PROSPECT OF SOLAR ENERGY USE IN BANGLADESH

By
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A Project Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of
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The project entitled **"Prospect of Solar Energy Use in Bangladesh"** submitted by **Somiron Mistry,** Student no.: 040510020F, Session: April 2005 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING in MECHANICAL ENGINEERING on January18, 2009

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ABSTRACT

People all over the world have been using solar energy mainly for drying from the very beginning of the human race. Use of solar energy more efficiently also started a long time ago. More recently, concern about the environment and possible shortage of conventional fuels prompted researcher all over the world to look for sustainable and non-depletable resources. Solar energy is one of the best among a score of other renewable resources.

Solar radiation data in Bangladesh are very scarce. Whatever recording is available has been collected and analyzed. These collected data are compared with other those from organizations which are related with solar energy business.

The daily Global Horizontal Insolation (GHI) has been measured continuously by a pyranometer, located at Dhaka University (Latitude 23°4'), for the last six years, starting from January 2000, is analyzed and presented. The daily, monthly and annual averaged GHI for Dhaka is collected and analyzed.

The monthly average solar radiation in Dhaka is found to be 4.24 kWh/m^2. Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east latitude which is a good location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available in the month of April-May and minimum in December-January.

An economic analysis is carried out with various solar technologies and recommends a suitable technology which is more useful for our country

ACKNOWLEDGEMENT

My project came into reality under the close supervision of our respectable supervisor Dr. Maglub Al Nur, Professor, Department of Mechanical Engineering, BUET. I bow to my supervisor for his contribution and inspiration.

I express my heartiest gratitude to Dr. Mohammad Mamun, Asst. Professor, Department of Mechanical Engineering, BUET for his co-operation.

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I firmly believe that this project could not be implemented without the assistance of some engineers from Rahimafrooz, Grameen Sakti, IDCOL, BRAC and some other organizations.

During data collection, cost analysis and status of present solar technology in our country, I had the advice and assistance of many people as GM (Rahimafrooz), Engineer Nazmun Nahar(Rahimafrooz), Engineer Palash (Grameen Sakti), Engineer Babu (BRAC) and so many thanks to them .

I offer my unconditional apology for any inadvertent mistake or omission.

DECLARATION

No portion of the work contained in this thesis has been submitted in support of an application for another degree or qualification of this or any other University or Institute of learning.

Somiron Mistry

DEDICATION

Father	Ratan Mistry
Mother	Sabita Mistry

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NOMENCLATURE

BAU	Bangladesh Agricultural University
BCSIR	Bangladesh Council of Scientific and Industrial Research
BIT	Bangladesh Institute of Technology
BPDB	Bangladesh Power Development Board
BUET	Bangladesh University of Engineering and Technology
CMES	Centre for Mass Education in Science
DU	Dhaka University
GEF	Global Environment Facility
GOB	Government of Bangladesh
GS	Grameen Shakti
IDCOL	Infrastructure Development Company Ltd.
IFRD	Institute of Fuel Research & Development
SWERA	Solar and Wind Energy Resource Assessment
LGED	Local Government Engineering Department
MEMR	Ministry of Energy and Mineral Resources
NEP	National Energy Policy of Bangladesh
NGO	Non-governmental Organization
PBS	Palli Bidyut Samity (Rural Electricity Co-operatives)
PV	Photovoltaic
RUET	Rajshahi University of Engineering and Technology
GHI	Global Horizontal Insolation
REB	Rural Electrification Board
REDA	Renewable Energy Development Agency
RERC	Renewable Energy Research Centre
RETs	Renewable Energy Technologies

SHS	Solar Home System
SRE	Sustainable Rural Energy
WB	World Bank
NREL	National renewable Energy Laboratory
DLR	Research and development
GHI	Global Horizontal Insolation
RE	Renewable Energy
NPV	Net Present Value
Co	Initial Investment
C1	Total Cost (Fuel cost and Maintenance cost) for 1^{st} Year
C2	Total Cost (Fuel cost and Maintenance cost) for 2^{nd} Year
CT	Total Cost (Fuel cost and Maintenance cost) for total Year
r	Discount Rate
Ah	Ampere Hour
GS	Grameen Sakti
ERD	Economic Relations Division
FE	Financial Express
CSP	Concentrating Solar Power

LIST OF FIGURES AND TABLES

CHAPTER-ONE

INTRODUCTION

1.1 Global Energy Crisis

Throughout history the demand on natural resources had been small compared to natural reserves. In recent years the demand has increased drastically because of the advance of industrialization. The increased rate of consumption depletes the natural reserves rapidly. Starting in the late 1972, shortage of fuel began to hit various part of our society and suddenly an energy crisis appeared.

World energy consumption is doubling every 16 years. The rate of increase is even higher in America, where 6 percent of world population consumes one third of the world's energy. As technology advances, new demands for energy emerge. The World Trade Centre Petronus towers in Malaysia consume an amount of electricity equal to that of the city of Syracuse. The insatiable demand of energy cannot be meet indefinitely. Sooner or later the depletion of energy resources will force us to change the energy consumption behavior.

For one thing, much of energy consumption at present time is wasteful, resulting from the business practice of maximization of profit without regard to conservation of resources. Once the finiteness of resources is realized, wasteful practices will have to be changed.

The solution for the energy crisis in the future is partly dependent on the use of nuclear energy. The safety of reactors has already become an issue. It is argued that the emergency core-cooling system of the reactors has not been tested and thus there is no guarantee that it will work as expected in an actual emergency. In fact, suit has been filed by environmentalist to close down all existing reactors because of this. Besides the possibility of accidental malfunctioning, one may also consider the possibility of sabotage and natural catastrophe that might destroy a reactor and disperse the radioactive material. In time of war, the possibility of bombing is so real that it would be very difficult to keep reactors operating safely

1.2 Energy Crisis in Bangladesh

Bangladesh has long been suffering from energy starvation with its humming population of 140 million, of which 80% live in villages. Bangladesh faces and will face in near future a crisis in energy sector. In the villages' fire wood, straws and cow dung are still the main source of energy.

Natural gas discovery does not make any help to the villagers. Extension of gasoline is out of question and LPG remains more a pious wish than a reality. Throughout the country trees are being fallen randomly by the thousands in order to burn brick which may give rise to horrible scene of deforestation and cause ecological imbalance in near future.

With a view to solving the problems partially, it is time to think of renewable sources of energy as a supplement to the existing traditional resources. Nature provides us with a number of renewable sources of energy such as sunshine, wind and tidal power. Unlike fossil fuel energy from these resources can be utilized for ages. Science came forward with the idea of trapping the vast energy that the sun floods the earth everyday. A number of devices have been worked out for trapping and storing solar energy.

Feasibility and utility of the renewable sources of energy should be studied with due consideration. It is required because fear of shortage in conventional energy sources. This is easily understood when we place a statistics on the energy resource availability, consumption and dependence on import of fuel.

1.3 Energy Reserve in Bangladesh

Natural Gas

Total reserve (tcf) : 22.935

Recoverable reserve (tcf) : 13.73

Recovered Till Jan'2008 (tcf) : 2.885

Source : Petro-Bangla

Resource	Total Reserve (million tons)	Recoverable (million tons)
Coal	1753	703
Peat	600	600
Oil	1.6	1.6

Table 1.1 **Sources**: Statistical Yearbook of Bangladesh, 2007

1.4 Renewable Energy Sources in Bangladesh

1.4.1 Solar energy

Solar energy is all sources of energy, viz; coal, petroleum, natural gas, hydraulic power, wind etc. with the exception of nuclear power derive energy from the sun. The main advantages of solar energy are that it is absolutely pollution free, inexhaustible and especially suitable for deserts and isolated places where other sources are not available. With the product of suitable low cost collector materials, solar energy can play a significant role in the future.

In our country, solar PV application primarily concentrates on rural home lighting. Lack of awareness at the ground level and absence and absence of financing facilitators are the major handing factors against mass solarization in Bangladesh. Besides, govt. Bureaucracy and detrimental cost consciousness of some development agencies are also responsible.

Solar photovoltaic: Solar photovoltaic (PV) systems are in use throughout the country with over 200,000 household-level installations having capacity of about 12 MW (June 2008). Scaling-up of solar PV systems assisted by the development partners are being implemented through the Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB) and other agencies implementing solar energy program. Renewable Energy Research Centre of the University of Dhaka has installed a model 1.1kW grid connected photovoltaic system. There is a strong potential for solar energy within the country.

Solar Thermal Power/Concentrating Solar Power (CSP): The technology involves harnessing solar radiation for generation of electricity through a number of steps finally generating mechanical energy to run a generator. This technology needs to be disseminated in the country to supplement the power supply.

1.4.2 Wind energy

Wind power was used for driving flower mills in many parts of the world. For many years wind power was harnessed for driving the ships that were sailing around the world. Because of the increasing fuel cost, interest has once again been generated for the improvement in the design of wind mills, especially for the areas where higher wind velocity is available for a considerable period of time. In Bangladesh areas such as Anwara, Teknaf and Kutubdia average wind speed V is 5-6 m/sec. Energy from wind is proportional. So, large amount of energy can be extracted from wind.

1.4.3 Hydraulic energy

The main disadvantage of a hydraulic power plant is its high initial cost and longer commissioning period. But these disadvantages are offset by the low cost of generation coupled with the control of floods and increased irrigation facilities.

For the generation of hydraulic power generally a dam is constructed at a suitable place to collect a large quantity of water during rainy season. The water so collected produces a pressure head. This is then released in a controlled manner to drive a turbine for generation of power. In Bangladesh potentials sites are at Kaptai, Sangu and Matamuhuri. So far, hydropower generation is made at Kaptai.

1.4.4 Geothermal energy

Geothermal energy is the natural heat of the earth. It is a renewable source of energy if the exploration process doesn't hamper the ecosystem or emit greenhouse gases. There is a known hot salt water spring, known as Labanakhya, in Bangladesh at five kilometer to the north of Sitakunda (40 kilometer from Chittagong). Possibility of extracting energy from this site or any other unknown sites can be investigated by satellite remote sensing or physical surveys.

1.4.5 Fossil

Biomass is the most significant energy source in Bangladesh, which accounts for 65% of the total final energy consumption in Bangladesh. The main sources of biomass fuels are – (a) Trees -wood fuels, twigs, leaves, plant residues (b) Agricultural Residues - paddy husk, bran, bagasse, jute stick etc. and (c) Livestock -animal dung. A comprehensive study should be carried out to assess the biomass potential of the country for modern renewable energy applications like gasifies. The main cities of Bangladesh are already over burdened with solid wastes from different sources. According to the World Bank study, the rural population generates only 0.15 kg per capita per day, while their urban counterparts generate 0.4 to 0.5 kg per capita per day [World Bank, 1998]. All city corporations, responsible for waste management, are unable to handle the solid waste properly. Waste-to-energy project should be given serious contemplation, which will not only provide electricity, but also reduce the overwhelming waste disposal problems of metropolitan cities of the country.

