STUDY OF SOLAR IRRADIATION PATTERN OF A CERTAIN AREA FOR ELECTRICITY GENERATION

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

Submitted By

Md Imam Hossain Sujan
ID: 191-33-858

Md. Shahadat Hossain
ID: 191-33-891

Supervised by
Mr. Md. Dara Abdus Satter
Associate Professor & Associate Head
Department of EEE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
FACULTY OF ENGINEERING
DAFFODIL INTERNATIONAL UNIVERSITY

October 2022

Declaration of Authorship

This is to certify that the thesis, “SOLAR IRRADIATION PATTERN OF BANGLADESH FOR ELECTRICITY GENERATION” presented here is the result of work done by the undersigned student in order to complete the requirements for a B.Sc. in Electrical and Electronic Engineering under the guidance of Mr. MD. DARA ABDUS SATTER, Associate Professor and Associate Head of Electrical and Electronics Engineering at Daffodil International University.

The student undersigned completed this and has not submitted it to another institution for the award of a degree or diploma.

Signature of Candidates:

Md. Imam Hossain Sujan	**Md. Shahadat Hossain**
ID: 191-33-858	ID: 191-33-891
Date: ………………	Date: ………………

Certificate of Approval

The Project titled "SOLAR IRRADIATION PATTERN OF BANGLADESH FOR ELECTRICITY GENERATION" submitted by Md Imam Hossain Sujan (ID: 191-33-858) and Md Shahadat Hossain (ID 191-33-891) has been accepted satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on October, 2022.

8/12/22

Mr. Md. Dara Abdus Satter

Associate Professor & Associate Head

Department of Electrical and Electronic Engineering

Faculty of Engineering

Daffodil International University

Dedicated to

My Parents
&
Teachers
With love & Respect.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

FF	Fill Factor
RE	Renewable Energy
PC	Personal Computer
RF	Ripple Factor
SP	Solar Panel
KW	Kilowatt
MW	Megawatt
CFL	Compact Fluorescent Lamp
REB	Rural Electrification Board
SHS	Solar Home System
PWM	Pulse Width Modulation
LCD	Liquid Crystal Display
USB	Universal Serial Bus
EVA	Ethylene Vinyl Acetate
PVA	Polyvinyl Fluoride
RTD	Resistance Temperature Identifier
AGM	Absorbed Glass Mat
BSTI	Bangladesh Standards & Testing Institute
PDB	Power Development Board
NGO	Non-Government Organization
REB	Rural Electrification Board
LGED	Local Government Engineering Department
BCSIR	Bangladesh Council of Scientific and Industrial Research
BPDB	Bangladesh Power Development Board

ACKNOWLEDGMENT

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, Associate Professor & Associate Head, Mr. Md. Dara Abdus Satter, department of EEE, for being dedicated to supporting, motivating, and guiding us through this thesis. This project couldn't have been done without his helpful advice and helps. Also, thank you very much for allowing us to choose this project. Also, thank him very much for allowing us to select this thesis.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us make 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 for their inspiration and encouragement during our studies at this University.

ABSTRACT

In today's world, the need for electric power is increasing daily. Aside from that, the demand for current energy supplies has prompted engineers and scientists to consider alternative energy sources. Solar energy has the potential to be a source of electric power. This solar system is currently rising in popularity

Energy is one of the most critical factors in a developing country and for a sustainable economy. Like the rest of the countries on 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 the sun in Dhaka city in the month of July and August 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 (July and August) two months 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 the solar home system and create a standard form of power production of the solar home system in 2018

CHAPTER 1

INTRODUCTION

1.1 Introduction

Bangladesh is a well-developed and flourishing country nowadays. The requirement for sustainable power in the power area is constantly developing. We worked on housetop sunlight-based charger execution testing and investigation on our college's roof. For our country, sun-oriented energy is essential. Notwithstanding, on a stormy or shady day, the sun is based. The most widely recognized issue with the framework is the absence of daylight. Solar power systems are supplying a significant amount of energy to Bangladesh's rural areas in particular, helping to ease the country's current energy problem. In addition, 30 companies in Bangladesh operate solar energy businesses [1]. We directed research. Its proficiency, impede, cut off, top circuit, and different attributes: the fill factor and the voltage (FF). At regular intervals, the world's energy use changes. The increment is drastically better in USA, where 7% of the population consumes 32% of the world's strength. The intake of strength materials will compel us to alternate faster or later. The instance of strength use Part of the predicted solution for the strength predicament relies upon utilizing atomic strength. Reactor wellness has proactively been a worry. It is assumed that the reactors' predicament network cooling component has no longer been attempted & there may be no warranty that it will continue to form. During an emergency, Solar strength is more secure thus, and one may say that sun-orientated power is around one hundred percent secure. Our state at present could make 19000MW of force. However, that is deficient, so we continually include new establishments. These are the close-by planet companies related to the community, and the rooftop pinnacle SPs now no longer connected to the matrix.

1.2 Current Situation in Renewable Energy

Energy deficiency is discouraging the financial and modern improvement of Bangladesh. Environmentally friendly power contributes around 560 Megawatt (MW) of the all-out power creation of 20,430 MW, which can be a manageable answer for the interest supply emergency[2]. This paper sums up the ongoing energy circumstance in Bangladesh and looks at the accessible environmentally friendly power assets and their future possibility. It has been uncovered that Bangladesh is intensely (62%) dependent on gaseous petrol even though the administration has proactively done whatever it may take to produce power from environmentally friendly power sources. Current strategies and regulations connected with Bangladesh's sustainable power age have been talked about unequivocally[3]. At long last, a few ideas have been made to handle the continuous energy emergency in the country, notwithstanding sustainable power.

1.3 Energy Crisis in Bangladesh

Giving continuous and dependable power to all at a reasonable cost is a significant endeavor for the legislatures of progressively eager energy nations. This study evaluates Bangladesh's energy supply request hole, progress, and prospects of elective energy sources. A few strategies, including elucidating, pattern, and near investigations, were completed utilizing time-series energy information to decide the current and verifiable energy status[4]. The discoveries demonstrate that between 1990 and 2018, the country's energy utilization expanded around 3.05 times, from 12,743 to 38,807 kW, while its energy creation expanded by around 3.11 times, from 10,760 to 33,504 kW. The hole between supply and utilization is approximately 26%[5]. However, it may be shut if strategy, administration through administrative activities, speculation, transmission and appropriation, asset enhancement, energy proficiency, protection, examination and training, and territorial participation boundaries to energy broadening.

1.4 Top Countries Using Solar Power System

Solar energy is getting decreasingly accepted among grown and growing countries. The government recognizes the energy troubles and gives more impulses for going solar to the general public and pots. The countries are beginning to share in leading the renewable energy race in solar energy. I started wondering which countries have the most significant number of installed solar systems. So, I wanted to make a top ten list of countries that use a good number of solar energy (in Mega Watts, MW) worldwide[6]. I wanted to try and do this in a Letterman style, but I believe it's bettered to write a brief note about each country, stating its highlights and many motivating data. The countries are given below:

Table 1.1: Top Ten Solar User Countries[7]

Country	Generation (MW)	Percentage (%)
China	306,973	35.8
United States	95,209	11.1
Japan	74,191	8.7
Germany	58,461	6.8
India	56,951	6.6
Italy	22,698	2.6
Australia	19,076	2.2
South Korea	18,161	2.1
Vietnam	16,660	1.9

1.5 Renewable energy usage in Bangladesh

I. Solar
II. Wind Power
III. Biomass Energy
IV. Biogas Energy
V. Hydro Power
VI. Geothermal Energy
VII. Tidal Power

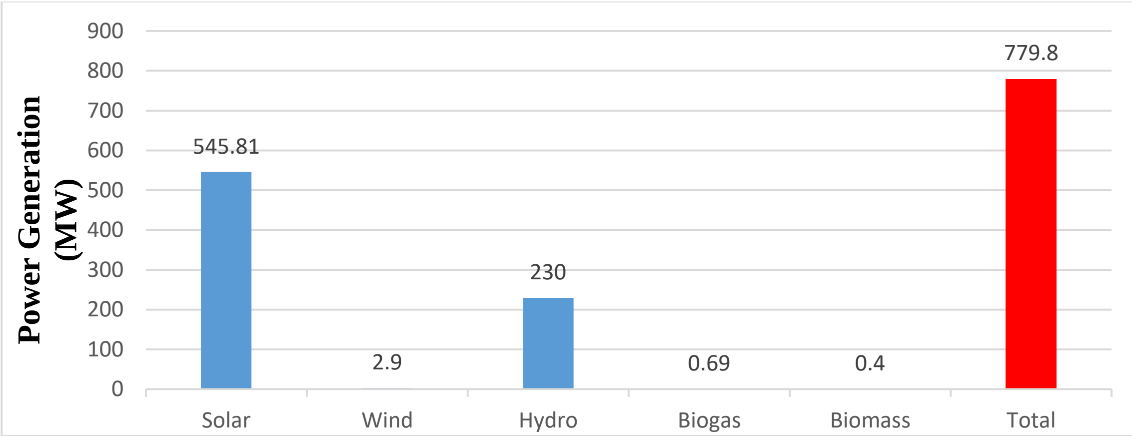

Figure 1.1: Power Generation in Bangladesh[8]

1.6 Problem Statement

Solar energy is the most abundant, reliable, and cleanest energy source. The main obstacle to solar electricity is the high cost of the technology. To produce electricity directly from sunlight, solar panels need expensive semiconductor materials. Solar cells have low efficiency[9]. This means that it is costly to develop and maintain semiconductor plants. However, this is improving as the efficiency of solar cells is increasing.

In some cases, the efficiency can be as high as 40%. The remaining sunlight energy that enters the panel is lost as heat. Since a solar panel needs to be kept clean and free of debris on every square inch to work well, maintaining it can quickly become expensive. They must create large storage systems to provide a consistent and reliable power source at night or when clouds pass. If the solar panel does not produce energy, it will take time to recover the cost of installing and maintaining the solar panel.

1.7 Energy Classification

I. Primary & Secondary energy
II. Renewable & Non-renewable Energy
III. Commercial & Non-commercial Energy

1.7.1 Primary & Secondary Energy

There are several ways to categorize the various energy sources now in use. Since we obtain these resources from the natural world, they can be used directly as primary sources. These include coal, oil, natural gas, uranium, the sun, wind, tides, mountain lakes, and rivers. By extracting energy from flowing water, it can produce electricity and heat.

Primary energy sources are converted into secondary sources: for example, gasoline is obtained from the processing of crude oil, and electricity is obtained from the conversion of mechanical energy (hydroelectric power plants, Aeolian power plants), nuclear power plants, or thermoelectric chemical plants (nuclear power plants).

1.7.2 Renewable & Nonrenewable Energy

Nonrenewable energy sources include coal, gas, and oil. Most cars, trains, and planes use energy that is not renewable. They are produced by burning fossil fuels to generate energy. Renewable energy sources include solar, hydroelectric, and wind power. Wind energy is created when the wind moves the blades of a wind turbine. This movement creates wind energy which is converted into electrical energy[10].

1.7.3 Commercial & Noncommercial Energy

The sources of energy that are used for commercial purposes by the people. The use of commercial sources of energy is an indicator of economic progress in a country. The primary commercial energy sources are coal, petroleum, natural gas, and hydroelectricity. Energy sources used by people for domestic purposes can indicate a country's living standard. Noncommercial sources of energy can be an essential part of this picture. Noncommercial sources of energy include firewood, cow dung, and agricultural waste.

1.8 Objectives

I. To collect data on solar irradiation in Savar city for July & August.
II. To analyze the collected information to urge normal light and discover the relationship between sun-powered irradiance and control.
III. To study the solar Photo Voltaic system for Bangladesh.
IV. To get to the part of SHS on socio-economic advancement in Bangladesh.
V. To introduce renewable power as a substitute for fossil fuels in the production of electricity.

1.9 Scope of our work

We worked on our university's authoritative building's roof beat. Here we measured different information like solar irradiances, effectiveness, voltage, current, etc. It may be a German-provided thing. Bangladesh incorporates a part of the demand for control. Bangladesh commonly confronted the unconquerable demand-supply crevice of power amid the summer season. The vitality aperture is one of the many misfortunes losses misfortunes in Bangladesh and obstructs development financially. At this time, the sun-powered framework is created in our nation. SHS is designed in a social setting and financially in Bangladesh.

1.10 Thesis outline

i. Chapter 1 Introduction.
ii. Chapter 2 Literature reviews
iii. Chapter 3 Methodology.
iv. Chapter 4 Solar Equipment
v. Chapter 5 conclusions.
vi. Chapter 6: Conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Demand for renewable energy is increasing day by day. It is always used because it is natural and therefore derived. For example, sunlight and wind constantly shine and blow, but seven are available depending on the weather and time. While it is common to think of renewable energy as a new technology, harnessing nature's power has historically for lighting, heat, and transportation. The wind drives the boat to grind grain; the ship runs around the sea and the windmills spin. The sun provided heat during the day and helped extend the day's warmth into the evening. However, in the past, many have become accustomed to readily available, non-renewable energy sources such as postpaid gas and coal.

2.2 Literature Review

Estimate the substantiation by taking the deals data of Grameen Shakti (GS) every time (Figure.2.1). The number of guests increases yearly. At the end of 1997, it installed only 228 solar systems, but by the end of 2015, the number had increased to (Fig.2.1). The most familiar use of SHS is to light up places similar to homes and shops. Solar power's other benefits are running radios, boxes, mail players, and charging cellular phones. The trust ability and recognition of using solar electricity as a cover energy source are getting current. Solar electricity is easy to install and comes with little conservation cost and no yearly payments. Grameen Shakti (GS) is furnishing training about solar power technology to the original people to initiate their businesses by using their chops, creating new jobs, and reducing severance in Bangladesh, perfecting wide. The operation of renewable energy in Bangladesh isn't the rearmost, but renewable electricity generation has been restrained to the demonstration stage. Current renewable energy technologies include a position. Current renewable energy technologies include Solar (PV) as SHSs, Biogas, and Biomass machines, and they bettered cooking ranges. The first solar PV and largest installation was a 62 KW system in the Narshingdi quarter. The early circumstance of this demonstration design indicated the eventuality of further operations[11].

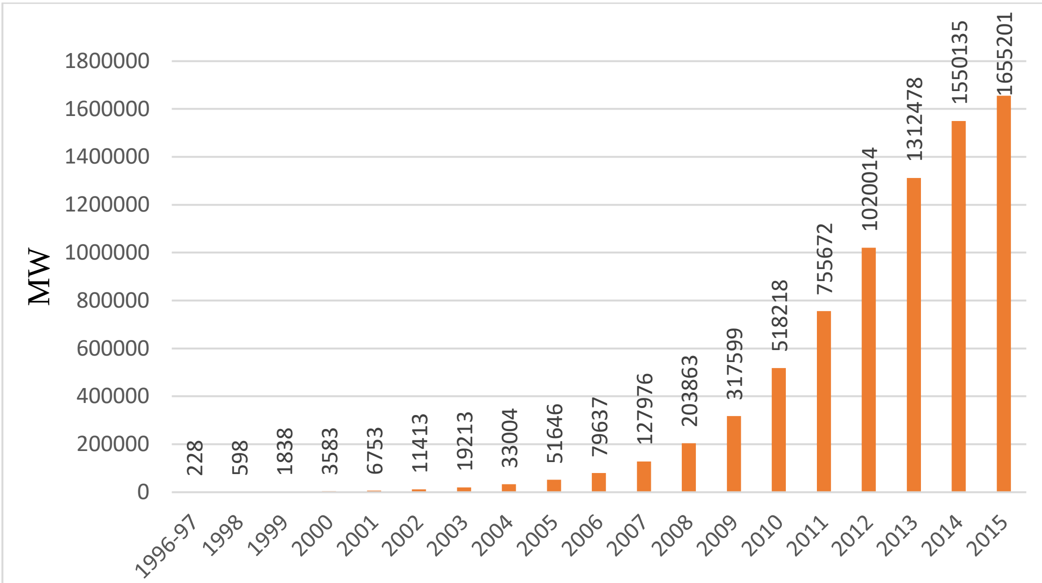

Figure 2.1: Year-wise installation of solar systems.

