificial Neural Network (ANN) and Data Mapping Using GIS Technology - -Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka – 1000, Bangladesh.

[4] https://en.wikipedia.org /wiki/Renewable_energy_in_Bangladesh

[5] # "Present Installed Generation Capacity (MW) as on 30 June, 2018". bpdb.gov.bd. Bangladesh Power Development Board. Retrieved 17 July 2018.

[6] S. I. Sharif, M.A.R Anik, M. Al-Amin, M. A.B Siddique: The Prospect of Renewable Energy Resources in Bangladesh: A Study to Achieve the National Power Demand –Dept. of EEE, IUBAT-Intl. Uni. of Bus. Agri. and Tech., Uttara Model Town, Dhaka, Bangladesh

[7] http://www.sreda.gov.bd/initiatives and program/Renewable energy/solar home system

[8] http://www.sreda.gov.bd/initiatives and program/Renewable energy/solar rooftop system

[9] http://www.sreda.gov.bd/initiatives and program/Renewable energy/solar mini grid

[10] https://mpemr.gov.bd/Ministry of power, Energy and Mineral Resources

[11] http://cleangreenenergyzone.com/how-do-photovoltaic-pv-solar-cells-work/

[12] World Energy council-World energy resouces -2016

[13] Renewable Energy Scenario in Bangladesh: Opportunities and Challenges
Md. Mohai Menur Rahim, Mohammed Hosam-E-Haider-Dept of EECE, Military Institute of Science and Technology (MIST) Dhaka-1216 .

[14] Solar Home System in Bangladesh: Prospects, Challenges and Constraints
Al-Amin, A. Sultana, J. Hasan ,M.T. Islam, F. Khan-Department of Electrical &Electronic Engineering(United International University) Dhaka, Bangladesh.

[15] B. Bhandari, K.T.Lee, W.,S Chu, C.S. Lee, C.K.Song, P. Bhandari, and S.H Ahn: Socio-Economic Impact of Renewable Energy-Based Power System in Mountainous Villages of Nepal

[16] M.A Kabir , H.S. Dey and H.M Faraby: Microfinance: The Sustainable Financing System for Electrification and Socio economic Development of Remote localities by Solar Home Systems (SHSs) inBangladesh –Dept. of EEE , BUET & Sandiego university and technology.

[18] Bangladesh M. A. Matin1, H. Rahman1, M. R. Hossain, M. A. Ehsan1, G. M. I. Hossain1 and M. M. I. Mahfuj **: (**Present Scenario and Future Prospect of Renewable Energy in) Department of Electrical and Electronic Engineering, Chittagong University of Engineering and Technology, Chittagong, Bangladesh.

[19] https://www.redarc.com.au/how-do-solar-panels-work

[20] https://www.techopedia.com/definition/16316/battery

[21] https://freedomsolarpower.com/blog/types-of-solar-panels

[22] https://en.wikipedia.org/wiki/Charge_controller

APPENDIX-

Data Collection Questionnaire for SHS

Site -2	
District	Bhola
Upazila	Monpura
Sample set number	
Load type	
Age group	
Appliances	

Technical Information

Date of installation/operation		
Company name		
Plant Capacity		
Panel life		
Battery	Origin	
	Capacity (Ah)	

	Warranty (Years)			
	Battery life			
Charge controller	Origin			
	Capacity			
	Warranty (Years)			
	C. controller life	3 years ; It worsted after 1 year then direct connection		
Appliances	**Load**	**Watt**	**Quantity**	**Total use hours (estimated)**
	Light			

Data Collection Questionnaire for SHS

Economic Information

Cost of SHS (Tk.)	
Down payment (Tk.)	
Interest rate (%) per year	
Loan repayment/installment (Tk.)	

Payback period (years)	
Total number of installment	
Reduced loan repayment	
Maintenance cost/year	
Battery Price (Tk.)	
Charge controller price (Tk.)	

Social Assessment (By Individual)

Name of SHS owner		
Occupation		
Number of family members		
Monthly income before using SHS (Tk.)		
Monthly income after using SHS (Tk.)		
Change of number of students	☐ Before using SHS	
	☐ After using SHS	
Study hour at night	☐ Before using SHS	
	☐ After using SHS	
How did they find the performance of SHS?	✓Bad ☐ Satisfactory ☐ Good ☐ Very good	

Are you satisfied with your system provider service?	✓Bad ☐ Satisfactory ☐ Good ☐ Very good	
What types of problems do you faced with your SHS?	Battery, bulb ,controller	
Is SHS electricity is enough for your family?		
Do you have any comment about installment?	High cost , worse panel	
What amount (Liter) kerosene did you used?	☐ Before using SHS	
	☐ After using SHS	
Do you like to use TV or Fan or others/to increase your SHS capacity?		

Technical Data Measurement by Equipment (for SHS)

Voltage (V)	
Current (Amp)	
Power (W)	
Energy Generation (kWh/day or month or year)	
Irradiance (W/m2)	
Efficiency (%)	
Temperature (environment), °C	
Temperature (cell), °C	
I-V graph	