1.5 Objectives of Renewable Energy Policy

The objectives of renewable energy policy are to:

(1) Harness the potential of renewable energy resources and dissemination of renewable energy technologies in rural, peri-urban and urban areas;

(2) Enable, encourage and facilitate both public and private sector investment in renewable energy projects;

(3) Develop sustainable energy supplies to substitute indigenous non-renewable energy supplies;

(4) Scale up contributions of renewable energy to electricity production;

(5) Scale up contributions of renewable energy both to electricity and to heat energy;

(6) Promote appropriate, efficient and environment friendly use of renewable energy;

(7) Train; facilitate the use of renewable energy at every level of energy usage.

(8) Create enabling environment and legal support to encourage the use of renewable energy.

(9) Promote development of local technology in the field of renewable energy. Promote clean energy for CDM; and

(10) Policy sets targets for developing renewable energy resources to meet five percent of the total power demand by 2015 and ten percent by 2020.

1.6 Objectives

Specific objectives of the present study are listed below

i. To collect solar radiation data in Dhaka for the last twenty years.

ii. To analyze these data.

iii. To compare these data with those of the other organizations involved in solar energy business.

iv. To make an economic analysis among the available solar technologies.

v. To recommend a suitable technology appropriate for Bangladesh

CHAPTER-TWO

BASICS OF SOLAR PV SYSTEM
AND
DETAIL STUDY OF SOLAR HOME SYSTEM

2.1 The Basics of Photovoltaic

"Photovoltaic" refers to the creation of voltage from light, and is often abbreviated as just "PV". A more common term for photovoltaic cells is "solar cells", although the cells work with any kind of light and not just sunlight.

A solar cell is a converter. It changes energy of light into electrical energy. A cell does not store any energy, so when the source of light (typical the sun) is removed, there is no electrical current from the cell. If electricity is needed during the night, some form of electrical storage (typical a battery) must be included in the circuit.

2.2 What are Solar Cells?

There are many materials that can be used to make solar cells, but the most common is the element silicon. (This is not to be confused with "silicon", a synthetic polymer.). Silicon is the second most abundant element in the Earths crust, next to oxygen, and silicon and oxygen together make quartz or common sand. It is therefore very abundant, as well as non-toxic and safe. This is the same silicon that is used to make computer chips, and some of the processing steps involved in making solar cells are similar to the steps in making computer devices. However, solar cells are much larger than typical individual computer circuits, and they must be much less expensive. A typical solar cell used for terrestrial (Earth-based) applications is 3-6 inches in diameter and costs only a few dollars.

The conversion process occurs instantly whenever there is light falling on the surface of a cell. And the output of a cell is proportional to the input light: the more light, the greater the electrical output. The cell does not use up any internal "fuel" for the conversion process. The solar resources are more uniformly distributed over the Earth surface than other renewable sources of energy light wind or hydro.

2.3 Overview of Current Cell Technologies

The single crystal silicon technology used in solar cells is not the only method for fabricating solar photovoltaic devices. We present here a brief discussion of the most common competing cell technologies in the field today.

2.3.1 Single crystal silicon

The most type of thick solar cell is made by melting purified chunks of silicon in a crystal growing furnace and slowly solidifying the silicon into a large cylindrical crystal. In this process the atoms of silicon are aligned and the electrical properties are optimized. This process is called the single crystal silicon technology.

This has been the predominant method for making solar cells for 30 years. Silicon is abundant, electrically stable and relatively easy to manufacture. Efficiency of 12% on a final module are typical.

2.3.2 Cast polycrystalline silicon

Another method of creating a block of silicon is to melt purified silicon rocks in a rectangular block shape mold. When the silicon is cooked slowly, it solidifies into the block shape. But in the solidifying process, the atoms do not align into a large single crystal as in the Single Crystal Silicon. Small regions of single crystal structure crystallize next to each other, creating a polycrystalline block of different grains and orientations.

At the boundaries between the grains, it is possible for incomplete atomic bonds to interfere with the current follow and typically a slightly lower output is produced compared to equivalently processed single crystal cells.

Efficiencies of 10-12% are typical.

2.3.3 Single crystal silicon

The silicon process in the previous two methods is wasteful, often converting 40-50% of the material into dust. This is because the wafers are only approximately 0.015 inch thick, and the saw blade is about this thickness as well.

Very fast growth rates are possible, but the speed results in polycrystalline structures. If the pulling process is done very carefully, near single crystal structure is possible. The ribbon thickness is approximately 0.010-0.015 inch. So no further sawing is necessary. The ribbon is simply scribed and broken to produce rectangular wafers.

Efficiencies similar to polycrystalline are typical.

2.4 Efficiency of Cell Technology

Efficiency Defined

- Efficiency = Output/Input
- Module Efficiency = Electrical Power out/ Solar Power in

Specifically for solar photovoltaic cells or modules, we define efficiency as follows:

<u>Efficiency = Electrical power out of device / Solar Power into device</u>

Cell Type	Best Cell Efficiency	Module Area Efficiency	Advantages
Silicon	22.7%	12-15%	Well understood; Receiving Renewed attention
Cd Te	15.8%	6-8%	Low cost
Amorphous Silicon	13.2%	4-9%	Low cost
CulnSe2	16.9%	10%	23% potential; Low cost
Single Junction Concentrator	28.7%	NA	Hybrid PV/thermal
Multi Junction Concentrator	355	NA	Hybrid PV/thermal Space

Table 2.1 Efficiency of Cell Technology

2.5 Solar Module Manufacturing and Testing

The manufacturing process used by Siemens Solar involves many proprietary elements and is quite involved. But it is important to discuss the manufacturing process so that we can appreciate the technical features and benefits of the modules and cam have confidence in the durability and longevity of the products.

The manufacturing can be presented as three segments or phases: crystal and wafer fabrication; cell manufacturing; and module assembly. Each of these processes is discussed next.

<u>**Module Manufacturing Flow**</u>

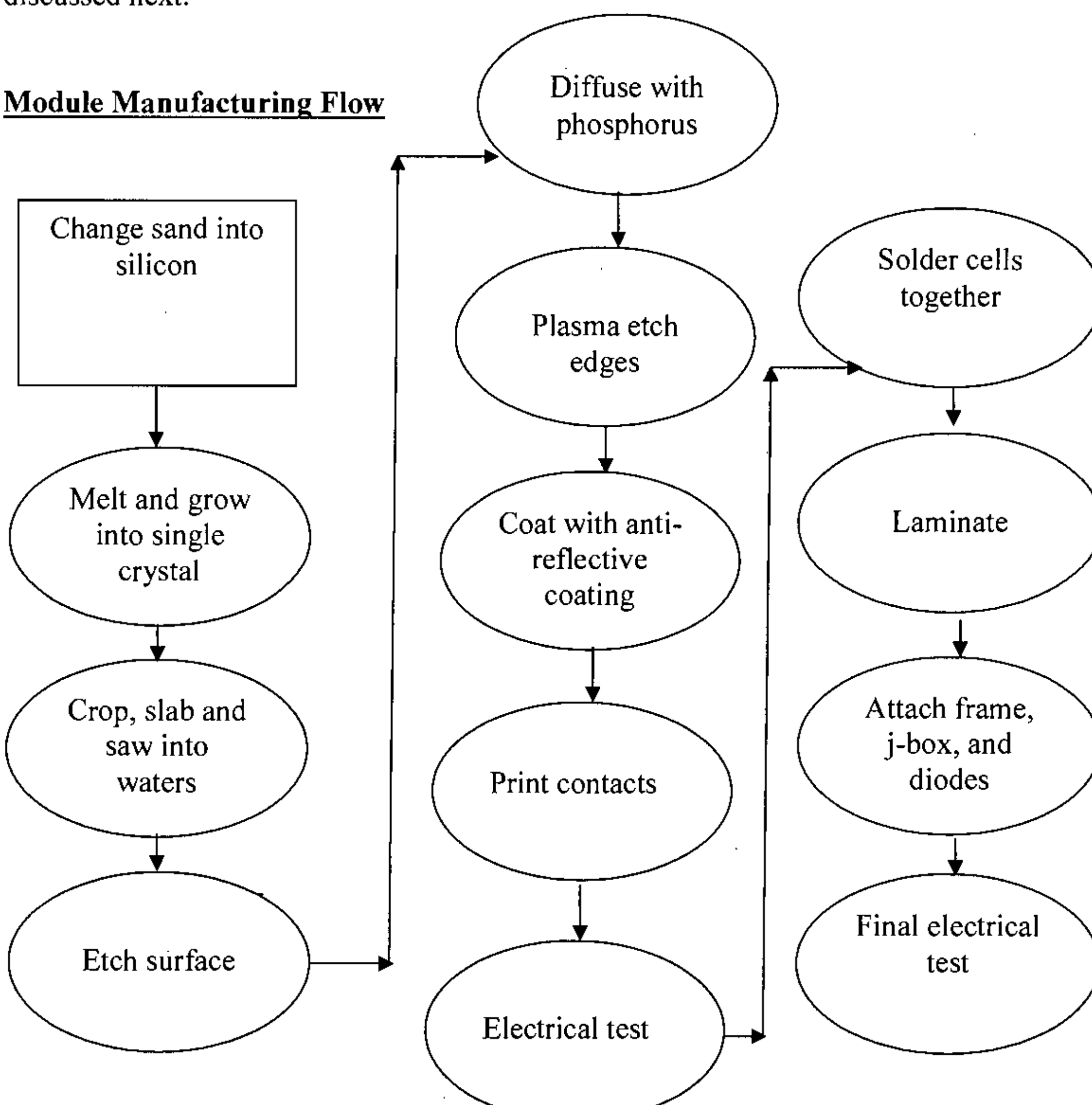


Fig. 2.1 Module Manufacturing Flow

2.6 Cell Manufacturing

2.6.1 Cell manufacturing steps

- Diffuse with phosphorous to make N-type layer
- Doping penetrates both sides and edges
- Remove edge layer
- Deposit anti-reflective coating of TiO
- Print silver grid patterns on front and back

  Back grid allows with silicon and neutralizes back N-type layer

Electrically test and sort 100% of cell

2.7 Purpose of Batteries in Solar PV System

Autonomy

Nighttime operation

Cloudy or bad weather operation

The most important function of batteries in PV power is to allow the loads to operate when the PV array cannot supply enough power. This occurs each night, on overcast days, and during days or weeks of severe bad weather.

Supply large or momentary surge current

Another important function of batteries in PV power systems is to supply a level of current that may be demanded by a load that is higher than the PV array can produce. The current output of the PV array is limited to the array Isc. The array may be large enough to supply the total energy needed by a load over a day, but not large enough to meet a momentary load demand at any particular time. A battery can act as a buffer supplying large currents to the loads for short periods and being slowly changed by the array during daylight.