Due to the deficit of fossil energies worldwide and in Bangladesh, the need for a definitive transition to indispensable sources is pivotal. Solar power requires a massive investment in precious silicon panels. Solar panels covering a rooftop would be hard enough to supply its ménage conditions (without exertion) and would need extensive battery use at night. Wind pets in Bangladesh are too small for commercial practicability because of the manacle of the Himalayas to the North. Recently, there has been an actor in the West to produce biodiesel from grain, a slight chance of which is mixed with gasoline. But, the invention of biodiesel uses land that could have been differently used for comestible foods.

2.3 Types of Renewable Energy

There are many kinds of renewable vitality. Most of these renewable energies depend in one path or another on daylight. Wind and hydroelectric controls are the coordinate results of differential heating of the Earth's surface, leading to the discussion of moving approximately and precipitation shaping as they are lifted. Sun-based vitality is the straight change of daylight utilizing boards or collectors[12]. Biomass energy is accumulated sun contained in plants. Other renewable energies that don't depend on sunlight are geothermal energy, which could result from radioactive rot within the crust combined with the unique warmth of the Soil, and tidal vitality, which could be a transformation of gravitational energy.

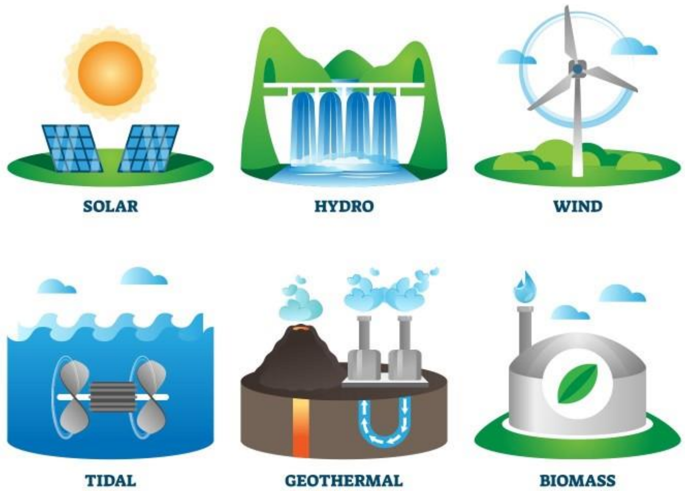

Figure 2.2: Types of Renewable Energy

2.3.1 Solar Energy

Solar radiation that can generate heat, cause chemical reactions, and generate electricity is called solar energy. The total amount of solar energy that falls on Earth far exceeds the world's current and future energy needs. Solar energy is the radiant heat from the sun. Generates energy from sunshine. They directly employ concrete or other forms of solar energy and indirectly use the photovoltaic system. In our nation, energy is an excellent off-grid area[13].

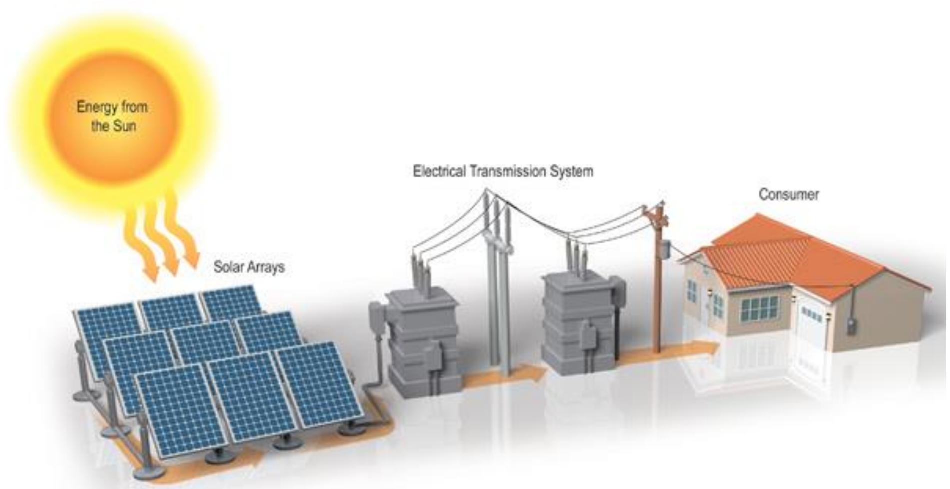

Figure 2.3: Solar Energy Process

2.3.2 Importance of Solar Energy

Oil, coal, gas, & nuclear power are the primary sources of the element to generate energy in the world. CO2 is released; when we burn this fossil fuel, greenhouse gases are released, hurting our atmosphere. Global warming badly impacts our society and environment. From the fig, we can analyze that electricity and heat generation is the main reason for global warming. On the other hand, fossil fuels reservoir is decreasing daily because of their great use[14]. So, the time has come to think about an alternative energy source. As a renewable energy, solar energy is the best option in Bangladesh. Bangladesh's government has understood the importance of solar energy & it its mandatory to set up solar panels on rooftops of every hi-rise building and open place. Everywhere on the earth, solar energy is available to generate electricity. Infrastructure Development Company Limited (IDCOL), BPDB, and NGOs are working for sustainable solar[15].

2.3.3 Problems of Solar Energy

I. Cost.
II. Weather-Dependent.
III. Solar Energy Storage is Expensive.
IV. Uses a lot of Space.
V. Associated with Pollution.

2.4 Wind Power

Wind energy has been utilized since the earliest times as windmills for milling and water lifting in countries like Denmark, Norway, and the USA. In Bangladesh, wind energy has found very inadequate applications simply because of the non-availability of consistent wind. Some coastal locations of Bangladesh have a fair wind speed between 4.0 and 4.5 m/s at 25m above sea level. Between 4.5 and 6 m/s at 50m above ground level is suitable for wind turbines.

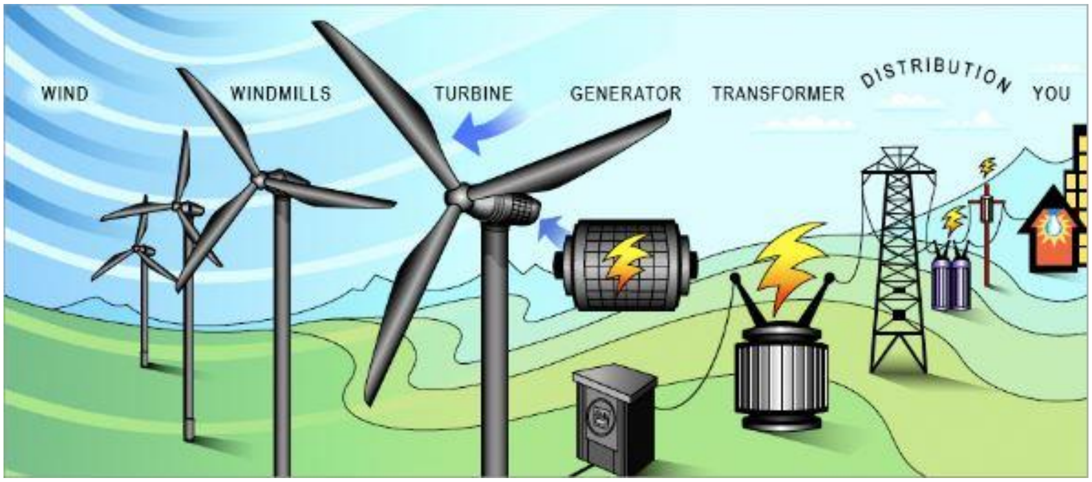

Figure 2.4: Wind Energy

2.4.1 Importance of Wind Power

Wind energy is a renewable energy source. Does not contaminate. It is inexhaustible and reduces the consumption of fossil fuels, the head of greenhouse gases that cause global warming. In addition, wind energy is "native" energy because it can be used almost anywhere on the site, helping to reduce energy imports and create wealth and jobs in the region. For these reasons, generating electricity from wind energy and using it efficiently contribute to sustainable development[16].

2.4.2 Problems of Wind Power

i. Noise pollution
ii. Threat to wildlife
iii. Affects local weather
iv. Safety issues at sea
v. Far off location
vi. Aesthetic impact
vii. The carbon footprint of turbines
viii. More environmental impacts

2.5 Hydro Energy

Hydropower is one of the cleanest energy sources compared to other traditional energy sources widely used for power generation. Many rivers in Bangladesh are indispensable for the lives of Bangladesh people. Bangladesh is blessed with many rivers, but hydropower is inadequate due to its high heat and lack of high flow. Resources are limited, and their proper use can lead to sustainable energy production to meet the ever-increasing demand. About 20% of the world's electricity consumption comes from hydropower[17]

.

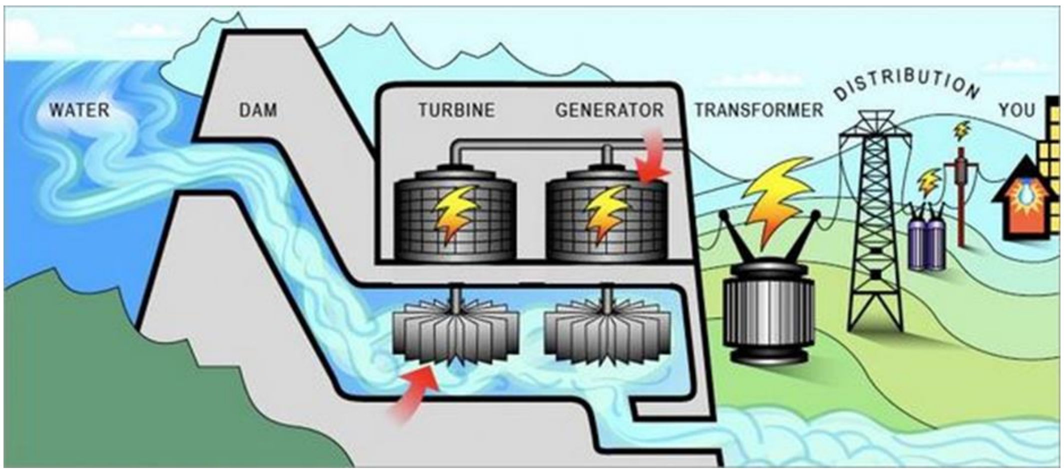

Figure 2.5: Hydro energy power generation system

2.5.1 Importance of Hydro Energy

i. The environment benefits from it.
ii. It can be replenished.
iii. It is Highly Reliable and Effective.
iv. It's adaptive and reliable.
v. It's reasonable.
vi. For Recreational Use, it's Wonderful.
vii. It acts as a critical tool for development.

2.5.2 Problems of Hydro Energy

i. Impact on Fish
ii. Limited plant location
iii. Higher initial costs
iv. Carbon and methane emissions
v. Susceptible to droughts
vi. Flood risk

2.6 Biogas

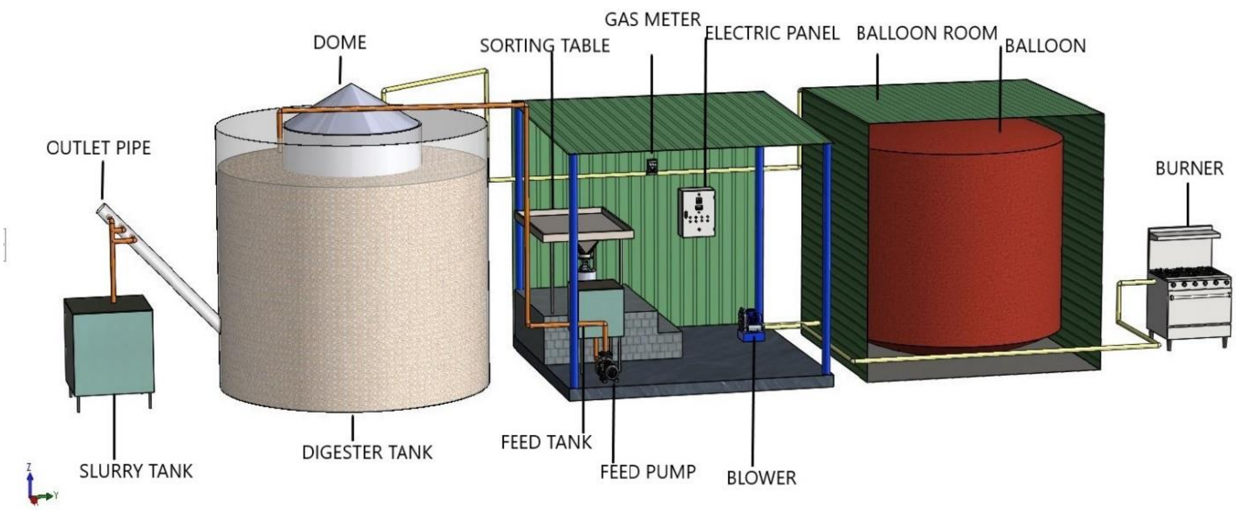

Figure 2.6: Biogas plant power generation process

Our country is one the lowest energy-consuming country in the world. Currently, the energy consumption per person is 220 kg. The National Grid covers only 35% of the total population, and only 3% of people have a pipeline gas supply. About 70% of Bangladesh's people live in rural areas where the situation is deteriorating. As a result, there are many migrations from rural areas to urban areas in Bangladesh. Houses are scattered in rural areas. Neither trunk lines nor pipe supplies are suitable for these areas. There are no alternatives to decentralized supply systems such as solar, biogas, and wind. Approximately 90% of the electricity produced domestically is based on natural gas. Its reserves are limited and will soon be depleted.

2.6.1 Importance of Biogas

A clean, renewable energy source is biogas. Biogas is a safe and dependable energy source produced during digestion. Gas produced from digestion is clean and reduces greenhouse gas emissions (i.e., reduces the greenhouse effect). Using garbage gas as an energy source, they can stop global warming because there is no need for combustion and no release of greenhouse gases into the atmosphere. Unsurprisingly, environmental concerns have greatly influenced the expanding usage of biogas. Biogas plants decrease methane emissions by capturing this hazardous gas and using it as fuel, which significantly lessens the greenhouse effect.

2.6.2 Problems with Biogas

i. Few Technological Advancements.
ii. Contains Impurities.
iii. Effect of Temperature on Biogas Production.
iv. Less Suitable for Dense Metropolitan Areas[18].

2.7 Tidal Power

Tidal or tidal energy is hydroelectric power that converts the generated energy. It converts tides into proper forms of energy, primarily electricity. Not widespread yet, but tide Energy has the potential for future power generation. Given an average drop height of at least 5 meters. It is usually considered the minimum possible tidal current generation. Therefore, there is little potential for tidal resources in Bangladesh. In coastal areas, there may be room for integrated tidal power generation.

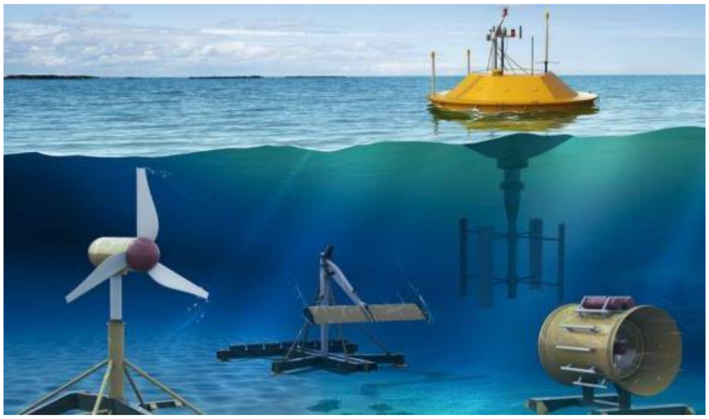

Figure 2.7: Tidal power system

2.7.1 Importance of Tidal Power

Tides are cheap to maintain and thus are easily predicted. It has a higher power density than other renewable energy sources and is a stable energy source. It doesn't generate any trash or greenhouse gases. Offshore and vertical-axis turbines are less costly to create and have a more negligible adverse environmental impact. Tidal turbine productivity is 80% higher than either solar or wind power stations.

2.7.2 Problems with Tidal Power

Tidal forces can harm marine life, as tidal turbines with rotating blades can cause the death of sea creatures. Noise from the rotation of the turbine can also affect the fish habitat of tidal power plants. Tidal energy can also affect water quality and sediment processes[19].

2.8 Geothermal Energy

Geothermal energy is the electricity produced by the warm temperature of the earth. Water is used as a warm medium to extract energy from the subsoil. The crust is tremendously cracked and permeates liquids, so floor water, specific rainwater, penetrates deep and exchanges warmth with rocks. Within the crust, basic styles of warmth switch occur. Conduction and convection. The ensuing convective warmth switch may be very green, while the stone is exceptionally overwhelmed and plentiful in circulating fluid. It may be without problems by excavating nicely and freeing a warm liquid to the floor. The earth's geothermal sources are theoretically greater than enough to satisfy human electricity needs; however, a small part of them may be beneficially used. Drilling and exploring deep sources is expensive. Future projections of geothermal electricity depend upon technology, power prices, subsidies, plate boundary movements, and hobby charge assumptions.

2.9 Use of Solar Energy

1. Solar electricity system
2. Solar water heating
3. Solar heating system
4. Solar ventilation system

5. Solar lighting system

6. Portable solar system

7. Solar transportation system

2.10 Bangladeshi NGOs Work with Solar Project

I. Australia Bangladesh Solar Power Ltd
II. Energy System Company
III. Solar Power & Electric Industries Ltd.
IV. VEC
V. Rahimafrooz Solar Office
VI. Greenergy Solutions Limited
VII. XOLAREN Bangladesh[20]

2.11 Energy Efficiency policy

A free program distribution of CFLs (compact fluorescent lamps) was carried out in various offices in PDB and at the head office to reduce energy tension and motivate customers to adopt CFLs. Instead of a radiant bulb, use compact fluorescent bulbs or T-5 tubes. All BPDB offices will eventually have Daffodil International University. The stepladder was adopted to encourage using heat-sensitive glass for passive cooling in commercial buildings to use energy efficiently. In addition, the national textbook curriculum for schools and universities defines the topics of alternative and renewable energy sources. BSTI launched the Energy Star listing program to encourage consumers to use energy suitable appliances. Since 2010, The Electricity Week initiative aims to encourage consumer energy-saving businesses and education. Every year, this program ends nationwide on December 7.

2.12 Summary

In this chapter, we attempt to illustrate the other components of the RE and solar household systems. We introduce energy, solar energy, preferred renewable energy technologies, and Bangladesh's ongoing commitment to renewable energy. Our government helps Bangladesh and improves its environment.

CHAPTER 3

SOLAR EQUIPMENT

3.1 Introduction

People have taken solar Energy as an alternative to grid electricity in this modern era. Solar Energy is an excellent source for resolving the power crisis in Bangladesh. The sun-oriented PV framework may be an outstanding developing choice to supply power with quality light, substantial benefit & long-term supportability.

3.2 Energy

Vitality is the amount of a physical framework. It characterizes the capacity of the changes and forms within the Universe, beginning with development and wrapping up with considering. Energy can exist in different forms, such as electrical, mechanical, chemical, warm, or atomic, and can be changed from one state to another.

3.3 Photovoltaic Modules

PV modules are done from sun-based cells related in plan and parallel to get the perfect current and voltage levels. Sun-fueled cells are exemplified as they should be weatherproofed, and electric accomplices also should be outrageous and utilization free. The ordinary manufacture of a PV module can be found in figure 3.1.

As the phones are weak, they are embodied in a sealed shut layer of Ethylene Vinyl Acetate (EVA), a polymer, so the phones are padded and, in that way, are limited amid transport and taken care of. The best cover is a safety glass treated with an antireflection covering, so the best light is transmitted to the phone. Underneath is a sheet of polyvinyl fluoride (PVF), likewise known as a manufactured polymer (CH2CHF) & that comprises an obstruction to dampness and keeps the cell from substance assault[21]. An aluminum outline is utilized to make minor complex mounting, take care of, and give extra assurance.

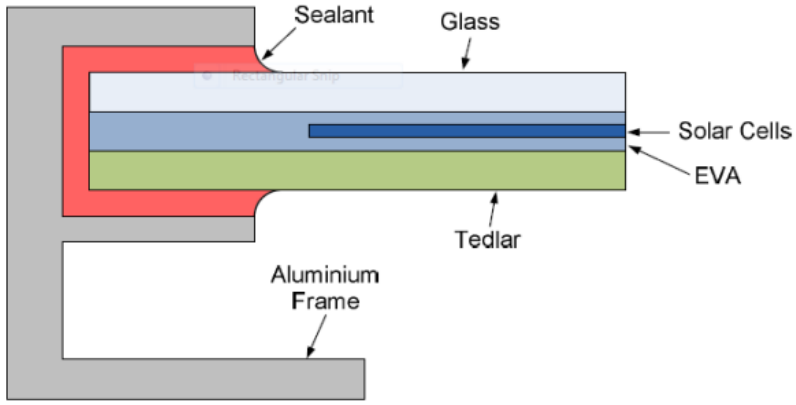

Figure 3.1: PV Module Typical Construction

Frameless modules are here and there operated in exteriors for stylish reasons. This normal development is utilized because the PV module needs to "endure" outside for no less than 20-25 years under differing climate conditions, sometimes extraordinary. This development guarantees, at any rate, the lifetime of the PV modules. PV board producers give a certification of no less than 20 years. For instance, BP Solar guarantees 85 % of the slightest sum justified power yield following 25 years of administration, 93 % of the base explained power yield at 12 years, and a five-year guarantee of materials and artistry.

3.4 Solar Cell

An electrical device that frequently transforms light energy into electrical power is called a photovoltaic cell. In Figure 3.2, it is also referred to as a solar cell or a photovoltaic device. When a photoelectric cell is exposed to light, its electrical characteristics, such as flow, voltage, or blockage, change. The cornerstones of photovoltaic modules or sun-oriented boards are solar-powered cells. Whether the light source is natural or artificial, cells that face the sun are referred to as photovoltaic. They can recognize light or other electromagnetic radiation close to the recognized range, quantify light intensity, or identify an object in photos (much as infrared indicators).

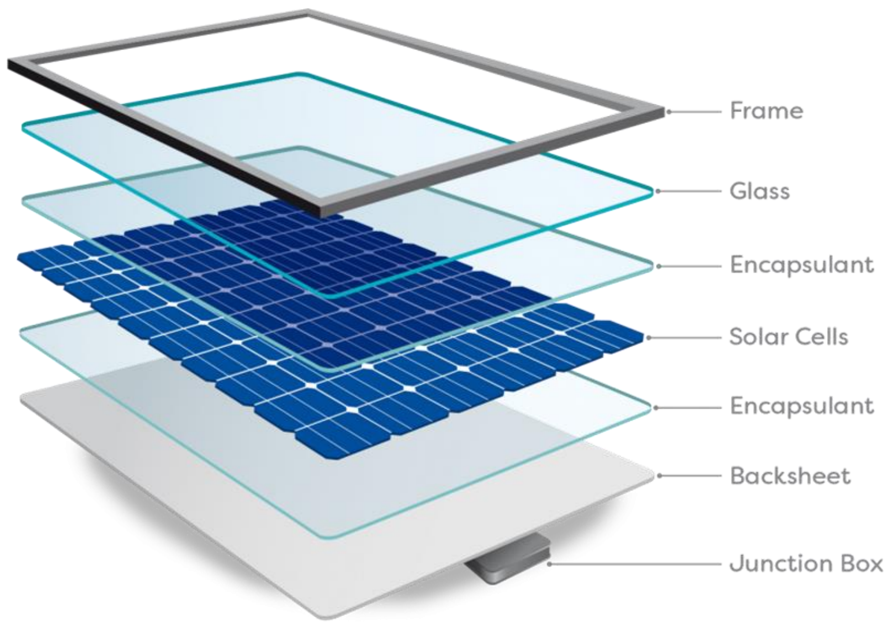

Figure 3.2: Parts of a Solar Cell

A photovoltaic (PV) cell must possess three crucial qualities in order to function. As follows:

I. Either electron-hole pairs or exactions are produced by the interaction of light.
II. The division of charge carriers into several categories.
III. The independent removal of such carriers to an outside circuit.

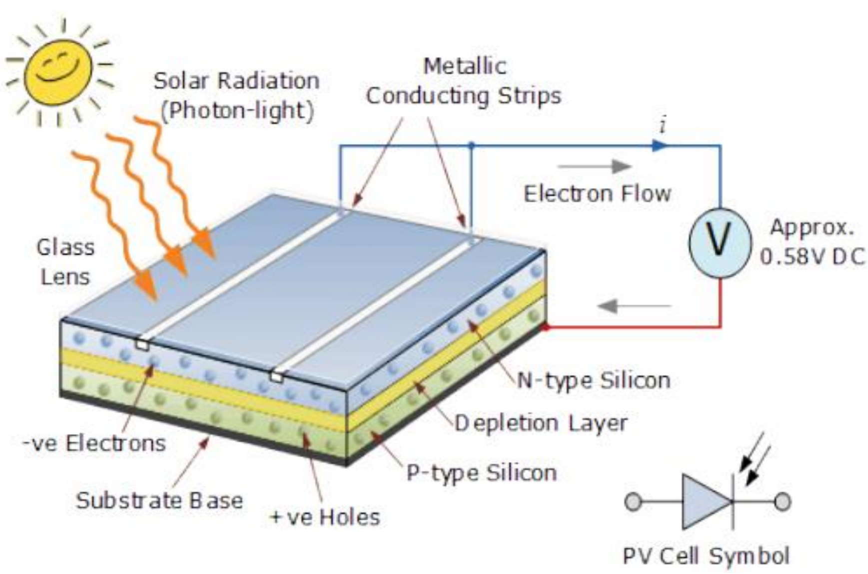

Figure 3.3: Structure of Solar cell

The essential steps in the production of a solar cell are shown in fig. 3.3.

I. The generation of light-generated carriers' system
II. The collection of the light-generated
III. The era of a large voltage over the sun powered cell.
IV. The indulgence of the power in the stack and parasitic resistances.

3.5 Solar Panel

Solar panels take in the sun's rays and convert them into heat or energy. A solar panel is a set of photovoltaic (or solar) cells that can produce electricity thanks to the photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels.

As a result, another way to define it is as a collection of photovoltaic modules put on a supporting structure. A 610 solar cell assembly that has been packaged and connected is known as a photovoltaic (PV) module. These panels are exceptionally resilient to wear and tear. Solar panels deteriorate incredibly slowly; in a year, their efficiency barely drops by one to two percent (sometimes even lesser)[22].

3.5.1 Classification of Solar Panel

There are two types of solar energy-

i. Electricity Production
ii. Water Heating

3.6 Photovoltaic Solar Power

Sun-based vitality is energy that is accessible during the day. It has been used worldwide for a long time and on various routes. In addition to its traditional human usage for heating, cooking, and drying, it is also used today to generate power in places where there are no other power sources, such as in distant areas in space. Making energy from sunshine is becoming less expensive, and most of the time, it is now competitive with power produced from coal or oil.

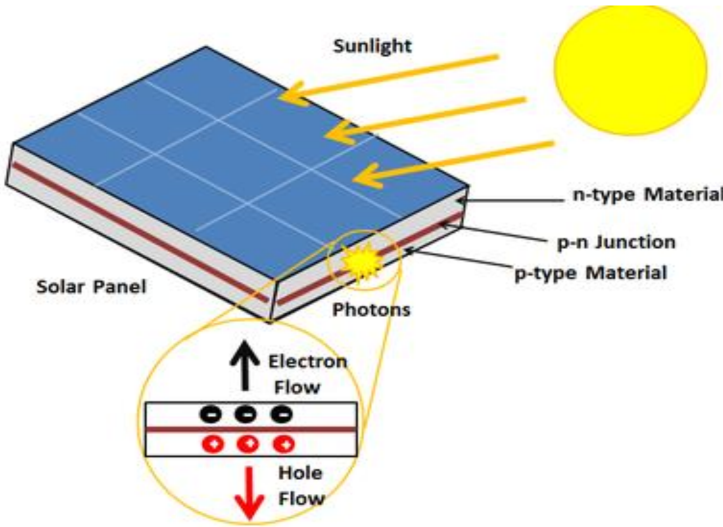

Figure 3.4: Photo voltaic Solar Power

Recent employment of PV technology has expanded to include house power age and framework-associated power generation because of the continual decline of assembling expenses (declining 3 percent to 5 percent every year as of late). PV system establishment has also been attributed mainly to comprehensive incentive schemes that help reduce the costs of these systems and enable customers to distribute excess power back into the population matrix. New ideas are emerging and available with the growing need for solar-powered energy.

3.7 Various Types of Solar Cells

i. Single-crystalline cells
ii. Multi-crystalline cells
iii. Amorphous cell

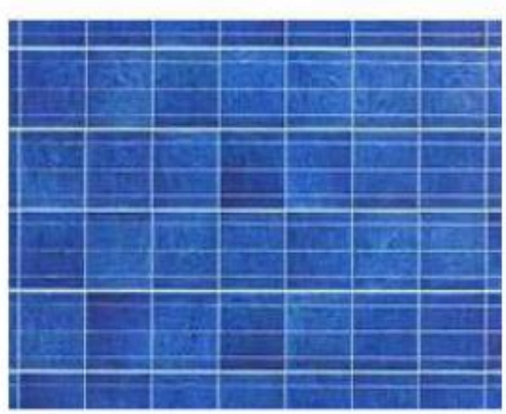

Figure 3.5: Single-crystalline cells **Figure 3.6: polycrystalline cells**

Figure 3.7: Amorphous cell

3.7.1 Monocrystalline or Single-crystal

Due to its highest conversion efficiency (25%) and silicon, the primary material already widely employed in producing semiconductors, monocrystalline cells are the most important. The two primary processes for producing single silicon crystals are the Czochralsky procedure and the floating zone approach. In the Czochralsky method, monocrystalline silicon grows on a seedling, and I carefully withdrew from the silicon melt. Both processes result in silicon rods sliced into 0.2–0.4 mm-wide slices. The discs (wafers) created in this manner go through several more processes. As follows:

I. Doping
II. Grinding and cleaning
III. Antireflection coating
IV. Metallization

3.7.2 Polycrystalline Solar Panels

Polycrystalline silicon (Poly-Si) is usually favored, while monocrystalline silicon's manufacture takes more energy and is consequently quite expensive. Poly-Si develops when a silicon melt is cooled down slowly and controlled. The yielded silicon ingot is sliced for further processing. Pulling off the single crystal can be given up this way. Inside the Poly-Si crystal are crystalline regions separated by grain boundaries. Polycrystalline cells have a poorer efficiency (less than 20 percent) due to losses at these grain boundaries than monocrystalline cells. Despite this drawback, polycrystalline cells are becoming increasingly important because of their cheaper production costs.

3.8 Amorphous Silicon

Nebulous silicon is the latest in thin film innovation. In this innovation, unstructured Silicon vapor is kept on two or three miniaturized scale meter-thick nebulous movies on tempered steel rolls. This innovation utilizes just 1% of the material in contrast with crystalline silicon. The most recent development in thin films is nebulous silicon. This invention's unstructured silicon vapor is preserved on two- or three-millimeter-thick nebulous films on tempered steel rolls. This invention uses only 1% of the material compared to crystalline silicon.

3.9 Thin Film Panels

It is the sun-based cell technology that is currently being discussed the most. Most commonly, thin film assets include gallium arsenide, cadmium telluride, and copper indium dieselizes. They are directly mounted on glass, steel, or other coordinated substrate materials, and some of them outperform crystalline modules slightly in low light. A few micrometers or a smaller amount is considered thin film.

3.10 Components of a Solar PV System

Figure 3.8: Solar PV System All Components

The types of equipment of the Solar Home System are listed below

i. Battery
ii. Solar PV module
iii. Charge controller
iv. Load (light, fan, television, etc.)
v. PV module supporting structure

3.11 Charge Controller

The Charge controller is an electronic gadget utilized within the elective sun-based vitality framework. All sun-powered control frameworks that use batteries require a sun-oriented charge controller. The sun-based charge controller manages the office's transition from solar-powered boards to batteries. Battery cheating will reduce battery life and, in the worst-case scenario, destroy the batteries because they are rendered useless. When the battery voltage reaches a particular point, the primary fundamental charge controller monitors it, opens the circuit, and stops the charging. More experienced charge controllers used a mechanical hand-off to open or close the course, stopping or initiating control aiming at the batteries. As the storms approach closer to being fully charged, modern charge controllers use (PWM) to progressively reduce the amount of power connected to them. These controllers offer grants.