2.8 Inverter Technology

The photovoltaic array and battery produce DC Current and voltage. If AC power is required by the loads, an inverter can be used to convert from DC to AC. Commonly available inverters can output in 1 or 3 phase, 50 or 60 hertz, and 117 or 220 volts, and can range in continuous output power from a few hundred watts to thousand of kilowatts. Large utility scale inverters are made to output at 480 volts AC or higher and have capacities exceeding 1000 kilowatts.

The three key characteristics of inverters

- Output power and surge power capability
- Output efficiency
- Output waveform

2.9 Comparison of Diesel and PV Generators.

Characteristic	PV only	Diesel Only
Dependence on natural cycles	Highly dependent	independent
Cost effective size	Below 20-30 kWh/day	Above 150 kWh/day
Reliability	excellent	Depends on maintenance
Fuel	none	Frequent deliveries
Maintenance	Annually or semi-annually	frequent
Characteristic	PV only	Diesel only
Handling load peaks	moderate	good
Battery charge rate	slow	fast
Initial cost	high	low
Operating cost	low	high

Table 2.2 Comparison of Diesel and PV Generators.

2.10 Detail Study of Solar Home System

2.10.1 Introduction

1 The Sun, most powerful planet of the solar system, converts 660 million tones of gaseous mass containing hydrogen and helium, into energy every second.

2 Earth receives about 150 billion Mega-Watts of energy which is about 16,000 times of the total global energy consumption.

2.10.2 Why suitable technology for our country

Bangladesh is a populated country. Present population of this country is 14 cores and 71 lacks. About 80% people are living in villages. There are many villages in our country having no electricity and some other villages have about 8-10 hour load shading daily. So, solar home system can give an alternate solution for electricity in these villages. It is an investment for a longtime completes the project of SHS because it is a renewable energy source. Solar radiation intensity is also suitable for this technology.

2.10.3 Working principle

Sunlight is converted to electrical energy when it passes through PV modules which contain silicon cells. At first silicon cells are connected electrically and placed between two layers of protective materials. This sandwiched silicon material with protective materials is then heat laminated to a protective glass sheet.

2.10.4 Functioning

- Solar PV module converts the sunlight in to electrical energy as the sunlight passes through the module. It also produces DC current suitable for charging 12V battery.
- Charge controller controls the amount of charge going into the battery from the solar module and prevents the battery from overcharging
- The battery preserves the electrical energy during the day time and gives power during the absence of sunlight. Industrial deep cycle battery with higher cyclic life is recommended for solar application.
- On cloudy days, the battery can be still being charged since ultra-violet rays penetrate cloud cover but the power will be lesser than the clear days.
- Load is the total electrical equipment i.e. light, fan, television which is powered by electrical energy.

2.10.5 How do solar cells generate electricity?

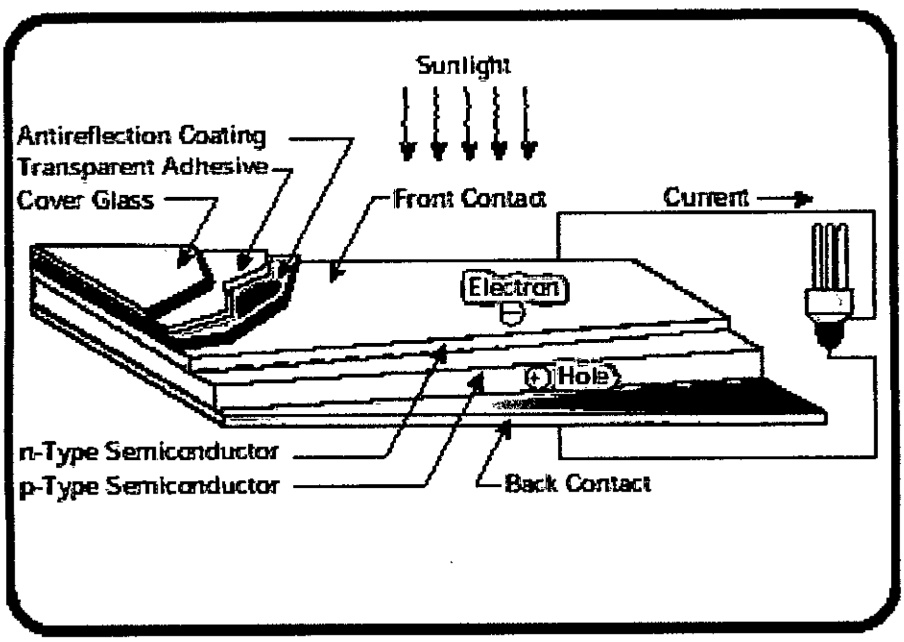


Fig.2.2 How Do Solar Cells Generate Electricity?

PV is like a DC generator powered by the sun. When light photons of sufficient energy strike a solar cell, they knock free electrons in the silicon crystal structure forcing them through an external circuit (battery or DC load), and then returning them to the other side of the solar cell to start the process all over again. The voltage output from a single crystalline solar cell is about 0.5V with an amperage output that is directly proportional to cell's surface area (approx. 7A for a 6 inch square multicrystalline solar cell). Typically 30-36 cells are wired in series (+ to -) in each solar module. This produces a solar module with a 12V nominal output (~17V at peak power) that can then be wired in series and/or parallel with other solar modules to form a complete solar array to charge a 12, 24 or 48 volt battery bank.

2.10.6 Components of solar home system

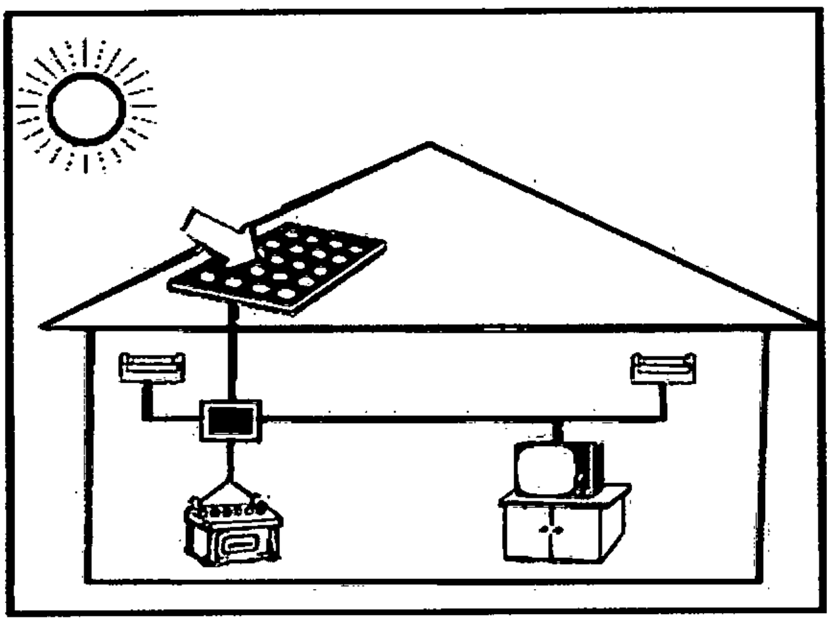


Fig. 2.3 Components of Solar Home System

- Solar PV module
- Charge controller
- Battery
- PV module supporting structure
- Load (light, fan television etc.)

2.10.7 Offgrid Solar Systems

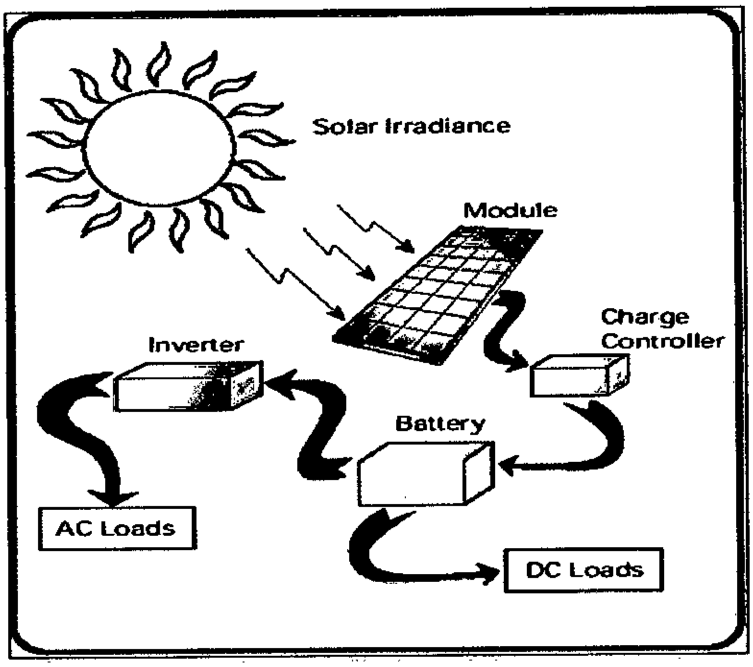


Fig. 2.4 Offgrid Solar Systems

- Solar module
- Charge controller
- Inverter
- Battery bank
- AC/DC loads

2.10.8 Impact of Solar Home System

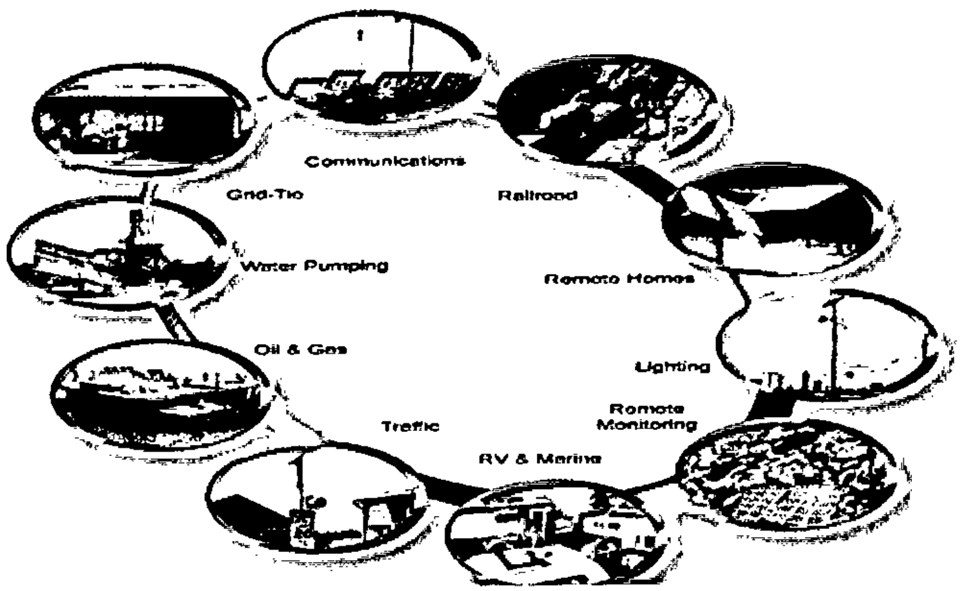
1 Better environment of children's education at night and healthy atmosphere due to non emission of CO2 gas from lighting source