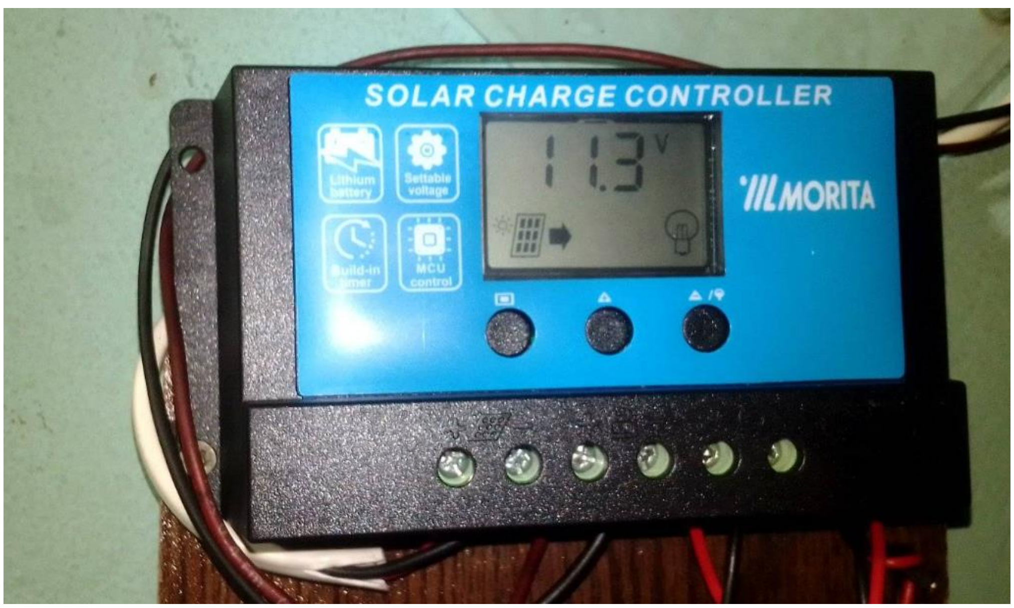

Figure 3.9: Charge Controller

The batteries are more thoroughly charged while putting less strain on them. The Batteries can also be kept perpetually in a state of float, which is an associated passing full charge. Although more complicated, Pulse Width Modulation (PWM) has no mechanical connections that can fail. The solar panel generates electricity, which is then stored in the battery. The battery's stored electricity is utilized at night[23]. The charge controller keeps an eye on the entire process. Figure 3.9 depicts a typical charge controller using the PWM approach.

3.11.1 Function of the Charge Controller

The most fundamental charge controller essentially manages the device voltage and, when the battery voltage rises to a predetermined level, opens the circuit, stopping the charging. More charge controllers stopped or started electricity going to the electric storage devices by opening or closing the circuit using a mechanical relay.

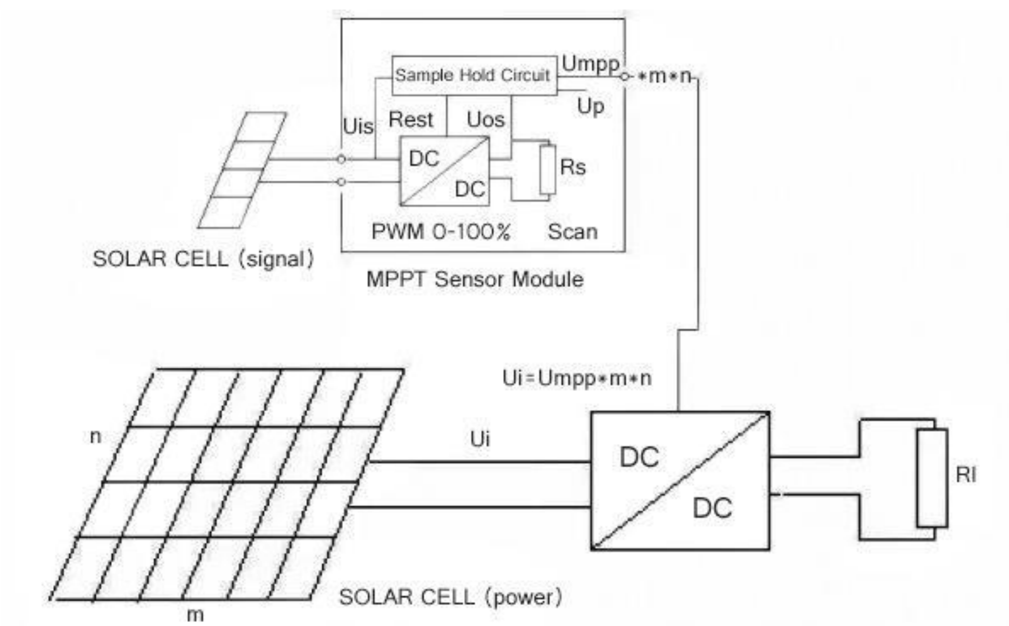

Figure 3.10: Diagram of Charge controller

Solar power systems often use 12V batteries. Solar panels can deliver more voltage than is required to charge the battery[24]. While the amount of time needed to set the electric storage devices fully is reduced, they can maintain the charge voltage at its optimal level. This enables solar systems to operate at their best all the time. Power dissipation in the cables is reduced by running higher voltage in the wires from the solar panels to the charge controller.

3.11.2 Charge Controller Principles

A charge controller's or controllers' primary function is to charge a battery while preventing overcharging and reversing current flow at night. Other features include:

i. Don't charge the battery when it reaches 100%
ii. If there is a high voltage time, disconnect the load.
iii. Disconnect the load during high voltage
iv. Constantly check the battery voltage
v. Give an alarm during a fault condition process
vi. Current measure.
vii. When the solar panels are not producing any power, they are detected, and the circuit is opened, cutting off the reverse flow of current and separating the solar panels from the batteries.

The charge controller handles battery, load, and solar panel coordination and control. The cost controller offers the load (mostly lamps) at night as it does during the day by storing electrical energy within the storm. On the other hand, if the battery is fully charged, the charge controller will immediately supply power to the load (a fan, a cell phone charger, etc.) during the daytime from the photovoltaic panel. Typically, a voltage regulator also serves as a charge or charge controller. In general, it regulates the voltage and modernity of the solar panel to store energy in the battery. The solar panel frequently generates 16 to 21 volts, while the battery needs 14 to 14.4 volts to charge appropriately. The charge controller reduces this voltage level, which functions as a buck converter. A DC-AC or DC-DC converter serves as the charge controller in most cases. The solar panel typically uses a Buck converter to transform the high-level DC voltage into the low-level DC voltage.

3.11.3 Types of the Charge Controller

The charge controller is mainly two types-

i. Shunt controller.
ii. Series controller

3.11.4 Shunt Controller

An ON/OFF switch is a shunt controller. When the cell power drops, a switch is flipped on, allowing energy to flow from the solar array to the battery (i.e., requires a charge). As the cell voltage rises, the button goes OFF, and the charging process ends (i.e., charged).

A charge controller is connected in parallel to the battery and load in this arrangement (Fig. 3.11). The controller cuts off the solar panel when the battery is charged. A blocking diode is needed in this arrangement. This blocking diode becomes warm as the battery is being charged through it. To prevent the battery to the panel, reverse current.

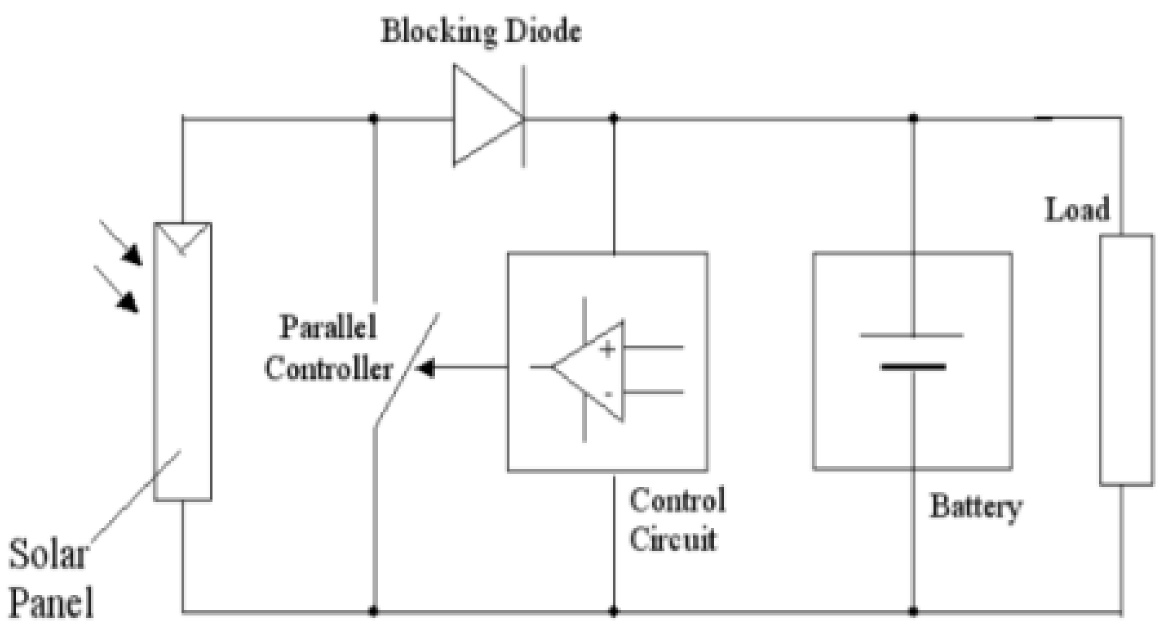

Figure 3.11: Use of Parallel Controller in SHS

There are some disadvantages of shunt controllers such as:

i. Loss of electricity.
ii. Huge amount of short-circuit current flows by the switch when the panel is short-circuited.
iii. Compared to the series controller, the shunt controller gets hotter.

3.12 Tracking Systems

The following frameworks are equipment tools occasionally used on shaft-mounted solar power systems to enable the positioning of the sun-oriented boards to track the sun's progress. This makes it easier to confirm that the sun-oriented cells have the most rugged appearance. Compared to non-followed frameworks, the following framework can increase your PV framework's yield by up to 30% in late spring and 15% in the winter. The following frameworks are frequently private because they are either dynamic or dormant. When the system is inactive, the tracker follows the sun from east to west without using any electric engine to guide the growth. Instead, the foundation is based on a warm and weighty action sequence.

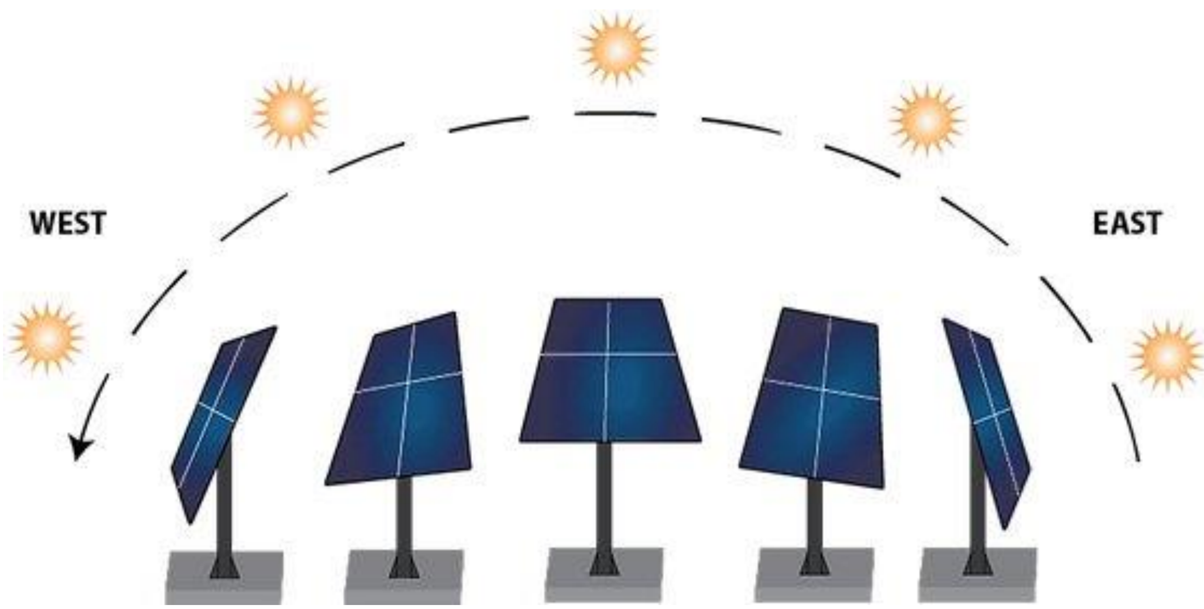

Figure 3.12: Solar tracking system

These frameworks are ideal for usage with water siphoning systems where the peak order occurs in the middle of the year, as no external establishment of power is necessary. Following frameworks are occasionally categorized according to the number of hubs they follow. Simple one-pivot frames have a straight turn from left to right rather than a curve. Both left to right and here and there will be followed by a two-pivot structure. This makes it possible to follow the sun's actual angle directly throughout the day even more successfully[25].

3.13 Kinds of Solar Energy

There are two kinds of solar energy. They are:

I. Generation of electricity (Photovoltaic or PV Technology)

II. Heating the water (Solar Thermal or Flat Plate Technology).

3.14 Battery

Batteries are used to store charges. Batteries come in a wide variety and are available in the market. However, none of them are suitable for solar PV technologies. Nickel/cadmium batteries are the most often used batteries. Other high-energy density battery types include zinc/bromine pour, and sodium/sulfur pour batteries. However, the nickel/metal hydride battery has the best cycling component for medium-term batteries. Iron/chromium and zinc or manganese batteries are the greatest for the long term. Absorbed Glass Mat (AGM) batteries are one of the best accessible options for solar PV utilization.

Figure 4.13: Batteries of the solar system

3.15 Lithium ion

A lithium-ion battery is a more advanced type that uses lithium ions as a key component of its chemistry. Lithium ions are ionized and separated from their electrons during a discharge cycle. The lithium ions move from the anode and pass through the electrolyte until they reach the cathode, recombining with their electrons and electrically neutralizing each other. The lithium ions are small enough to move through a micro porous separator between the anode and cathode. Lithium-ion batteries have a high voltage and charge storage per unit mass and volume, which is why they are popular for electronic devices[26].

3.15.1 Lead Acid

Lead acid batteries are the type of battery that uses sponge lead and lead peroxide to transform chemical energy into electrical power. Lead acid batteries are most frequently utilized in power plants and substations because of their higher cell voltage and lower price. In lead acid battery construction, the plates and containers are crucial. The below section provides a detailed description of each component used in the building.

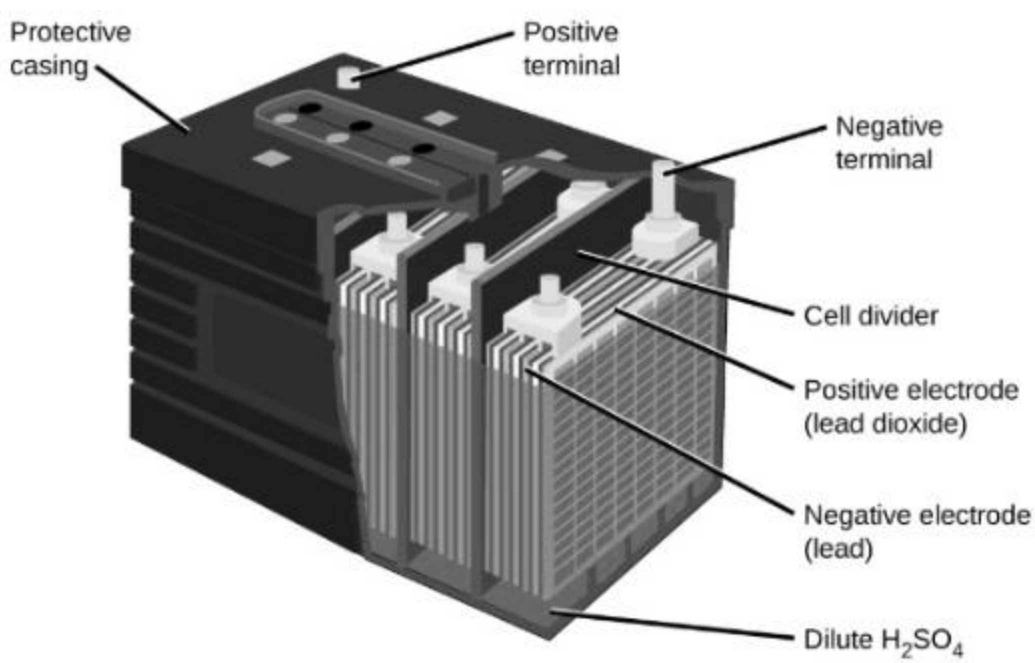

Figure 3.14: The lead acid battery diagram

3.16 Inverter

The third element of the photovoltaic system is a solar inverter. Its function is to change the solar panels' direct current (DC) electricity into alternating current (AC). Both the local transmission system and the provision of power in households use this electricity. One inverter for all modules is typically more economical and easier to cool down and service when necessary. On the other hand, because they will function independently from the modules still exposed to sunlight, the micro-inverters may be more useful if some modules are covered by shadow. In their absence, a sophisticated "smart inverter" was created, enabling two-way communication between the solar inverter and the electricity grid. Doing this makes it possible to strike a balance between supply and demand, which lowers costs, ensures grid stability, and lessens the likelihood of power outages.

Figure 3.15: An inverter

3.16.1 Types of Inverters

There are three types of solar inverters. They are:

i. Sine wave inverter
ii. Modified sine wave inverter
iii. Square wave inverter

3.16.2 String Inverter

The solar array is a series of solar panels connected to a string inverter. A line of solar panels can be linked in numerous ways. A solar array can typically produce around 15 watts of power. The string inverters and each solar panel are connected in series. The inverter combines each solar panel's direct current and transforms into alternating currents.

3.16.3 Stand-alone Inverter

The battery that the photovoltaic system has charged serves as the source of DC energy for the inverter. They are typically not associated with the power supply organization and needn't bother with being safeguarded against islanding. At the point when AC power is free, numerous independent inverters additionally incorporate an installed battery charger to top off the batteries.

3.16.4 Battery Backup Inverter

An inverter converts direct current (DC) from batteries into alternating current (AC) at the correct voltage and frequency to power lights, appliances, or anything else that usually runs on electricity from the utility grid.

3.16.5 Grid-tie Inverter

Grid-tie inverters use a power source that matches the frequency of a utility-supplied sine wave. This prevents energy from being lost or wasted and helps to ensure consistent power delivery. Grid-tie inverters are designed for the compact car upon lack of software delivery because of safety. They now no longer offer backup electricity at some point of software outages.

3.17 Efficiency

Efficiency is defined as the ratio of energy input from the sun to energy output from the solar-powered cell. The most common criterion used to compare the presentation of one solar cell to another is effectiveness. The sun-powered cell's temperature, light intensity, and solar band spectrum all affect efficiency.

3.18 Types of Solar Plants

Based on the storage system, there are two types of solar power plants. They are given below-

i. Grid Connected Solar Power Plant.
ii. Off Grid Solar Power Plant.

3.19 OFF-Grid Solar Plant

The local community or the electrical grid is not connected to the off-grid solar system. Off-grid systems require maintenance and more care, but they can provide one with a strong sense of independence that eliminates the fear of utility grid power outages forever. Off-grid solar systems don't interact with the primary grid because solar energy is produced and used in the exact location.

CHAPTER 4

METHODOLOGY

4.1 Introduction

Bangladesh is the best place for solar energy manufacturing. We receive a lot of sunlight for six to eight months because summer lasts so long here. Our country has rural areas where there is no electricity. However, these areas are ideal for solar energy generation using solar panels. Buildings in Dhaka city now have solar panels on their roofs connected to the grid. An average-sized solar panel can reduce power bill costs by roughly 8,000 to 10,000 taka per year in electricity bills.

4.2 Site Determination

We collect data from one of our neighbor house, who has solar system in his house. Where we collected data for our crucial work. It's in Savar city in Bangladesh. There are two types of solar panels whose are 45watt and 100watt have been installed. We investigate the performance of 45W and 100W off-grid solar panels, as well as their comparison.

Figure 4.1: Solar system in Rooftop

4.3 Research Apparatuses & Instruments

To collect data, a variety of devices were used, including an I-V 400w, a temperature sensor, a 60W and 100W solar board, and an illumination sensor (HT304N).

4.4 System Design

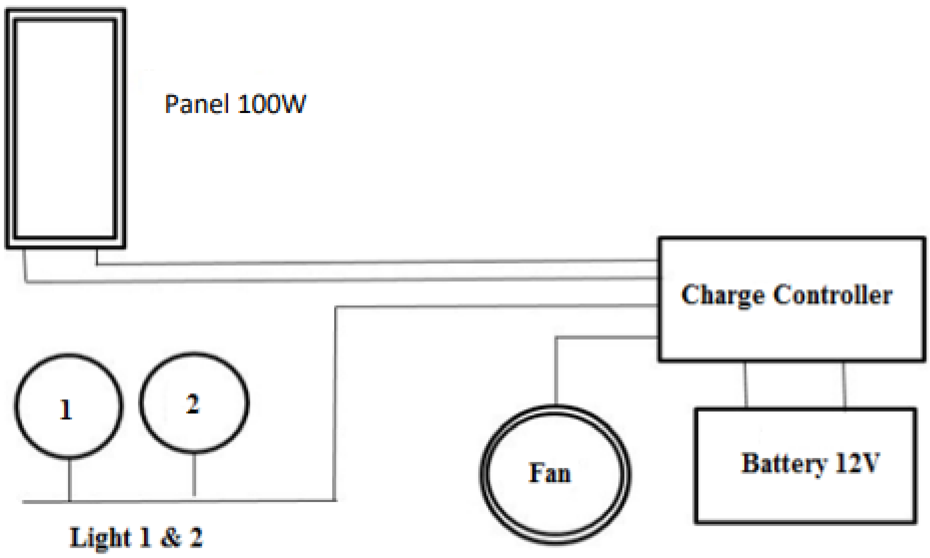

Figure 4.3: System Design of Solar System

4.5 Solar Panel

Solar panels are devices that turn sunlight into electricity. Some refer to them as photovoltaic, but they are actually light-energy devices. Increasing the amount of light in a cell, which produces electricity. Our office had three different types of solar panels. When the solar modules' front surfaces are illuminated, electricity is created. There were three different kinds of panels:

i. A solar panel with a power output of 45 watts.
ii. A solar panel with a power output of 60 watts
iii. A solar panel with a power output of 100 watts

In the first ten years, the cells must produce no less than 90% of their original lowest claimed power, and for the next 25 years, they must have no less than 80% of their actual minimum stated ability[27].

4.6 45W Solar Panel

A 45-watt panel refers to a solar photovoltaic module that is rated 45 watts. This means that it has a power output of up to 45W. Solar panel are mainly made in Germany. Efficiency of this solar panel is 14%

Figure 4.4: 45W Solar Panel

4.7.1 Main Features

i. Clever engineering makes for minimal power losses during prolonged periods in shade.
ii. Fully weather-resistant - durable white tempered glass, EVA resin and weather-resistant film enclosed in anodized aluminum frame

4.7.2 Electrical specifications

Table 4.1: I-V 400 W Calibration[28]

Type of Module	**100W**
Maximum Power	100W
Tolerance	± 3%
Open Circuit Voltage	22.44 V
Short Circuit Current	5.06A

Maximum Power Voltage	19 V
Maximum Power Current	5.6A
Module Efficiency	15%
Solar Cell Efficiency	17,2%
Series Fuse Rating	13A
Terminal Box	IP65
Maximum system voltage	1000V DC
Operating Temperature	-40°C - 85°C
Dimensions	1200mm x 680mm x 33mm
Weight	8.2 kg

4.7.3 I-V 400W

For PV systems up to a maximum of 1000V and 15A, I-V400 W (Figure. 4.5) enables field detection of the I-V Curve and the primary characteristic parameters of a single module and strings of modules. The I-V400 W manages an internal database of the modules for calculating the I-V Curve, which the user can update at any time. Comparing the measured data with the rated values enables an immediate determination of whether the string or the module satisfies the efficiency requirements acknowledged by the manufacturer[29].

Figure 4.5: I-V 400W Photovoltaic Panel Analyzer

4.7.3.1 Electrical Specifications

Table 4.2: Range, Resolution & Accuracy[30]

Parameter	Range (V)	Resolution (V)	Accuracy
IDC Current @ OPC	0.10 ÷ 10.00	0.01	±(1.0%rdg+2dgt)
VDC Voltage @ OPC	5.0 ÷ 999.9	0.1	± (1.0%rdg+2dgt)
Max Power @ OPC (Vmpp>30V, Impp>2A)	50 ÷ 9999	1	±(1.0%rdg+6dgt)
IDC Current (@ STC and OPC), IVCK	0.10 ÷ 10.00	0.01	±(4.0%rdg+2dgt)
VDC Voltage (@ STC and OPC), IVCK	5.0 ÷ 999.9	0.1	±(4.0%rdg+2dgt)
Max Power @ STC (Vmpp>30V, Impp>2A)	50 ÷ 9999	1	±(5.0%rdg+1dgt)
Temperature of module	-20.0 ÷ 100.0)	0.1	±(1.0%rdg+1°C
Irradiance (with reference cell)	1.0 ÷ 100.0	0.1	±(1.0%rdg+5dgt)

4.7.3.2 General Specifications

DISPLAY AND MEMORY:

Features: 128x128 pixel with custom LCD backlight

Memory size: 256 kilobytes

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

POWER SUPPLY:

Tests for the SOLAR I-autonomy: V's > 249 curve (I-V curve), 999 IVCK

Roughly 120 hours (yield test)

Four 1.5V AAA LR03 alkaline batteries are the SOLAR-02 power source.

Maximum recording time for SOLAR-02 (@ IP=5s): around 1.5 hours

POWER Source: 6x1.5V LR6, AA, AM3, and MN 1500 Alkaline batteries are used as the SOLAR I-V internal power supply.

OUTPUT INTERFACE

PC communication port: optical/USB

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

MECHANICAL FEATURES

Batteries included 1.2kg

Dimensions (L x W x H): 235x165x75mm Weight

ENVIRONMENTAL CONDITIONS

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

Storage humidity: <80%HR

Reference temperature: 23°C ± 5°C

Working temperature: 0° ± 40°C

Working humidity: <80%HR

GENERAL REFERENCE STANDARDS:

Insulation: double insulation

IEC/EN60904-5 (Temperature measurement)

Max altitude of use: 2000m

Pollution degree: 2

Max 1000V among inputs P1, P2, C1, C2

Safety: IEC/EN61010-1

Safety of measurement accessories: IEC/EN61010-031

I-V curve measurement: IEC/EN60891 (I-V curve test) [31]

4.7.4 Irradiation Sensor (HT304N)

This device (Fig. 35) can able to measure as MONO PANELS or MULTI PANELS. It is a passive sensor; therefore, no power source is required.

Figure 4.6: Irradiation Sensor

4.7.4.1 Technical Specifications

Table 4.3: Range & Accuracy of Irradiation Sensor

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

4.7.4.2 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 [32]

4.7.5 Temperature Sensor

A thermocouple or RTD (resistance temperature identification) is needed by a temperature sensor in order to detect the temperature using a tool and an electrical signal. The thermocouple, which consists of two different metals, causes a change in temperature that is inversely related to the atomic voltage. If an object is hot or cold, it can be determined by the temperature sensor. The output of the sensors is represented by the voltage across the base diode. At the base and emitter transistor terminals, the sensor monitors any voltage rises, temperature changes, and voltage dips. As the voltage difference widens, the gadget produces an analog signal that is inversely proportional to temperature.

Fig 4.7 Temperature Sensor

4.8 Flow chart of the research

We used flowcharts in analyzing, documenting or managing a process or program in different fields. A diagram that depicts a workflow or process is called a flowchart. The flowchart shows the processes as a variety of box types, with arrows indicating the sequence in which they should be completed.

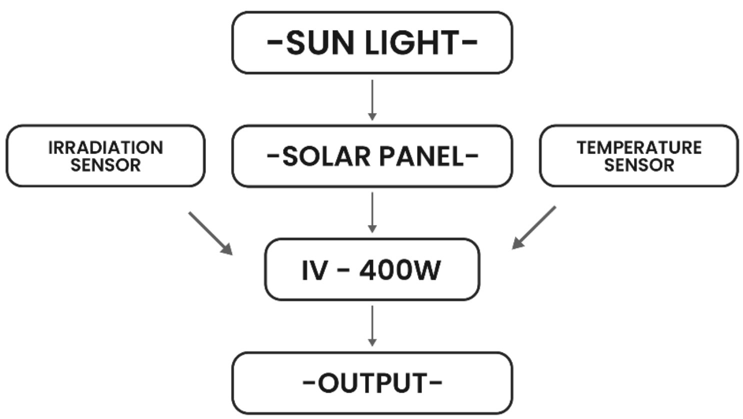

Figure 4.8: Flow Chart

4.9 Data Measurement Technique

In July, my friend and I went to a house rooftop and measured a solar system process. We collected data from sunrise to sunset (time 5.00 to 18.00) and used I-V 400w photovoltaic panel analyzer to measure data. Firstly, setting up irradiation and temperature sensor connects with I-V 400 W photovoltaic panel analyzer. Secondly, 100W solar panel output cables connected with I-V 400 W. The measured data was in Standard Test Condition form, and after that, we converted those data into in operational condition value.

Table 4.4: Data Sample of 100w panel on 12 July 2022

No	Time (sunrise - Sunset	Irradiance (W/m2)	Voltage (V)	Current (I)	Vmpp(V)	Impp(I)	Fill factor	Pmax (W)
1	5:19 AM							0
2	6:19 AM	123	19.4	.63	15.6	.5	.66	7.8
3	7:19 AM	156	19.6	.76	15.3	.77	.34	11.78
4	8:19 AM	232	19.8	.90	15.7	.43	.55	65.7
5	2:00 PM	454	19.7	5.12	14.6	4.5	.64	69.76
6	3:00 PM	765	19.6	4.54	15.4	4.53	.7	42.4
7	4:00 PM	456	19.5	2.32	16.7	2.54	.72	34.7
8	5:00 PM	143	19.6	1.3	14.9	.65	.75	9.7
9	6:30 PM	43	19	.6	14.1	.22	.65	3.1
10	6:49 PM	0						0

Here,

Voltage (V) – Open Circuit voltage

Current (I) - Short circuit current

Vmpp (V) – Maximum Power (voltage)

Impp (I) – Maximum Power (Current)

Fill Factor – Vmpp*Impp/Voltage (V) * Current (I)

Pmax - Vmpp*Impp

4.10 Summary

We discuss our working procedures and work principles, such as the use of photovoltaic meters, irradiation meters, and temperature sensors, in this chapter titled "Methodology." We display the I-V 400W calibration's technical and electrical specifications and a flowchart illustrating how sunlight operates on a solar panel. We adhered to all working procedures, including those necessary and those outlined in this chapter. Finally, the data entered based on measured elements into the lab sheet.

CHAPTER 5

DATA ANALYSIS & RESULTS

5.1 Introduction

Here, we will find the solar system's irradiance, the power generation process of 100W solar panels, solar panels' power production in percentage form, and sunny day and cloudy days' power graph. Then we will analyze our data very carefully.