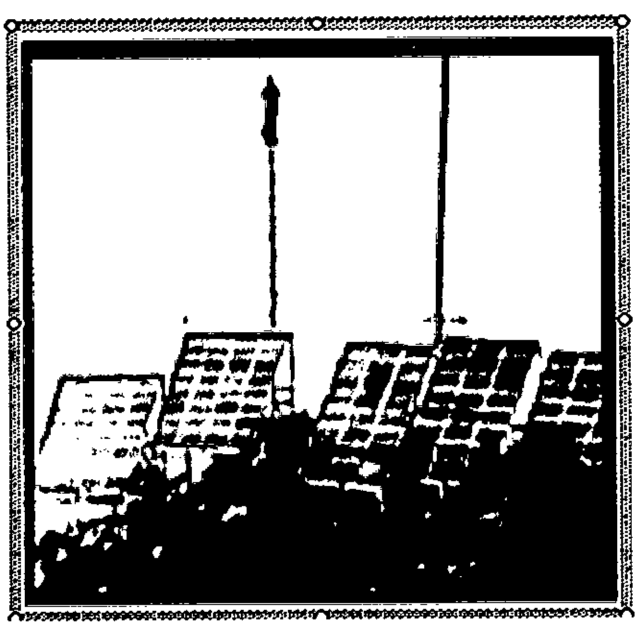
2 Women are getting extra time for income generation activity like sewing, poultry farming

3 Increased income due to extension of working hours after dusk

4 Starting of new business like radio/TV repairing shop, telephone service, power selling service, etc.

2.10.9 Solar Energy Applications





Remote telecommunication because the cost associated with installing a transformer and underground cable is substantial, solar electric power offers a reliable, cost-effective providing reliable and economical solar electric systems for remote power solutions. Typical applications powered by solar electricity include microwave repeaters, base stations, VSATs, and WLL telecommunication systems

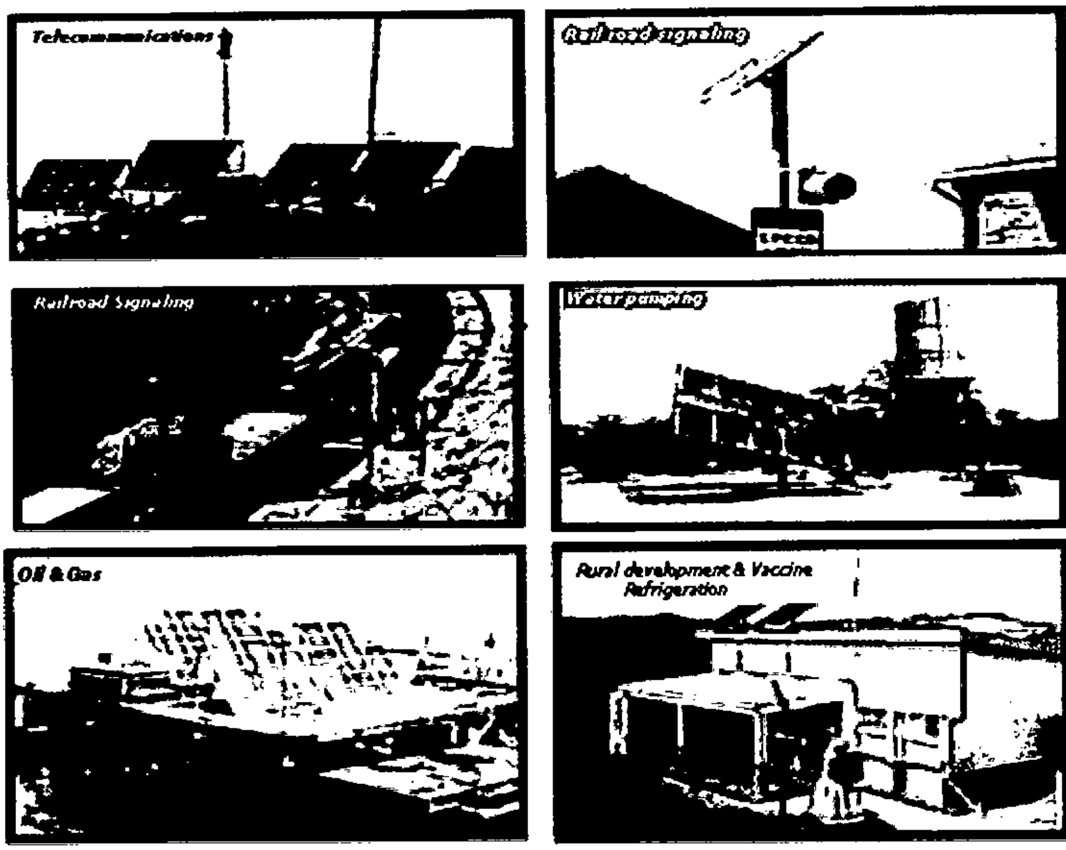


Fig.2.5 Solar Energy Applications

2.10.10 Why Charge Controller

- The main function of a controller is to fully charge a battery without overcharge
- Preventing reverse current flow at night
- If a non-self-regulating solar array is connected to lead acid batteries with no overcharge protection, battery life will be compromised.
- Simple controllers contain a transistor that shunts the PV charging circuit, terminating the charge at a pre-set high voltage and, once a pre-set reconnect is reached, opens the shunt, allowing charging to resume.
- More sophisticated controllers utilize pulse width modulation (PWM) or maximum power point tracking (MPPT) to assure the battery is being fully charged. The first 70% to 80% of battery capacity is easily replaced, but the last 20% to 30% requires more attention and therefore more complexity

2.10.11 Benefits of PV Electricity

- Renewable source of energy: PV system converts sunlight into electricity which is a renewable and free source of energy. Since sunlight is the fuel, unlike other conventional energy, there is no need of transportation of fuel.
- Decentralized source: One of the most important benefits is that the power can be generated locally where the power is to be consumed. PV generator can be as small as a few watts, therefore, combination of appropriate sizes of panels can give just the amount of power that is needed at each site
- Minimal maintenance and maximum reliability: PV systems typically require very minimal maintenance because there are no moving parts. Time and money required for maintenance is quite low. This is the primary advantage of a solar system when compared to any other form of electrical power generation.

2.10.12 Future Trends

- The European Union wants a fifth of its power to come from "renewable" sources by 2010. Some analysts believe that within 50 years half the world's electricity could come from non-fossil-fuel schemes, including well established hydro-power schemes but excluding nuclear energy.
- Solar power is becoming more economically viable. The cost of generating a single watt of electricity from a solar cell (a piece of silicon manufactured in a similar way to microchips) has fallen from $200 in 1980 to $3.50 today.
- The four biggest companies in this field are all large enterprises - Germany's Siemens, Kyocera and Sharp of Japan and the UK's BP
- Another form of energy production attracting interest is fuel cells - devices that create electricity efficiently by mixing hydrogen (possibly from natural gas) and oxygen from the air.

CHAPTER-THREE

SOLAR RADIATION

Solar radiation describes the visible and near-visible (ultraviolet and near-infrared) radiation emitted from the sun. The different regions are described by their wavelength range within the broad band range of 0.20 to 4.0 μm (microns). Terrestrial radiation is a term used to describe infrared radiation emitted from the atmosphere. The following is a list of the components of solar and terrestrial radiation and their approximate wavelength ranges:

- Ultraviolet: 0.20 - 0.39μm
- Visible: 0.39 - 0.78 μm
- Near-Infrared: 0.78 - 4.00 μm
- Infrared: 4.00 - 100.00 μm

Approximately 99% of solar, or short-wave, radiation at the earth's surface is contained in the region from 0.3 to 3.0 μm while most of terrestrial, or long-wave, radiation is contained in the region from 3.5 to 50 μm. Outside the earth's atmosphere, solar radiation has an intensity of approximately 1370 watts/meter2. This is the value at mean earth-sun distance at the top of the atmosphere and is referred to as the Solar Constant. On the surface of the earth on a clear day, at noon, the direct beam radiation will be approximately 1000 watts/meter2 for many locations.

The availability of energy is affected by location (including latitude and elevation), season, and time of day. All of which can be readily determined. However, the biggest factors affecting the available energy are cloud cover and other meteorological conditions which vary with location and time.

Historically, solar measurements have been taken with horizontal instruments over the complete day. In the Northern US, this results in early summer values 4-6 times greater than early winter values. In the South, differences would be 2-3 times greater. This is due, in part, to the weather and, to a larger degree, the sun angle and the length of daylight.

Solar radiation data were collected from RERC (DU), NREL and DLR. Most of these solar radiation data were collected from DU for Dhaka with different cities in Bangladesh. The collected data from 1985-2006 were presented below

Table: 3.1 DAILY BRIGHT SUNSHINE HOURS

For the Month: January

Location: Dhaka

Day of the Month	1981	1982	1983	1984	1985	Average
1	8.7	8.3	8.8	9	0.1	6.88
2	8.4	7.2	7.5	8.3	4.2	7.12
3	8.6	6.6	8.4	4.8	7.7	7.22
4	8.2	7.6	8.8	9.1	8.7	8.48
5	9.6	6.8	9.1	9.3	9	8.76
6	7	4.4	8.8	9.2	6.3	7.14
7	0.2	6.8	8.5	9	6.2	6.14
8	8.6	8.1	7.9	9.1	7.9	8.32
9	9.3	8.5	5.5	8.9	6.3	7.7
10	8.7	6.2	4.9	4.9	9.3	6.8
11	2.7	7.5	4.1	9.1	4	6.48
12	0.8	0	8.7	9.1	9.3	5.58
13	5.8	9	7.5	9.1	7.1	7.7
14	9.2	9.3	7.5	0.4	8.2	6.92
15	9.7	9.5	8.4	6.8	6.8	8.24
16	9.7	8.3	0	7.9	2.6	5.7
17	8.5	8.4	8.7	7.6	9	8.44
18	5.8	7	5.3	9	7.8	6.98
19	9.1	7.8	9.1	9	4	7.8
20	7.8	8.1	8.3	5.7	9	7.78
21	8.6	7.8	9.5	9	7.5	8.48
22	7.8	7.9	9.2	9	8.9	8.56
23	7.7	6.7	7.5	0	9.5	6.28
24	4.6	7.3	5.2	7.8	9.4	6.86
25	5.9	8.4	8.1	9	9.6	8.2
26	9.3	7	7.9	9.2	9.6	8.6
27	9.7	7.7	8.1	9.1	9.5	8.82
28	8.5	7.9	8.5	2.1	9.2	7.24
29	8.8	6.8	4	8.5	8.5	7.32
30	2	6	3.7	9	8.2	7.14
31	5	7.6	7.6	9	7.1	7.26