5.2 Panel Efficiency Report

100W Solar Panel Efficiency report of the month July 2022

Table 5.1: 100W Solar Panel Efficiency Report of the Month July 2022

Date	Irradiance (W/m^2)	Equivalent power of Irradiance (W)	Area of panel (m^2)	Output power Pmax(W)	Efficiency η%	Average Efficiency
1-July	254	195.53	0.75	13.4	7.98%	
2-July	365	232.34	0.75	27	9.45%	
3-July	345	299.1	0.75	34	6.58%	
4- July	484	350	0.75	23.54	4.87%	
5- July	325	287.43	0.75	32	7.64%	
6- July	378	365.5	0.75	12.34	7.24%	
7- July	454	232.6	0.75	33.54	8.14%	
8- July	253	132.54	0.75	22.5	5.34%	
9- July	348	287.5	0.75	23.7	6.47%	
10- July	245	160.43	0.75	14	6.78%	
11- July	345	256.5	0.75	15.53	5.44%	
12- July	154	43.36	0.75	16.71	9.71%	
13- July	425	310.45	0.75	24.8	7.54%	
14- July	340	254.5	0.75	19	5.47%	8.65%
15- July	366	266.44	0.75	21	9.65%	
16- July	245	145	0.75	12.8	8.61%	
17- July	458	232.32	0.75	21.45	9.97%	
18- July	235	154	0.75	36.6	6.53%	
19- July	412	381.5	0.75	27	11.44%	

20- July	364	232.72	0.75	32.6	6.65%	
21- July	452	342	0.75	22.6	9.08%	
22- July	498	394	0.75	27.1	7.64%	
23- July	180	54.12	0.75	12.3	9.52%	
24- July	564	462.43	0.75	36.5	10.99%	
25- July	458	362.34	0.75	25	7.39%	
26- July	245	184.3	0.75	16.6	14.8%	
27- July	133	59.3	0.75	11.42	7.68%	
28- July	189	161	0.75	28	8.33%	
29- July	307	235.55	0.75	38.5	9.61%	
30- July	254	199.14	0.75	22.8	8.12%	
31- July	274	221.55	0.75	24.8	7.05%	

5.3 Solar data analysis

Here we get the results from daily reading. We have the task of irradiance (Irr) of the solar system, and also, we have the output power (Pmax). From the table, we will find the solar system's efficiency. But we don't have any input power of the system. We have the irradiance input. So, we multiply w/m^2 and m^2 here. Then we get the output of this method. We know-

Efficiency Ƞ = Output power/Input power

Upper table 5.2 measures the efficiency of the 100Wt solar system of July 2022 by the efficiency equation. Then we calculate the input power by multiplying the irradiance and the panel size. So, the average efficiency we get is 8.56%

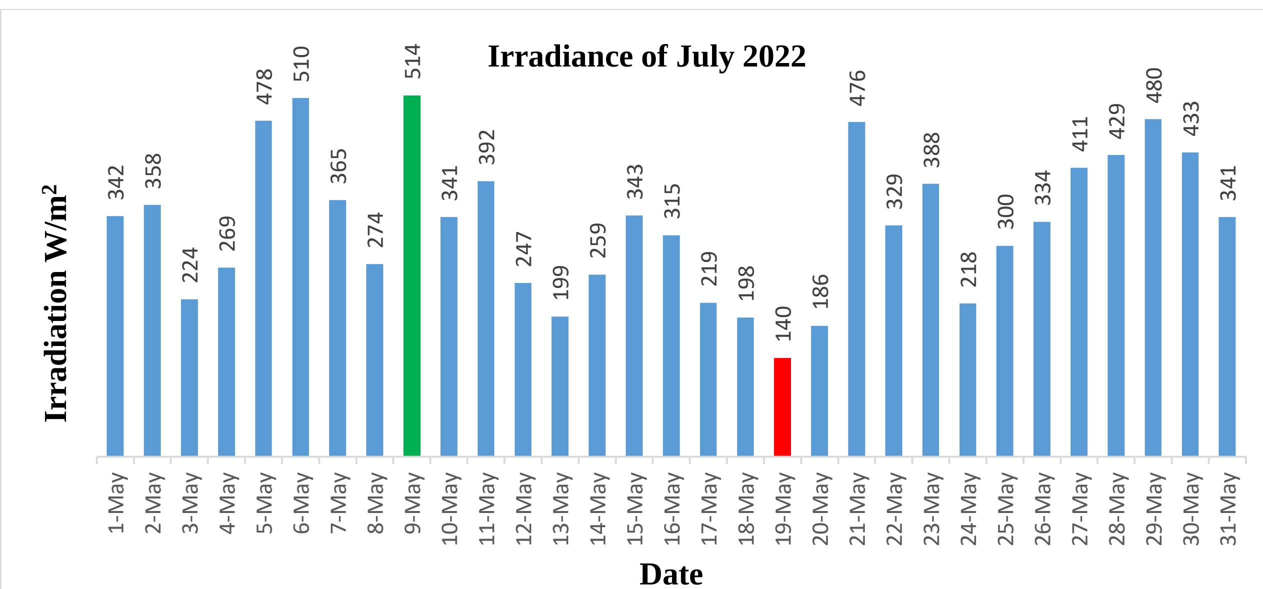

Figure 5.1: Daily Irradiance Report of July

Here in fig 5.1, we show the data for the month of July. On the 11th of the month, we get the highest value of irradiance, which is 514 W/m^2. Those things are happened for sunny days.

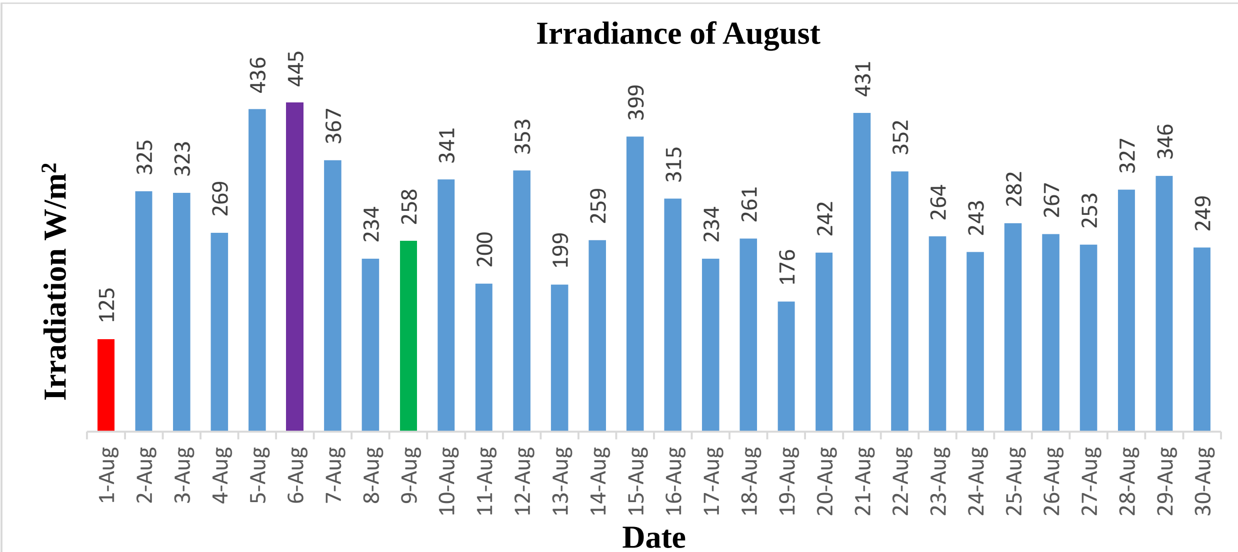

Figure 5.2: Daily Irradiance Report of August

From upper figure 5.2, we get the data on solar irradiation in August 2022. Here the highest value of solar irradiance is measured. The deal is 456, and the lowest value is 70. This month's exact reason is here for the highest and lowest value. In sunny weather, we get the highest number of values & in the rainy season, we get the lowest value.

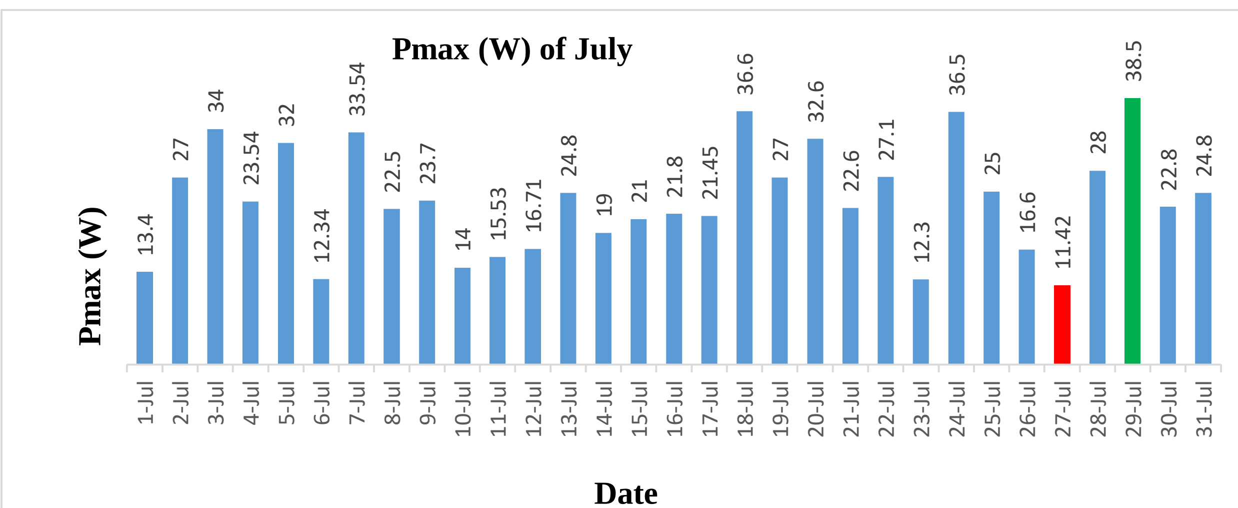

Figure 5.3: Daily Pmax (W) Graph of July

The data shows the 100 W solar panel power generation curve in July in figure 5.3. We found the lowest value of Pmax on 28th July, which is 11.42W. On the other hand, we found the highest value of Pmax on 30th July, which is 38.5W.

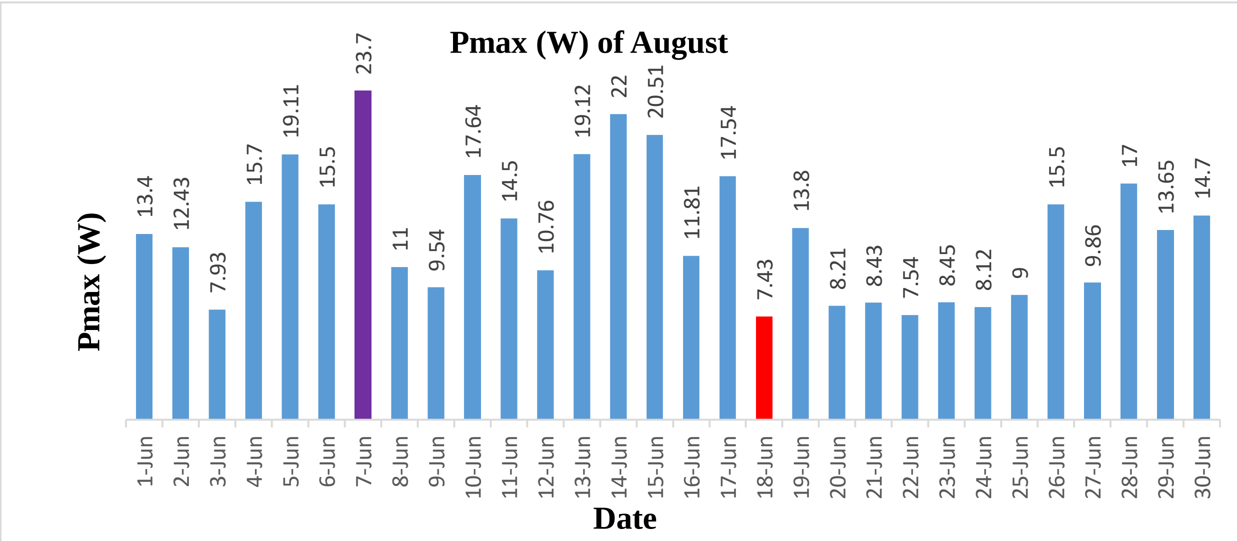

Figure 5.4: Daily Pmax (W) Graph of August

In the upper figure 5.4, we get the Highest and lowest value of Pmax for August 2022. The Highest value is 23.7W we got on 8th August. On the other hand, we got the lowest deal on 19th August, which is 7.43W.

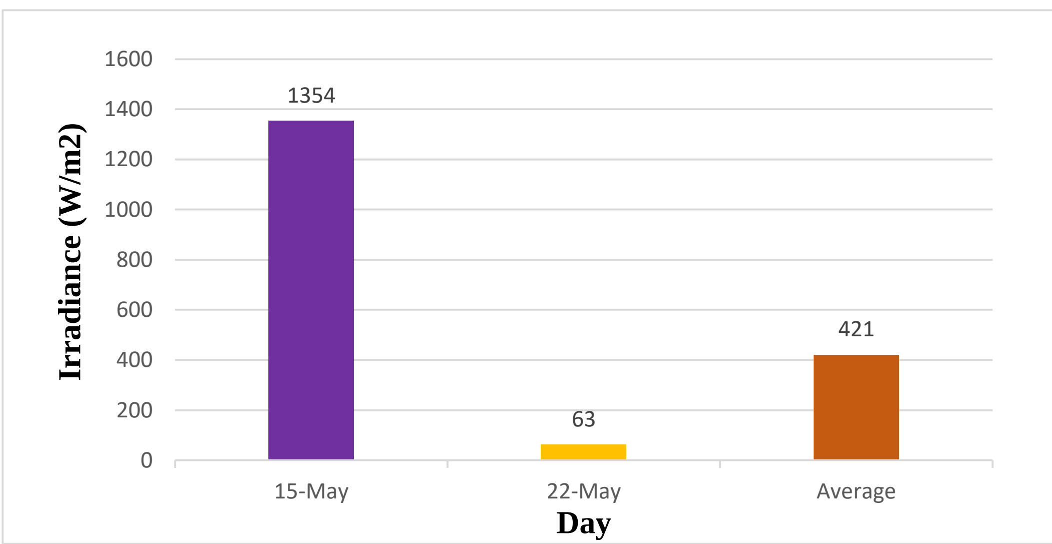

Figure 5.5: Irradiation Graph of July (highest, lowest & average)

From upper Figure 5.5, we saw the irradiation data for July 2022. On the 15th of 2022, we got the highest value of irradiance, which was 1354 W/m^2 & on 22 July 2022, we measured the lowest value of irradiance, which was 63 W/m^2.

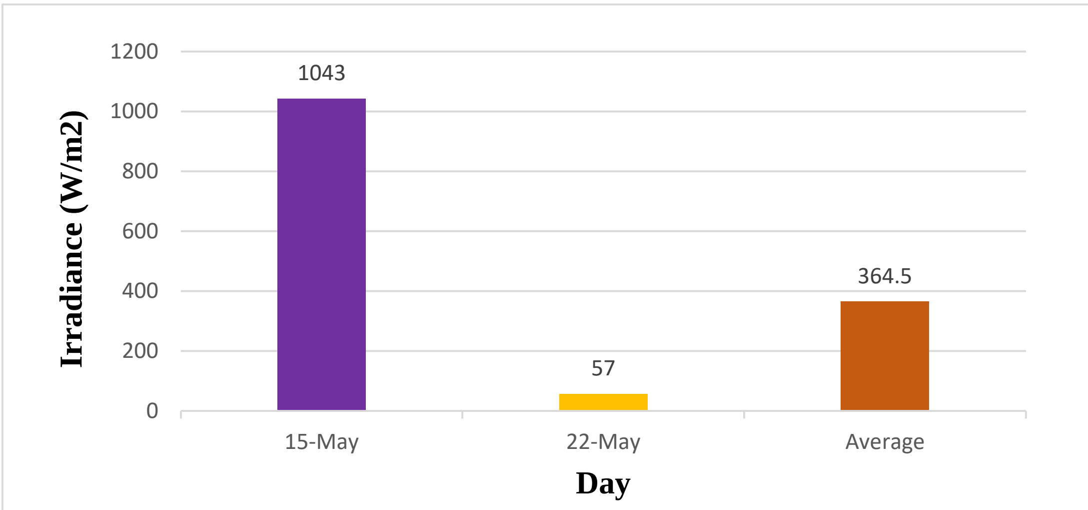

Figure 5.6: Irradiation Graph of August 2022 (highest, lowest & average)

Figure 5.6 shows the solar irradiation data for August 2022 2022. On the 4th of the month, we got the highest irradiation value, 1043 W/m^2 & on 19 August; we got the lowest value of irradiation, 59 W/m^2. The reason for that comparison is weather changing. When it is sunny weather, the matter becomes high & on rainy days or cloudy days, the value becomes very low.