Source: Dr. Md. Maksud Helali, BUET, recorded from 1981 to 1985

Table3.2 DAILY BRIGHT SUNSHINE HOURS

For the Month: February

Location: Dhaka

Day of the Month	1981	1982	1983	1984	1985	Average
1	6	0	4.4	9.3	1.4	4.22
2	8.1	6.9	6.2	9.4	8.6	7.84
3	10	8.2	8.3	8.8	9.2	7.42
4	9.8	0.9	9.6	6.7	9	7.2
5	9	7.8	9.7	9	9.4	8.98
6	9	9.3	9.7	0.4	8	7.28
7	8.7	7.9	6.8	0.3	9.6	6.66
8	9.2	7.9	3.7	11	9.5	6.28
9	0	8.9	7.2	9.8	9.7	8.32
10	0	9.4	9.2	9.6	10	7.64
11	2.9	8.8	9.3	8.3	9.2	7.7
12	8.1	7.6	9.6	9.9	10	9.04
13	8.7	8.8	9.6	0	10	9.12
14	7.3	6.9	4.9	10.1	4.9	5.6
15	6.6	5.7	6.5	10.1	0.4	5.86
16	4.7	8	9.2	9.8	7.5	7.9
17	9.2	1.6	9.4	10	9.6	8.14
18	8.3	6.2	6	9.8	9.2	9.02
19	9.3	7.8	8.8	7.1	9.4	8.54
20	9.7	6.1	9.6	9.9	10.2	9.68
21	9.6	9.7	9.1	10.2	10.1	9.64
22	9.5	8.7	9.7	10.4	10.1	8.42
23	8.2	4.5	9.1	10.5	9.9	8.12
24	8.1	8.4	3.7	10.6	9.9	8.82
25	8.7	8.9	5.7	10.4	10.2	9.38
26	9.9	10.1	6.8	10.4	9.7	9.3
27	9.2	9.7	8.9	10.4	8.3	8.38
28	8.1	5	10.3	10.1	8.4	8.38

Source: Dr. Md. Maksud Helali, BUET, recorded from 1981 to 1985

Table 3.3 MONTHLY BRIGHT SUNSHINE HOURS

Year: 1981-1985

Location: Dhaka

Month of the Year	1981	1982	1983	1984	1985	Average
January	7.24	7.31	7.26	7.65	7.39	7.37
February	7.71	7.13	7.89	8.58	8.62	7.98
March	6.73	6.5	7.83	8.67	8.29	7.6
April	7.1	7.08	7.67	8.82	8.12	7.76
May	8.02	7.64	7.74	6.09	6.57	7.21
June	6.42	4.23	6.2	3.84	4.59	5.05
July	3.02	4.37		4.52	4.22	4.03
August	6.46	5.72	5.64	4.36	6.09	5.65
September	4.95	5.58	4.87	5.07	6.02	5.29
October	8.56	8.12	7.5	6.2	8.66	7.8
November	8.62	7.77		9.46	8.24	6.81
December	7.54	6.92	8.62	8.53	7.39	7.8

Source: Dr. Md. Maksud Helali, BUET, recorded from 1981to 1985

Table 3.4 SOLAR RADIATION DATA (1985-2005)

NREL, DLR and RERC values of GHI for Dhaka

Month	NREL (1985-91)	RERC (1987-89)	RERC (1992)	DLR (2000-2002-03)	RERC (2003-05)
January	4.18	4.29	3.34	4.58	3.16
February	4.68	4.86	4.05	4.81	4.46
March	5.55	5.53	5.24	5.31	4.88
April	5.65	5.23	6.02	5.84	5.28
May	5.58	5.67	5.76	5.21	5.46
June	4.48	5.13	5.39	3.85	4.22
July	3.9	3.87	4.2	3.76	4.48
August	4.12	3.92	4.87	4.11	4.12
September	3.96	4.5	5.38	3.76	3.78
October	4.7	4.61	4.93	4.19	3.57
November	4.25	4.22	3.72	4.47	3.92
December	4.06	3.89	3.39	4.34	3.19
Annual Average (kWh/m^2-day)	**4.59**	**4.64**	**4.69**	**4.52**	**4.21**
Annual (kWh/m^2-year)	**1676**	**1695**	**1712**	**1649**	**1536**

Table3.5 Monthly averaged hourly GHI for Dhaka (2002-05) from RERC, DU

Hours/ month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
5:30			1	5	17	19	11	7	3			
6:30	3	8	29	66	106	93	86	66	58	46	31	11
7:30	57	93	148	198	252	200	198	180	165	169	157	97
8:30	175	254	318	354	406	321	355	288	303	324	331	237
9:30	300	424	489	521	561	416	438	433	435	473	490	382
10:30	411	573	629	666	681	494	503	514	485	487	580	479
11:30	494	672	712	751	727	532	548	537	485	520	614	498
12:30	518	701	722	764	711	543	570	535	486	488	573	489
13:30	483	646	657	693	641	500	503	482	441	406	510	426
14:30	379	528	541	553	577	451	463	453	385	323	377	309
15:30	236	353	377	402	419	329	372	356	281	208	204	183
16:30	94	175	204	237	257	215	244	231	164	76	57	54
17:30	10	37	55	72	93	93	107	89	45	6	1	2
18:30			2	4	11	17	18	8	1			
Daily average (kWh/ m^2-day)	**3.16**	**4.46**	**4.88**	**5.28**	**5.46**	**4.22**	**4.42**	**4.18**	**3.74**	**3.5**	**3.9**	**3.17**

Table 3.6 Monthly Global Solar Insolation at Different Cities of Bangladesh ($kWh/m^2/day$)

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessore
Jan	4.03	3.96	4.00	4.01	4.17	4.25
Feb	4.78	4.47	4.63	4.69	4.81	4.85
Mar	5.33	5.88	5.20	5.68	5.30	4.50
Apr	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
Jun	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
Aug	4.82	5.16	4.56	4.84	4.42	4.93
Sept	4.41	4.96	4.07	4.67	4.48	4.57
Oct	4.61	4.88	4.61	4.65	4.71	4.68
Nov	4.27	4.42	4.32	4.35	4.35	4.24
Dec	3.92	3.82	3.85	4.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source: Dr. Shahida Rafique, Dhaka University, recorded from 1988 to1998

Table 3.7 Monthly GHI for Dhaka (2002-05) from RERC, DU

Month	2003	2004	2005	2002-2005
Jan	3.03	3.08	3.37	3.16
Feb	4.36	4.3	4.73	4.46
Mar	4.87	4.96	4.82	4.88
Apr	5.6	4.78	5.47	5.19
May	5.55	5.56	5.26	5.56
Jun	3.77	4.23	4.67	4
July	5.03	4	4.4	4.52
Aug	4.82	4.14	3.39	4.48
Sept	3.86	3.23	4.25	3.87
Oct	3.41	4.17	3.12	3.87
Nov	4.04	3.74	3.97	3.74
Dec	2.94	3.22	3.4	3.12
Monthly average (kWh/m^2)	**4.27**	**4.12**	**4.24**	**4.24**

Table 3.8 Monthly averaged GHI for Dhaka (kWh/m^2) (2006) from RERC, DU

Month	Dhaka
January	3.4
February	3.79
March	5.04
April	5.06
May	5.09
June	4.8
July	3.84
August	4.73
September	5.15
October	3.18
November	3.35
December	2.84
Average	4.45

CHAPTER-FOUR

METHODOLOGY

4.1 Solar Data Analysis

Bangladesh receives an average daily solar radiation of 4 – 6.5 kWh/m2. Despite large potential, utilization of solar energy has been limited to traditional uses such as crop and fish drying in the open sun. Solar photovoltaic (PV) are gaining acceptance for providing electricity to households and small businesses in rural areas. In 1988, Bangladesh Atomic Energy Commission (BAEC) installed several pilot PV systems. The first significant PV-based rural electrification programme was the Norshingdi project initiated with financial support from France. Three Battery charging stations with a total capacity of 29.4 kWp and a number of stand alone solar home systems (SHS) with a total capacity of 32.586 kWp were installed. Rural electrification Board (REB) owned the systems and the users paid a monthly fee for the services. Since 1996, penetration of SHS's increased rapidly, mainly due to the efforts of Grameen Shakti, which sells PV systems on credit to rural households through its extensive network. Several other NGOs such asa CMES and BRAC are also engaged in promoting PV technology. PV modules are generally imported, while there are a few private companies manufacturing PV accessories (Shakti, 2002). According to a World Bank funded market survey, there is an existing market size of 0.5 million households for Solar Home Systems (SHS) on a fee-for-service basis in the offgrid areas of Bangladesh. This assessment is based on current expenditure levels on fuel for lighting and battery charging being substituted by SHS [World Bank, 1998]. It has been observed that in most developing countries, households typically spend not more than 5% of their income on lighting and use of small appliances. By this measure, about 4.8 million rural Bangladeshi households could pay for a solar home system [World Bank, 1998]. At present the national grid is serving only 50% of nearly 10,000 rural markets and commercial centres in the country which are excellent market for centralized solar photovoltaic plants. Currently private diesel genset operators are serving in most of the off-grid rural markets and it has been found that 82% of them are also interested in marketing SHS in surrounding areas if some sorts of favorable financing arrangements are available [World Bank, 2000].

Throughout the country, different government administrative offices, NGO offices, Schools, banks, police stations etc are functioning. In the off-grid locations, these offices are either using traditional means (lantern, candles, kerosene wick lamps etc.) or operating their own diesel gensets. These offices have separate budgets for electricity and they can be easily served with solar photovoltaic applications.

4.2 Comparison of Solar Radiation Data for Different Years

Table 4.1 NREL, DLR and RERC values of GHI for Dhaka

Month	NREL (1985-91)	RERC (1987-89)	RERC (1992)	DLR (2000-02-03)	RERC (2003-05)
January	4.18	4.29	3.34	4.58	3.16
February	4.68	4.86	4.05	4.81	4.46
March	5.55	5.53	5.24	5.31	4.88
April	5.65	5.23	6.02	5.84	5.28
May	5.58	5.67	5.76	5.21	5.46
June	4.48	5.13	5.39	3.85	4.22
July	3.9	3.87	4.2	3.76	4.48
August	4.12	3.92	4.87	4.11	4.12
September	3.96	4.5	5.38	3.76	3.78
October	4.7	4.61	4.93	4.19	3.57
November	4.25	4.22	3.72	4.47	3.92
December	4.06	3.89	3.39	4.34	3.19
Annual Average (kWh/m^2-day)	**4.59**	**4.64**	**4.69**	**4.52**	**4.21**
Annual(kWh/m^2-year)	**1676**	**1695**	**1712**	**1649**	**1536**

In the year 1985-1991, annual average solar radiation was 4.59 kWh/m^2/day and it was increased at 4.64 kWh/m^2/day in1987-89.

But in 2000-03, annual average radiation was 4.52 kWh/m^2/day and recently decreased as 4.21kWh/m^2/day in 2003-05.

In 2006, radiation was increasing as 4.42 kWh/m^2/day.