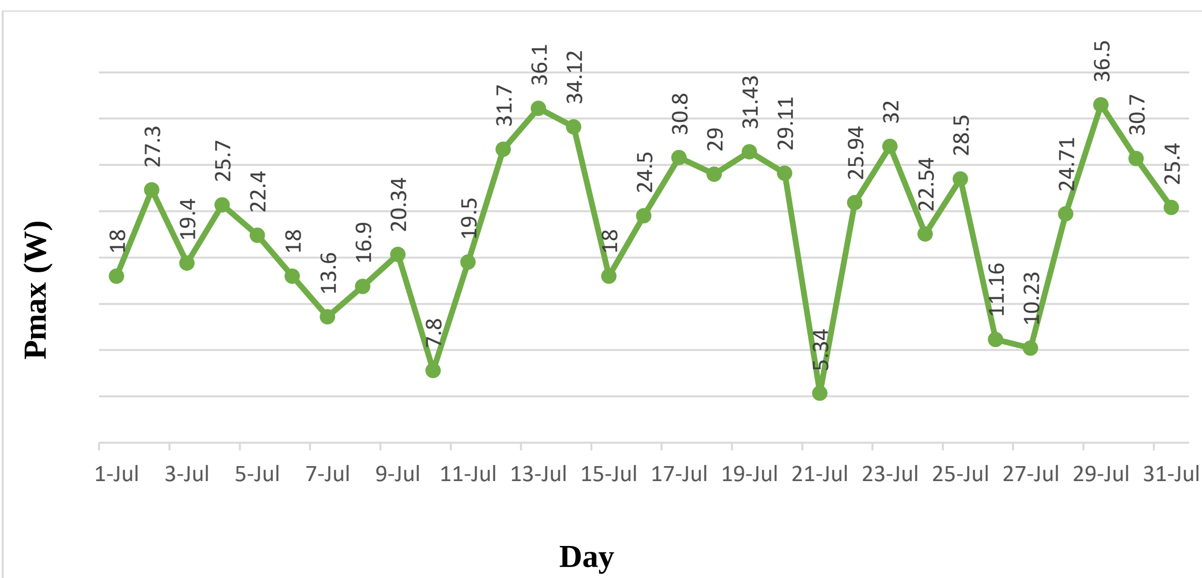

Figure 5.7: Graph of Power Generation for July 2022

In figure 5.7, we measure the daily average power generation graph of the 100W solar panel system for July 2022. We found the high value on 29th July, which is 36.5W. On the other hand, we found the lowest power consummation on 10th August 2022. And the value is 7.8W.

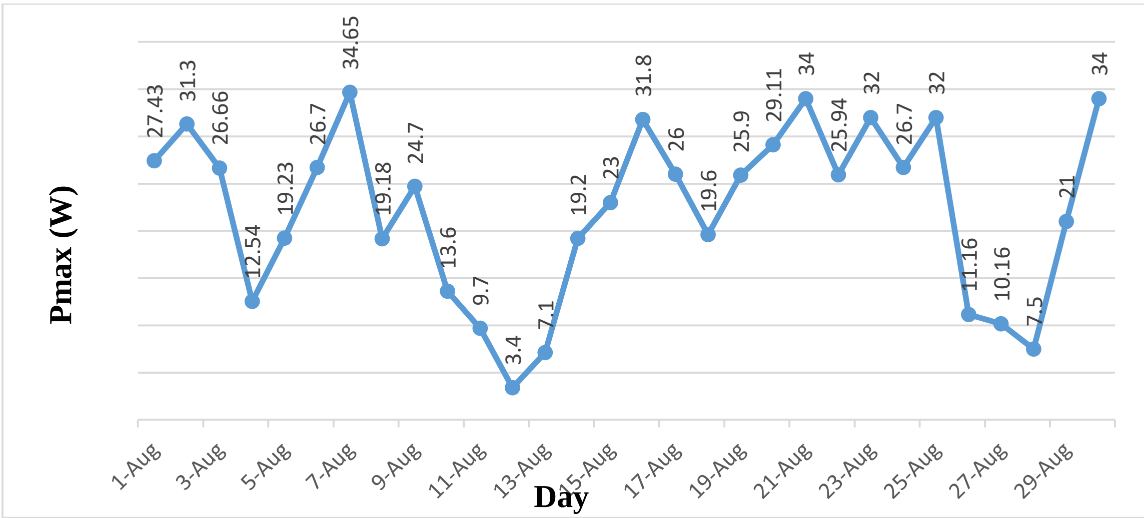

Figure 5.8: Graph of Power Generation for August 2022

We get the highest and lowest values of power consummation from Figure 5.8. The highest value we get is on 8th August 2022. Also, we get the lowest value from the upper graph, which is 3.4W. The date is 12th August 2022.

Power Generation Comparison between July & August 2022

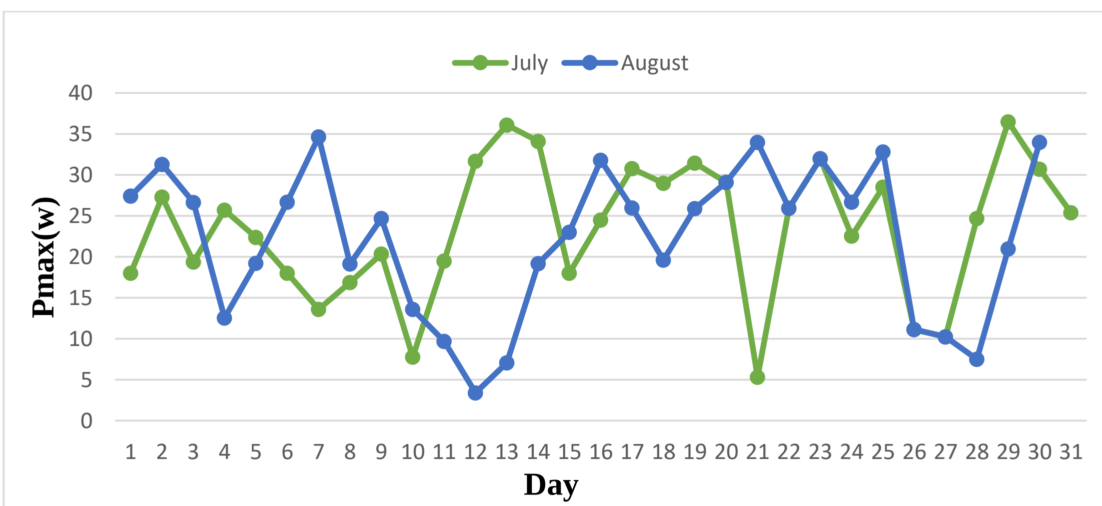

Figure 5.9: Graph of Power Generation for July & August 2022

In Figure 5.9, we saw the comparison power for July & August. We see some similar differences between the two months. If we know the graph carefully, July month is one step better than July month. That is because we have more sunny days in July if we compare it with August.

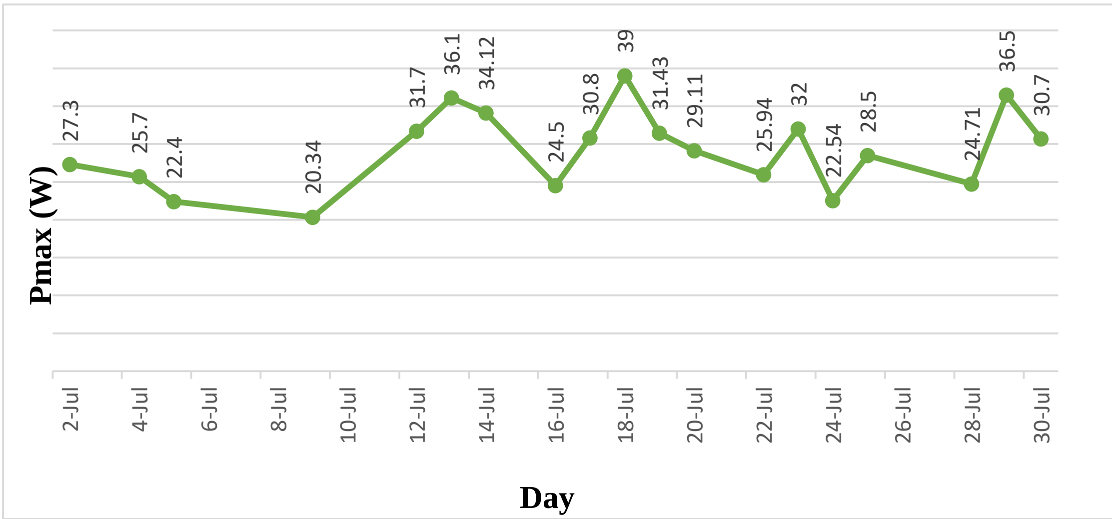

Figure 5.10: Sunny Days Power Graph of July 2022

Figure 5.10, shows the data for the sunny day season of July 2022. During sunny days, we measure the highest power, 36.5W & the lowest power, 20.34W. On sunny days in July, we estimate the power every hour & the average power of the month is 31.4W.

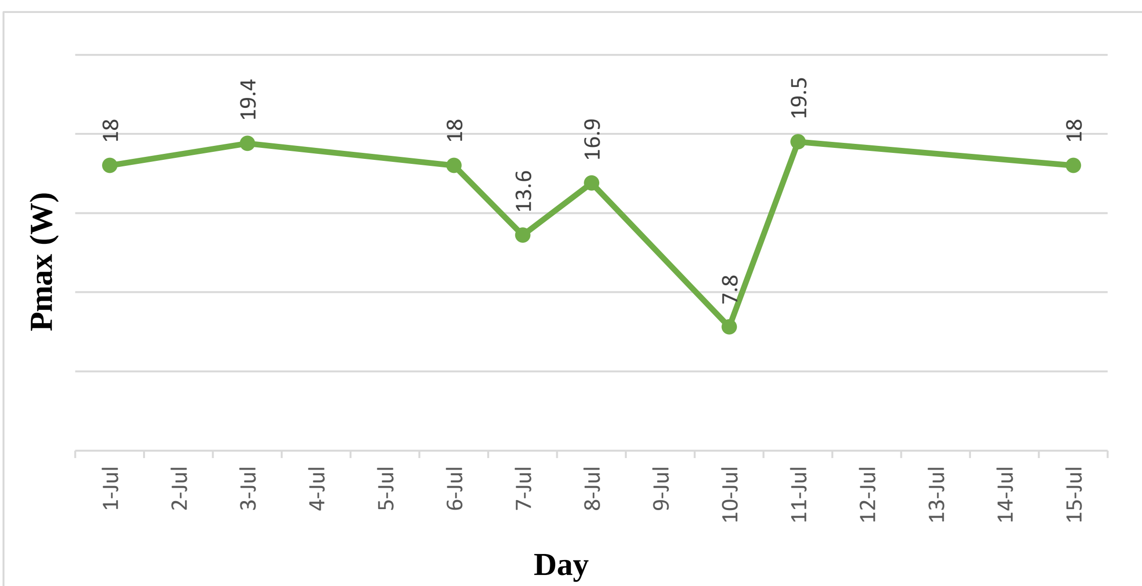

Figure 5.11: Rainy Days Power Graph of July 2022

From Figure 5.11, we see the rainy day's power generation in July month. These days we get the highest power which is 19.4W, and the lowest power, 7.7. The average strength of rainy days is 17.6W.

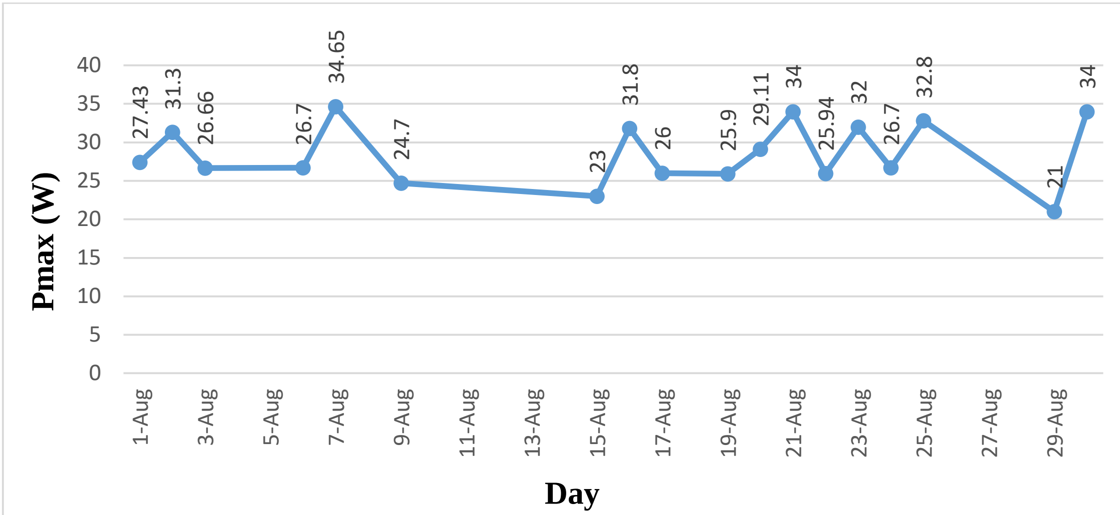

Figure 5.12: Sunny Days Power Graph of August

Figure 5.12, shows the data for the sunny day season of August 2022. On sunny days, we measure the highest power at 34.65W & the lowest energy is 21W. On sunny days in August, we estimate the power every hour & the average power of the month is 32.4W.

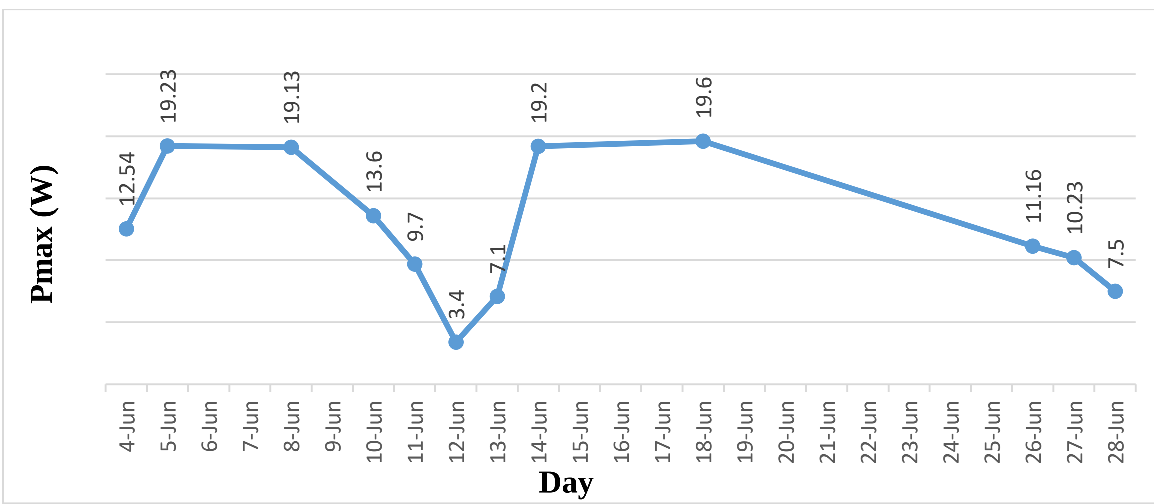

Figure 5.13: Rainy Days Power Graph of August

From Figure 5.13, we see the rainy days' power generation for August month. During this day, we get the highest power which is 19.6W, and the lowest intensity, 3.4W & the average force on rainy days is 17.6W.