4.3 Graphical Presentation of Solar Radiation Data for Different Months at Dhaka City

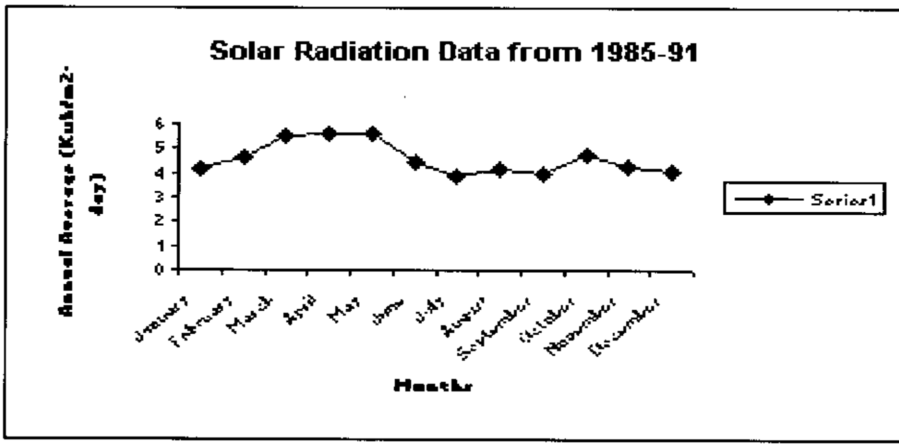


Fig.4.1 Curve of solar radiation data for 1985-91

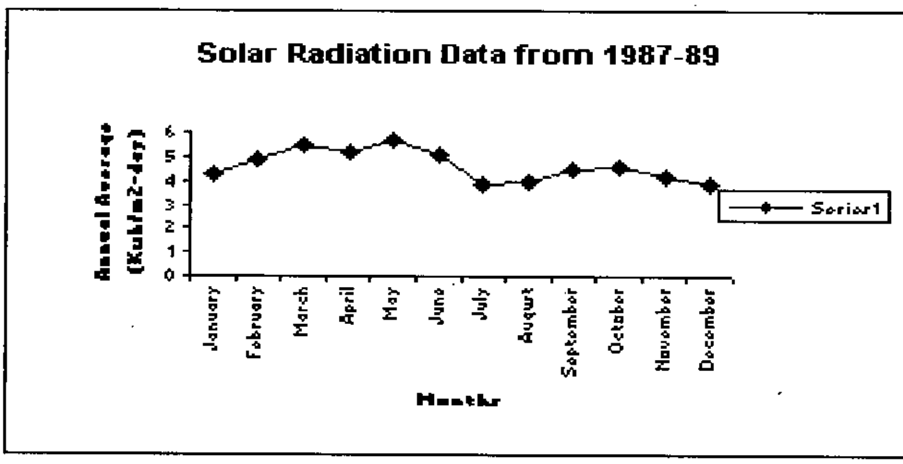


Fig.4.2 Curve of solar radiation data for 1987-89

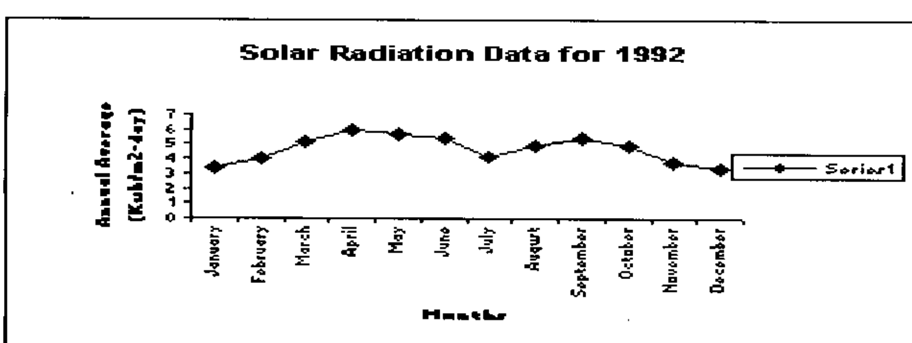


Fig.4.3 Curve of solar radiation data for 1992

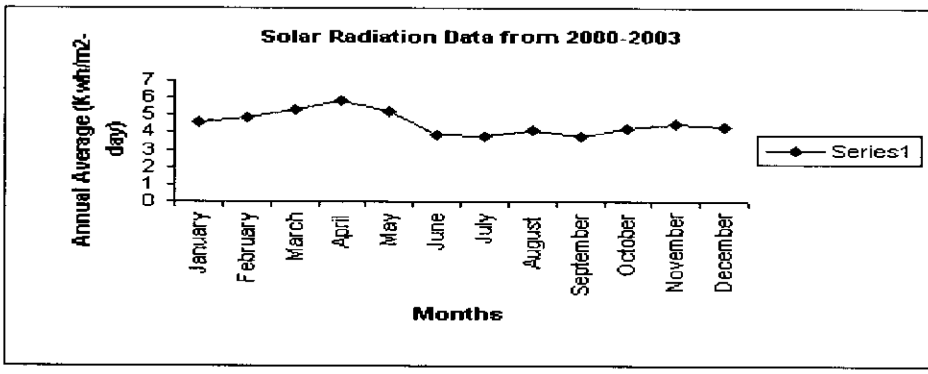


Fig.4.4 Curve of solar radiation data for 2000-03

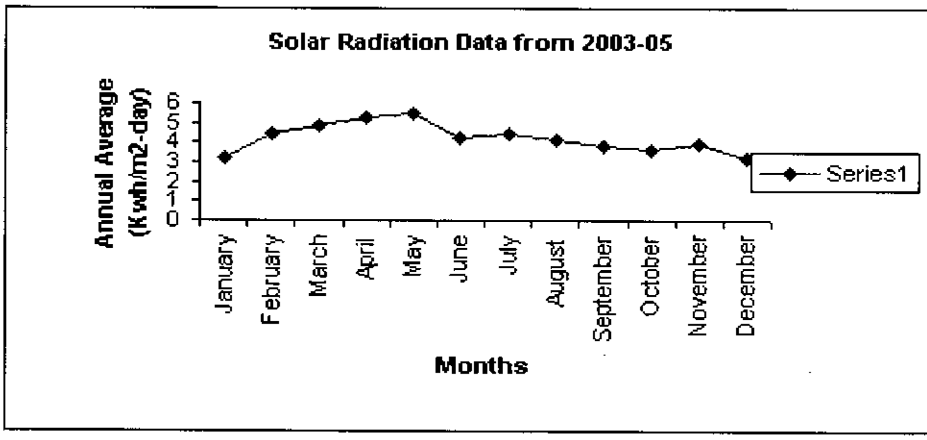


Fig.4.5 Curve of solar radiation data for 2003-05

From the above graphs we can see that the maximum annual average solar radiation was 4.69 kWh/m^2-day in 1992. Maximum radiation will collect from months of April and May.

4.4 Solar Data comparison with other organizations

The organizations those who are involved in solar energy business in our country as Rahimafrooz, Grameen Sakti Navana, BRAC, Micro Elecronics company etc are using the solar data from RERC (Renewable Energy Research Centre, DU) if required. They use 12V and 24V batteries to store the charge. The sunlight of four hours/day is required to complete charge of battery. So, they are not directly dependent on whole day for full radiation. But they consider average daily solar radiation 4.2 Kwh/m2/day.

CHAPTER-FIVE

RENEWABLE ENERGY TECHNOLOGIES IN BANGLADESH

5.1 Country Status

Bangladesh is situated between 20.34 – 26.38 degrees north latitude and 88.01 – 92.41 degrees east, which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of April and May and minimum on December and January.

Bangladesh at a glance

Area	: 1, 43,547 Sq. km.
Population	: 140 million
Main occupation of the people	: Agriculture
Number of district	: 64
Number of Upazilla	: 460
Number of Villages	: 68000
Average temperature	: 27 to 32 degrees
Average rainfall	: 2250mm

Bangladesh is a country with one of the lowest per capita and faces formidable development problems. The economy of Bangladesh presents perplexing paradoxes. In spite of its huge manpower resource and fertile land Bangladesh is one of the underdeveloped countries in the world. Environmental degradation (especially indiscriminate cutting of trees), misuse of biomass, and drying up of water-bodies are creating constraints for the poor in the rural areas. Energy is vital for economic and social development of any country. Energy is considered to be one of the essential inputs for overall improvement. The applications of small-scale photovoltaic systems have been a very recent phenomenon in rural areas of Bangladesh. Over the years significant technological advances have been made in developing renewable energy technologies, especially in the field of solar photovoltaic and biogas energy. It is important to note that the approach of promoting photovoltaic technology in Bangladesh has been different from other countries like India, Nepal and countries in Latin America. One important difference is that Bangladesh has taken a more commercial than those countries where number of systems installed are much higher but the programs are heavily subsidized by the government and donors.

5.2 Rural Energy needs

More than 80% of total population of the country lives in rural areas. At present major portion of total energy needs is met by locally produced biomass fuels which is mostly consumed in the house hold sector for cooking, ongoing rural electrification program meets a small portion of total energy needs. For overall national development there is a need to pay special attention so that the energy needs of rural areas for subsistence and productive requirements (e.g. agriculture, industries and transport) are met on a sustainable basis.

Different types of renewable energy technologies application suitable for Bangladesh are:

5.2.1 Solar photovoltaic (SPV)

- Solar home system (SHS)
- Rural market electrification
- School electrification
- Health clinic/hospital electrification
- Cyclone shelter electrification
- Micro enterprise
- ICT Training center electrification
- Mobile phone charging

5.2.2 Solar thermal

- Hot water system for domestic use
- Hot water system for commercial purpose
- Dryer for preservation of vegetables, fish, fruit etc.

5.2.3 Biogas

- Biogas for domestic cooking, lighting and fertilizer
- Biogas from poultry waste for electricity
- Biogas gasifies

5.2.4 Hydropower

The scope of hydropower generation is very limited in Bangladesh as the country consists of low and flat lands except some hilly regions in the north and northwestern part. The only hydro power station of the country, the Karnafuly Hydro Power Station with a generating capacity of 230 MW by 7 units, is located in Kaptai, across the river Karnafuly.

CHAPTER-SIX

UTILIZATION OF RENEWABLE ENERGY IN BANGLADESH

6.1 Status

- Area: About 145,000 sqkm
- Population: About 135 Million
- Per capita energy consumption: 237 koe
- Share of traditional energy: about 60%
- Access to electricity: 30% of the population
  (Rural Area with 85% of population: 20%,
  Remote Area with 15% of population: <5%)
- Area coverage by electrification: 40%

6.2 Renewable Energy Sources

- Solar energy
- Wind energy
- Biomass energy
- Mini- and microhydro
- Wave and tidal

6.3 Potential of Renewable Energy

6.3.1 Solar energy

- Insolation: 4 - 8 kWh/m2/day
- Seasonal variations over the year: small
- Rainy days: may be up to a few days at a time
- Potential for Solar PV and Solar Thermal

6.3.2 Potential of solar PV

- Most important use is in electrification of rural and remote areas without electricity.
- Remote Areas are inland river islands, coastal areas, hilly areas, enclaves and haors (internal water bodies).

  Many of them will probably not receive grid electricity even after 20 years.

6.3.3 Potential of solar PV

- **Solar home systems** have
  - Existing Market: 0.2 - 1 million
  - Potential market: 1.33 - 4.6 million
- **For electrification of**
  - Schools, community centers, religious institutions
  - Cyclone shelters: more than 1000
  - Health centers: both human and veterinary, especially for vaccine refrigeration
- For remote communication, operating computer
- For railway signaling, operating water pumps
- For surveillance of gas-pipe line

6.3.4 Potential of solar thermal

- Water Heater: Low temperature (less than 80°C) thermal application. Water at such temperature is required in hospitals, hotels, small industries and also in the households during the winter period.
- Solar cooker: throughout the country
- Solar dryer: for conservation of food, especially fruits, vegetables and fish
  - It allows conserving food in a cost effective and hygienic manner.

6.4 Potential of wind energy

- Wind energy resource is site and season specific.
- Data are currently being collected under
  - Wind Energy Resource Mapping project (Wind speed and direction are measured at 23 sites)
  - Solar and Wind Energy Resource Assessment project (data are collected from land based observations as well as by computing data from satellites)
- Collected wind data indicate a potential of wind energy utilization in the coastal areas during April - September (average wind speed: 6 m/sec).

6.5 Potential of Biomass

Biomass is the most available source of energy. There are potential for:

- Improved stove: Potential is more than 20 million
- Bio-gas plant: Potential of 4 million small plants
- Biomass briquetting: large potential of briquettes, especially for cooking and artisan use
- Bio-mass gasification: provide power for meeting the energy needs of the rural small industries, commercial establishments and households

6.6 Potential of Mini- and Micro-Hydro

Bangladesh is mainly a flat delta plain covered by a lot of big and small rivers. Current of river water and low head of water fall may be used for harnessing hydro-power.

- 23 sites of 10 kW - 5 MW capacity are identified
- Embankments with sluice gates of the coastal areas and coastal islands may be used for low-head micro-hydro plants for operation during July to September.

6.7 Potential of Wave and Tidal

- Wave
  - Wave in the Bay: 2 - 3 m
  - Potential of wave power: minimum 100 MW
- Tidal
  - Average tidal range near the coast: 4 - 5 m
  - Potential: not estimated

6.8 Status of Utilization of RE

- Utilization of renewable energy - not in its traditional form, but with modern and efficient technology (RET) - started in eighties.
- Since then a few efforts have been undertaken to popularize RETs.
- Till today, only solar PV has achieved some success in Bangladesh. Most of the other RETs are still more or less in the demonstartion phase.
- PV electrification has become a part of the rural electrification program of the country.

6.8.1 Status of utilization of PV

- PV is being used to meet the electricity need of remote areas. However, the activities in fields other than SHS are not significant. PV has been introduced
  - for vaccine refrigeration in 12 health centers
  - About 20 have got PV electrification
  - Mini-grids for 1 market and 2 villages
  - 1 battery charging station
  - Railway signalling on experimental basis
  - for surveillance of gas-pipeline

6.8.2 Status of utilization of SHS

- Solar home system (SHS) is the most prevalent utilization of PV in Bangladesh.
- First large project of 806 SHS with 62 kW capacity was done during 1997-1999 by Rural Electrification Board (REB) - a Govt. entity.
- One NGO and a few private organizations started production of Balance of System (BOS).
- Dessimination is done by several Govt. agencies, NGOs and private organizations.

6.8.3 Status of utilization of solar PV - SHS

- SHS is costly, not affordable for many people.
- NGOs and private organizations provide SHSs on
  - single payment (The consumer owns the SHS from the very moment.)
  - "hire & purchase" (Payment is on monthly installment of 2-5 years. The consumer owns the SHS only after payment of all installments.)
- Govt. organizations provide SHSs on
  - "fee for service"(The consumer will never own the SHS and pay only a monthly service fee.)

6.8.4 Status of utilization of solar PV - SHS

- Currently "Rural Electrification and Renewable Energy Development Program" is being implemented, under which 64,000 SHSs will be installed.
- Currently, 2500 SHSs are being installed a month.
- Cumulative number of SHSs installed is 37,000 (August 2007) with total capacity of about 2.5 MW.

6.8.5 Status of utilization of solar thermal

- The use of solar thermal is negligible.
- A few solar water heaters, solar cookers and solar dryers have been installed on experimental basis.
- Till today, there is no large scale implementation program.

6.9 Future Prospects of RE

- The prospects of solar PV and other renewable energy utilization depend on the role of the Government.
- The Government is facilitating RE development, which should be enhanced so that private entrepreneurs come forward to take the initiatives to disseminate renewable energy technologies.

It is expected that RE will play a more extensive role in meeting the energy needs

CHAPTER-SEVEN

ECONOMIC ANALYSIS

Rising population figures and economic development in developing countries will bring in a significant increase in energy needs. Even optimistic scenarios predict that energy consumption in developing countries will at least double in the next twenty years. In these countries the supply of energy is already a very big problem. People are cutting down trees, using harmful fuels to meet their energy needs, which are causing massive environmental damage - at the local, regional and global levels. Within a few decades, extractable fossil fuels - with the exception of coal - will be exhausted or unaffordable. In the interests of climate protection, greenhouse gas emissions must be reduced.

This means that there must be a reduction in energy consumption as well as increase of reliance on renewable sources of energy. There is a close correlation between the availability of energy services, such as lighting, communications and cooling, and social issues, such as poverty alleviation, demographic development, rural exodus/urbanization, opportunities for women, health care and education. And if income is to be generated in the crafts and small business sector, energy forms which can be used for production are essential in rural regions, too. So keeping the above mentioned scenario in mind this project will try to find a solution to provide renewable energy to the poor people in Bangladesh and improve their lifestyle sustain ably.

Some non-govt. organizations are providing SHS solutions to the rural areas of Bangladesh. They are selling SHS systems from 12Wp to 120Wp. The price of such system varies from 12,500 taka up to 75,000 taka (Appendix B). As the price of the whole unit is quite high for most of the rural people, some organizations are selling the system in easy installments. But there are still some people who even cannot think about spending the installment money, as their earning capacity is not enough. So the problem is that the technology is there to use but without any financial solution for them.

Our country is a low-economy country and per-capita energy consumption is one of the lowest in the world. The conventional resources in Bangladesh are inadequate for supplying the energy needs of our economy.

The only dependable indigenous gas, which is the major source of primary energy in the country, is used mainly for the production of electricity and fertilizer. According to expert's opinion our gas reserves will be exhausted within 2020. Therefore, we must find alternative sources of energy to maintain the energy supply of our country.

Renewable energy, which is environment friendly, inexhaustible and sustainable, can be considered as one of the important alternatives and it can play a significant role in the energy scene of the country. The most viable sources of renewable energy, in the country are solar, wind, biomass, and biogas. At present contribution of energy from solar and wind is only 0.1%.

It is encouraging that private organizations and NGOs have come forward by taking different projects to utilize solar devices and to provide photovoltaic (PV) electricity to villages in Bangladesh where national grid line has not yet reached.

Today, Solar Home Systems (SHS) are gradually becoming popular in the rural areas in Bangladesh. But in cities, where the power supply is insufficient, fluctuating and failure is a regular event, grid-connected PV system can be a good power source if installed on the roof-tops of the building. In the remote areas if the supply of power in the existing grid is needed to be increased to keep pace with the increasing demand, this system can be a good solution as the system is modular and easy to install.

The power produced by the roof-top grid-connected PV system can be used to supply local loads, with the excess energy fed into the local grid for use by other customers. At night, the local loads are simply supplied by the grid power. If the PV system is large enough, it can supply more energy into the grid than is used by local loads.

Instead of receiving a bill every month from the utility supply office, the owner of the system would then be able to earn money by generating surplus electricity.

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

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

Realizing the significant potential of this technology a model of 1.1kW rooftop grid connected photovoltaic system has been developed and successfully installed (Fig.I, Appendix A) at the roof-top of Renewable Energy Research Centre (RERC), Dhaka University under the financial assistance of the Ministry of Science and Information & Communication Technology.

The installed system was run for several days in different weather conditions and the performance was found to be quite satisfactory.

To understand the financial viability of the system, a preliminary economic analysis of the 1.1kW roof-top grid-connected PV systems along with various sizes (Table, Appendix-A) has been made. In the analysis standard methods of economics have been utilized considering various factors, viz., capital cost, and life-cycle of the system, interest rate, inflation rate, operation and maintenance cost with and without net metering benefit.

The above estimation was made by considering an average demand of 3000kWh for a four-member family. It is also seen from the table that a system of 2kW power for a single house-hold can produce surplus energy that can be fed to the national grid.

For 0% to 10% interest rates and 10% depreciation the unit-price of electricity with and without net-metering facilities will be respectively Tk.4.85-15.14 and Tk.4.85-15.14 only. As the system size becomes larger, the unit-price with net-metering decreases rapidly. The unit-price of electricity for the 1.1kW system at the above interest rates and depreciation is from 6.18 to 19.32 taka only.

At present Bangladesh is going through severe electricity crisis. In this situation, this system can be a good alternative small-scale power source on the roof-top of the building in the cities that does not require any fuel. It is observed from the preliminary economic analysis that the system would be financially feasible if subsidy is given and net-metering regulation is framed by the government. Moreover, the impact of the system on the environment friendly issue should be considered as the system does not pollute the environment at all. From the performance study it is also found that the system works efficiently. For emergency power supply of multistoried building Rajuk should frame some incentive based building-acts to encourage the integration of solar PV system as a part of future design and implementation.

The World Bank has planned to provide US $100 million funds by June this year to promote renewable energy particularly solar power as the government has taken move to develop alternative sources of energy.

A mission from the World Bank visited Bangladesh last week in December, 2008 to explore the possibility of renewable energy development.
The Bank has proposed to provide $90 million fund for setting up solar power and another $10 million for exploring other sources of alternative energy in the country, an official of the Economic Relations Division (ERD) told the FE.

We are hopeful that the Washington-based global lender will provide us with the money by June in 2009 for promoting the renewable energy sector as the country's traditional energy gas is depleting day by day, he said.

Bangladesh's main energy natural gas will be depleting fast after four years as the present recoverable gas reserve will meet demands only up to 2012, country's oil, gas and mineral corporation –Petrobangla –has already forecast.

Bangladesh is now facing over 250 million cubic feet of gas supply shortage per day against the demand fro over 2000mmcfd.

Against the backdrop of the crisis, the power generation is being hampered much over the last few years as country's nearly 80 per cent electricity is produced by utilization of gas.

The WB will provide the $100 million funds to the state-owned Infrastructure Development Company Limited (IDCOL) for leading the money to the private sector for promoting renewable energy across the country.

IDCOL, a public sector financial institution, was established to finance the private sector for developing the country's ailing infrastructure.

As both the donor and the government want to help the private sector for developing the country's infrastructure, and the ailing energy and power sector, IDCOL will get the money to disburse those for fulfilling the purpose, the ERD official said.