5.4 Comparison of solar radiation data among different Years

Table 5.2: Monthly Average Data of Solar Irradiance in 2008, 2009 & 2010.[33]

Month	Solar Irradiance(W/m^2) (2008)	Solar Irradiance(W/m^2) (2009)	Solar Irradiance (W/m^2) (2010)
January	164.9	165.6	151.5
February	209.8	219.1	186.7
March	225.8	228.3	238.2
April	283.3	273.1	236.7
May	261.2	235.1	215.8
June	212.4	210.1	176
July	176.5	197.1	201.6
August	174.1	176.4	166.2
September	189.6	156.8	165.5
October	179.7	189.1	175.1
November	208.2	164	168
December	124.7	142.5	159.2
Annual average Irradiance(W/m^2)	209.05	197.36	187.53
Annual Average (kWh/m^2/day)	5.01	4.73	4.50

If we see the upper table, we see the Solar Irradiation list of 3 years. In 2008, we got average irradiation of 5.01 kWh/m^2/day. Also, the value of the year 2009 is 4.72 kWh/m^2/day. In 2010, we got the average value of solar irradiance, which was 4.50 kWh/m^2/day.

Table 5.2 contains the solar radiation statistics gathered from the National Renewable Energy Laboratory, the Renewable Energy Research Center (Dhaka University), and Development and Research. Most of these sun radiation data were gathered by us from Dhaka University in several Bangladeshi cities.

Table 5.3: Collected Solar Irradiance Data of Bangladesh from 1985-2006 [34]

	Radiative Transfer Models		Measured data		
Month	NREL (1985-91)	DLR (2002-03)	RERC (1987-89)	RERC 1992	SWERA/RERC 2003-05
Jan	4.18	4.58	4.29	3.34	3.16
Feb	4.68	4.81	4.86	4.05	4.46
Mar	5.55	5.31	5.53	5.24	4.88
Apr	5.65	5.84	5.23	6.02	5.28
May	5.58	5.21	5.67	5.76	5.46
Jun	4.48	3.85	5.13	5.39	4.22
Jul	3.90	3.76	3.87	4.2	4.48
Aug	4.12	4.11	3.92	4.87	4.12
Sep	3.96	3.76	4.5	5.38	3.78
Oct	4.70	4.19	4.61	4.93	3.57
Nov	4.25	4.47	4.22	3.72	3.92
Dec	4.06	4.34	3.89	3.39	3.19
Annual average (kWh/m^2-day)	4.59	4.52	4.64	4.69	4.21
Annual (kWh/m^2-day)	1676	1649	1695	1712	1536

The sun's energy has decreased with time, as seen in Table 5.3. Additionally, the information on solar radiation was gathered from the Renewable Energy Research Center, National Renewable Energy Laboratory, and Development and Research and is presented in Table 5.3 of a book written by Prof. (Retied) Muhtasham Hussain, Chief Consultant Solar and Wind Energy Resource Assessment - Bangladesh Renewable Energy Research Centre University of Dhaka. The majority of these statistics were gathered in Dhaka and other Bangladeshi cities. The yearly average solar radiation was 4.59 kWh/m2/day from 1985 to 1991, and it grew to 4.64 kWh/m^2/day from 1987 to 1989. However, the yearly average radiation from 2000 to 2003 was 4.52 kWh/m^2/day, which fell to 4.2 kWh/m^2/day from 2003 to 2005. Radiation increased in 2006, reaching a value of 4.45 kWh/m^2/day.

Table 5.4: Collected irradiance from 1985-2005, 2008-2010, 2018 & Compare

Year	Month	Irradiance kWh/day
1985-1991	July	3.29
	August	4.12
1987-89	July	3.87
	August	3.82
1992	July	4.2
	August	4.86
2000-2003	July	3.56
	August	5.11
2003-2005	July	4.48
	August	6.12
2008	July	4.20
	August	5.13
2009	July	4.72
	August	5.26
2010	July	4.81
	August	3.99
2022	July	8.45
	August	6.82

After examining the information in the upper table, it is clear that September has higher irradiance values than October. The average sun irradiation in July and August from 1985 to 1991 was 3.29 and 4.12 kWh/m^2/day; in 1992, it jumped to 4.2 and 4.86 kWh/m^2/day. Although from 2000 to 2003, July and August's average daily irradiation was 3.56 and 6.11 kWh/m2, it rose to 4.48 and

6.12 kWh/m^2 from 2003 to 2005. The irradiation increased in 2008, reaching 4.20 and 5.13 kWh/m^2/day values. Additionally, in 2010 the irradiation dropped to 4.81 and 3.99 kWh/m^2/day. Additionally, the irradiation increased in 2022 and reached 8.45 & 6.82 kWh/m^2/

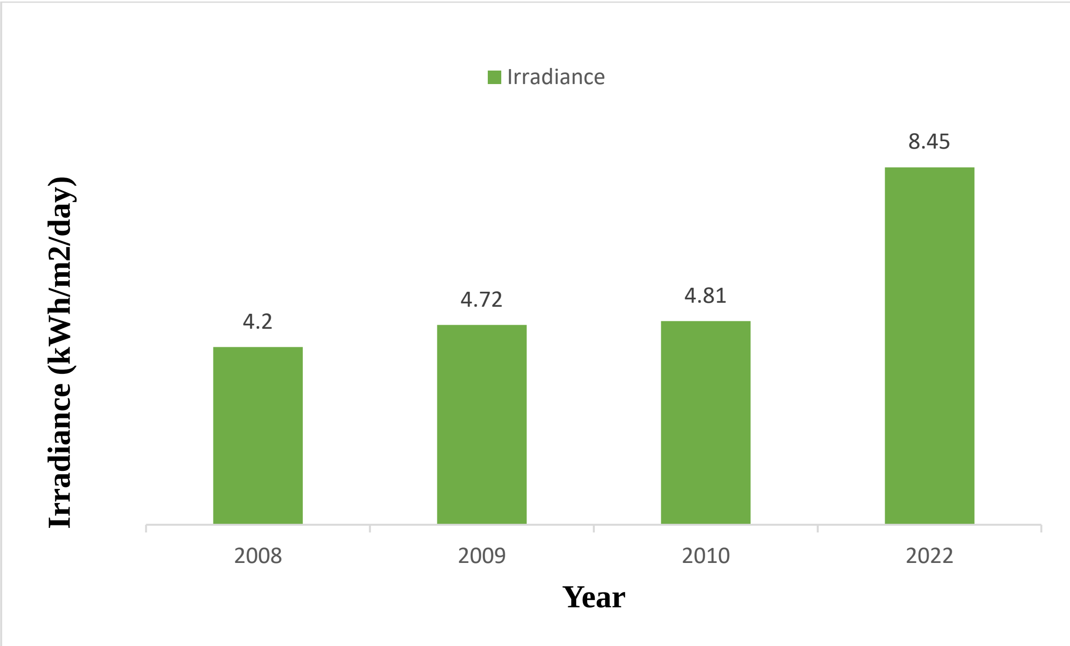

Figure 5.14: Irradiance on Different Years

5.5 Summary

This chapter outlines the nature of our job. We use 100W solar panels for our job and gather all our information online. Here, we measure the daily irradiation and Pmax for July and August. We conclude from comparing July and August's measurements that July's average irradiation is superior to August's; therefore, Julys' Pmax is likewise superior to August's.

CHAPTER 6

CONCLUSION

6.1 Conclusion

Bangladesh is a small nation with a large population. With 79% of the people residing in rural regions. One of the most significant obstacles to development is the energy crisis. The gap between electricity demand and supply is frequently unmanageable in this country. Both private and state-owned power plants in Bangladesh use fossil fuels to power their operations. Natural gas is in short store of demand. The more significant fact is that the previously reserved oil and gas will eventually run out. As a result, we must consider a different energy source. An alternative energy source might be solar energy.

Renewable energy from the sun is the most likely of all the sources. Therefore, solar power may be the solution to Bangladesh's power shortage. Additionally, Bangladesh's latitudes of 20.30 to 26.38 degrees North and 88.04 to 92.44 degrees east make it an ideal location for solar energy.

Using solar energy in Bangladesh can increase electricity generation and lessen load-shedding. The time has come to look ahead and use these renewable energy sources rather than solely relying on outdated technologies to produce electricity. SHS is already well-established in our nation. Nowadays, civilization's momentum, dynamics, and sustainability depend on energy. Hence, a country can be considered civilized if it has enough access to energy as required for industrial, agricultural, and economic growth.

6.2 Future Scopes of the Work

In this study, we try to determine how much energy may be generated by a solar system in July and August 2022. We have only been working for two months, but in the future, we will be able to monitor power and irradiation throughout the year and assess the effectiveness of the panels.

REFERANCE

[1] S. B. Amin, M. I. Chowdhury, S. M. A. Ehsan, and S. M. Z. Iqbal, "Chapter 30 - Solar energy sustainability in Bangladesh: tackling the management challenges," in *Design, Analysis, and Applications of Renewable Energy Systems*, A. T. Azar and N. A. Kamal, Eds. Academic Press, 2021, pp. 705–734. doi: https://doi.org/10.1016/B978-0-12-824555-2.00015-0.

[2] M. R. A. Bhuiyan, H. Mamur, and J. Begum, "A brief review on renewable and sustainable energy resources in Bangladesh," *Clean. Eng. Technol.*, vol. 4, p. 100208, 2021, doi: https://doi.org/10.1016/j.clet.2021.100208.

[3] M. A. N. Abir and M. T. Rahman, "Energy scenario of Bangladesh & future challenges," *Int. J. Sci. Eng. Res.*, vol. 9, no. 3, 2018.

[4] J. Al Rashid, A. Rahman, and A. A. M. Azad, "Electrification in rural Bangladesh using solar home system: progress, problems and prospect," *Int. J. Energy Inf. Commun.*, vol. 8, no. 3, pp. 1–30, 2017.

[5] M. S. Islam, A. Q. Al-Amin, and M. S. K. Sarkar, "Energy crisis in Bangladesh: Challenges, progress, and prospects for alternative energy resources," *Util. Policy*, vol. 71, p. 101221, 2021.

[6] B. K. Sahu, "A study on global solar PV energy developments and policies with special focus on the top ten solar PV power producing countries," *Renew. Sustain. Energy Rev.*, vol. 43, pp. 621–634, 2015.

[7] J. Yu, H. B. Saydaliev, Z. Liu, R. Nazar, and S. Ali, "The asymmetric nexus of solar energy and environmental quality: Evidence from Top-10 solar energy-consuming countries," *Energy*, vol. 247, p. 123381, 2022.

[8] "Bangladesh-Economic-Review-2022 - Finance Division, Ministry of Finance-Government of the People\'s Republic of Bangladesh." https://mof.portal.gov.bd/site/page/28ba57f5-59ff-4426-970a-bf014242179e/Bangladesh-Economic-Review-2022 (accessed Oct. 14, 2022).

[9] H. Toura, "Elaboration and characterization by electrochemical technique CZTS thin layers for photovoltaic application," PhD Thesis, Universitat Politècnica de València, 2020.

[10] "Nonrenewable Resources | National Geographic Society." https://education.nationalgeographic.org/resource/nonrenewable-resources (accessed Oct. 14, 2022).

[11] M. F. Hossain, S. Hossain, and M. J. Uddin, “Renewable energy: Prospects and trends in Bangladesh,” *Renew. Sustain. Energy Rev.*, vol. 70, pp. 44–49, 2017, doi: https://doi.org/10.1016/j.rser.2016.11.197.

[12] “What is renewable energy? | United Nations.” https://www.un.org/en/climatechange/what-is-renewable-energy (accessed Oct. 14, 2022).

[13] Ashok, S, “"solar energy". Encyclopedia Britannica, 20 Aug. 2022,” *Britannica*, p. 32, 2022.

[14] B. K. Bose, “Global warming: Energy, environmental pollution, and the impact of power electronics,” *IEEE Ind. Electron. Mag.*, vol. 4, no. 1, pp. 6–17, 2010.

[15] M. Z. Baten, E. M. Amin, A. Sharin, R. Islam, and S. A. Chowdhury, “Renewable energy scenario of Bangladesh: Physical perspective,” in *2009 1st International Conference on the Developements in Renewable Energy Technology (ICDRET)*, 2009, pp. 1–5.

[16] S. Agterbosch, R. M. Meertens, and W. J. Vermeulen, “The relative importance of social and institutional conditions in the planning of wind power projects,” *Renew. Sustain. Energy Rev.*, vol. 13, no. 2, pp. 393–405, 2009.

[17] H.-J. Wagner and J. Mathur, *Introduction to hydro energy systems: basics, technology and operation*. Springer Science & Business Media, 2011.

[18] O. Khayal, “Advantages and limitations of biogas technologies,” *No Dec.*, pp. 1–8, 2019.

[19] P. E. Robins, S. P. Neill, and M. J. Lewis, “Impact of tidal-stream arrays in relation to the natural variability of sedimentary processes,” *Renew. Energy*, vol. 72, pp. 311–321, 2014, doi: https://doi.org/10.1016/j.renene.2014.07.037.

[20] T. Singh, “Top Solar company in Bangladesh List 2022 Updated,” *Digital Marketing Blog India*, Jun. 07, 2022. https://digitalmarketingdeal.com/blog/solar-company-in-bangladesh/ (accessed Oct. 14, 2022).

[21] A. Ndiaye, A. Charki, A. Kobi, C. M. Kébé, P. A. Ndiaye, and V. Sambou, “Degradations of silicon photovoltaic modules: A literature review,” *Sol. Energy*, vol. 96, pp. 140–151, 2013.

[22] “What is Solar Panel? Definition of Solar Panel, Solar Panel Meaning,” *The Economic Times*. https://economictimes.indiatimes.com/definition/solar-panel (accessed Oct. 14, 2022).

[23] A. S. Hiwale, M. V. Patil, H. Vinchurkar, and others, “An efficient MPPT solar charge controller,” *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 3, no. 7, pp. 10505–10511, 2014.

[24] Monika.N and M. P. B. Manoj, “Prediction based Battery Power Management using Solar Energy,” *Int. J. Eng. Res. Technol.*, vol. 3, no. 19, Apr. 2018, doi: 10.17577/IJERTCONV3IS19147.

[25] S. Racharla and K. Rajan, “Solar tracking system–a review,” *Int. J. Sustain. Eng.*, vol. 10, no. 2, pp. 72–81, 2017.

[26] A. Barré, B. Deguilhem, S. Grolleau, M. Gérard, F. Suard, and D. Riu, “A review on lithium-ion battery ageing mechanisms and estimations for automotive applications,” *J. Power Sources*, vol. 241, pp. 680–689, 2013.

[27] “Photovoltaic Panel Converts Sunlight into Electricity,” *Alternative Energy Tutorials*. https://www.alternative-energy-tutorials.com/photovoltaics/photovoltaic-panel.html (accessed Oct. 14, 2022).

[28] “Sunworth 100Wp Mono,” *ABC Solar Electronics*, Aug. 30, 2019. https://abcsolarelectronics.com/product/sunworth-100wp-mono/ (accessed Oct. 14, 2022).

[29] “I-V400w | I-V Curve tracers | HT Instruments.” https://www.ht-instruments.com/en/products/photovoltaic-testers/i-v-curve-tracers/i-v400w/ (accessed Oct. 14, 2022).

[30] “HT Instruments SOLAR IVe I-V curve tracer up to 15A or 1500VDC and PV efficiency logger (15A, 1500VDC).” https://emin.com.mm/ht-instrumentssolar-ive-ht-instruments-solar-ive-i-v-curve-tracer-up-to-15a-or-1500vdc-and-pv-efficiency-logger-15a-1500vdc-myanmar-34926/pr.html (accessed Oct. 14, 2022).

[31] HT ITALIA 2017, “I-V400w – SOLAR I-Vw I-V500w – SOLAR I-Ve (User manual).” 2017. [Online]. Available: https://www.ht-instruments.com/en/products/i-v400w/download/manual/

[32] “HT304N- Reference cell for sun irradiation measurement.” HT ITALIA SRL, 2011. [Online]. Available: https://www.ht-instruments.com/media/filer_public/43/3b/433b18da-59bc-4f66-b186-e5e7e5dd1c6c/pdf_ht304n_en1-00.pdf

[33] T. SHAKIR-ul haque Khan and S. H. Rahman, “A brief study of the prospect of solar energy in generation of electricity in Bangladesh,” *Cyber J. Multidiscip. J. Sci. Technol. J. Sel. Areas Renew. Sustain. Energy JRSE June Ed.*, 2012.

[34] Md. S. K. Khadem *et al.*, *Solar and Wind Energy Resource Assessment (SWERA) - Bangladesh*. 2007.