The government has already formulated a "Renewable Energy Policy" to encourage both the private and public sectors to come forward for developing alternative sources of energy to be utilized in power generation and for other activities.

ERD would always welcome assistance from different donors like the proposed $100 million funds of the WB to promote renewable energy throughout the country, the ERD official said.

An Economic Analysis for Various Solar Technologies in Our Country

7.1 Conventional Fuel Savings by solar PV-SHS System

Costing of solar PV system for 130W is about Tk. 65,000/= (Appendix B)

But costing of Portable Generator for 130W is about Tk. 6,500/=

If we use a 130w generator, it will consume about 0.5 liter Octane per hour.

Let us consider

Running time for generator	=	6hour per day
Running time for solar PV system	=	6hour per day

Then

Solar PV system will save by 1 hour	=	0.5 liter octane
Solar PV system will save by 6 hour	=	3.0 liter octane (per day)
Solar PV system will save by 1 day	=	3.0 liter octane
Solar PV system will save by 24 day	=	90 liter octane
Solar PV system will save by 1 month	=	90 liter octane
Solar PV system will save by 1 year	=	1080 liter octane
Solar PV system will save by 10 year	=	10800 liter octane

So after 10 year, 10800 liter octane can be saved by using solar energy.

The price of 10800L octane is aboutTk.7, 23,600/=

7.1.1 NPV Calculation of Solar Home System and Gasoline Generator for 10 years

$$NPV = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_T}{(1+r)^T}$$

$$= C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

NPV (Net Present Value) for SHS

NPV= 65000+0/ (1+r) +0/ (1+r) ^{2}+............................+0/ (1+r) ^{10}

Let us consider

Battery (100Ah, Brand: Locus, Rahimafrooz) price per unit Tk. 7200/=

(Warranty for Battery: 5years)

So NPV (1st year) = 65000

NPV (2nd year) = 65000

....

....

NPV (6th year) = 72200 (Including Battery price)

....

....

NPV (10th year) = 72200

NPV (Net Present Value) for 130W Gasoline Generator

Let us consider

1st year fuel cost = (1L Octane) = 55Tk. (In 2001) = 2L per day = 40150/= per year

2nd year fuel cost = (1L Octane) = 55Tk. (In 2002) = 2L per day = 40150/= per year

3rd year fuel cost = (1L Octane) = 63Tk. (In 2003) = 2L per day = 45990/= per year

4th year fuel cost = (1L Octane) = 63Tk. (In 2004) = 2L per day = 45990/= per year

5th year fuel cost = (1L Octane) = 70Tk. (In 2005) = 2L per day = 51100/= per year

6th year fuel cost = (1L Octane) = 70Tk. (In 2006) = 2L per day = 51100/= per year

7th year fuel cost = (1L Octane) = 75Tk. (In 2007) = 2L per day = 54750/= per year

8th year fuel cost = (1L Octane) = 90Tk. (In 2008) = 2L per day = 65700/= per year

9th year fuel cost = (1L Octane) = 95Tk. (In 2009) = 2L per day = 69350/= per year

10th year fuel cost = (1L Octane) = 100Tk. (In 2010) = 2L per day = 73000/= per year

Discount rate, r = 5%= 0.05

Maintenance cost in 2001 = 800Tk

Maintenance cost in 2002 = 800Tk.

Maintenance cost in 2003 = 900Tk.

Maintenance cost in 2004 = 950Tk.

Maintenance cost in 2005 = 1000Tk.

Maintenance cost in 2006 = 1100Tk.

Maintenance cost in 2007 = 1150Tk.

Maintenance cost in 2008 = 1200Tk.

Maintenance cost in 2009 = 1300Tk.

Maintenance cost in 2010 = 1400Tk.

NPV = 6500 + (800+40150) /1.05+ (800+40150) / $(1.05)^2$+ (900+45990) / $(1.05)^3$ + (950+45990) / (1.05)4 + (1000+51100) / (1.05)5 + (1100+51100)/ (1.05)6 + (1150+54750)/ (1.05) 7 + (1200+65700)/ (1.05)8 + (1300+69350)/ (1.05)9 + (1400+73000)/ $(1.05)^{10}$

NPV = 6500 + 39000 + 37143 + 40422 + 38475 + 40703 + 38955 + 39929 + 44600 + 44156 + 45644

So NPV = 415327 Tk. (For 10 years)

NPV (1^{st} year) = **45500**

NPV (2^{nd} year) = 45500 + 37143 = **82643**

NPV (3^{rd} year) =45500 + 37143 = 82643+40422 = **123065**

NPV (4^{th} year) =45500 + 37143 = 82643+40422 = 123065+38475=**161450**

NPV (5^{th} year) = 45500 + 37143 = 82643+40422

= 123065+38475=161450+40703=**202243**

NPV (6^{th} year) = 45500 + 37143 = 82643+40422

= 123065+38475=161450+40703=202243+38955=**241198**

NPV (7^{th} year) = 45500 + 37143 = 82643+40422

= 123065+38475=161450+40703=202243+38955

=241198+39929=**281127**

NPV (8^{th} year) = 45500 + 37143 = 82643+40703

= 123065+38475=161450+40703=202243+38955

=241198+39929=281127+44600=**325727**

NPV (9^{th} year) = 45500 + 37143 = 82643+40703

= 123065+38475=161450+40703=202243+38955

=241198+39929=281127+44600=325727+44156=**369883**

NPV (10^{th} year) = 45500 + 37143 = 82643+40703

= 123065+38475=161450+40703

=202243+38955

=241198+39929

=281127+44600=325727+44156=369883+45644=**415527**

Table 7.1

10 Years Cost Comparison for Gasoline Generator and Solar Home System (SHS):

Base Year 2001

Year	Gasoline Generator Cost (Tk.)Capacity: 130W	SHS System (Tk.) Capacity:130W
2001	45500	65000
2002	82643	65000
2003	123065	65000
2004	161450	65000
2005	202243	65000
2006	241198	72200
2007	281127	72200
2008	325727	72200
2009	369883	72200
2010	415527	72200

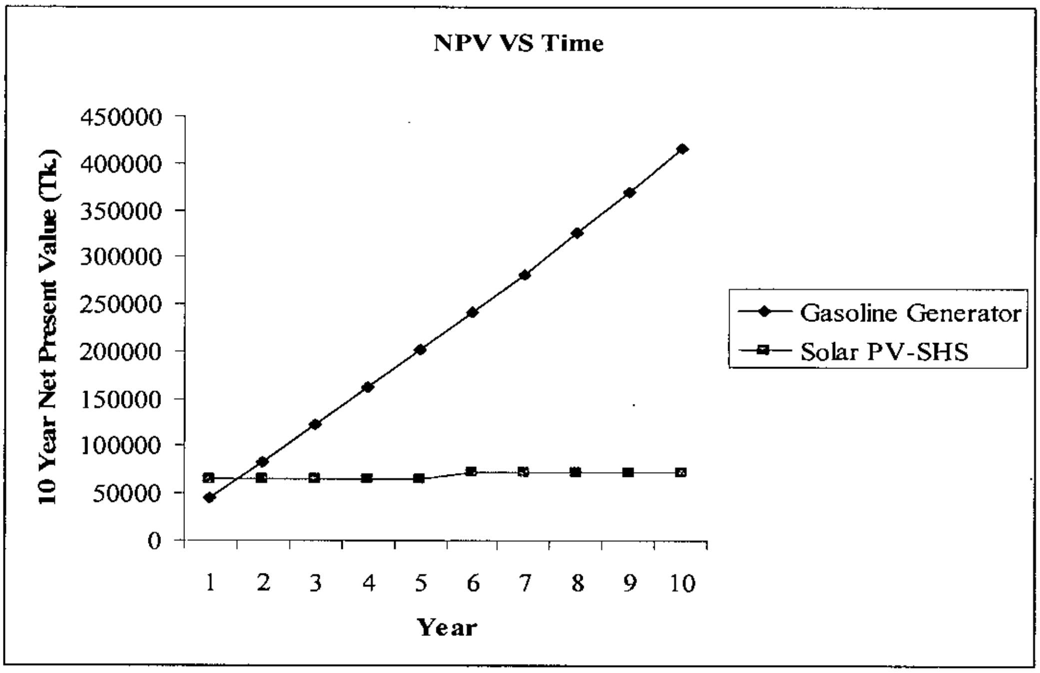


Fig. 7.1 NPV VS Time

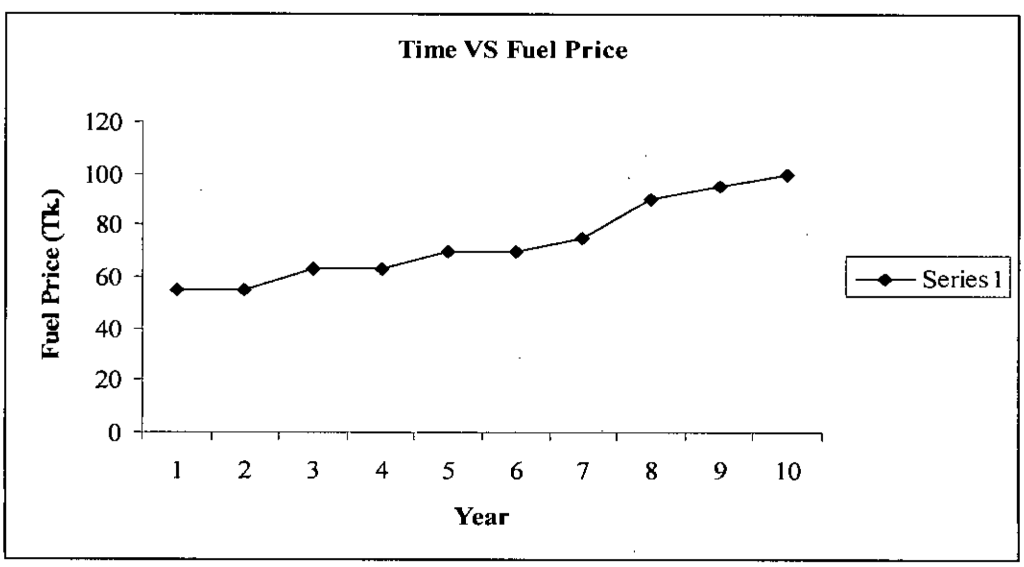


Fig. 7.2 Time VS Fuel Price

7.2 Conventional Fuel Savings by Solar PV Pump

Costing of solar PV pump system for 2400W is Tk. 13, 08,900/= (Appendix C)

But costing of Portable Generator for 2400W is Tk. 72,000/=

If we use a 2400W generator, it will consume 2 liter Octane per hour.

Let us consider

Running time for generator = 6hour per day

Running time for solar pv pump system = 6hour per day

Then

Solar PV system will save by 1 hour = 2.0 liter octane

Solar PV system will save by 6 hour = 12 liter octane (per day)

Solar PV system will save by 1 day = 12 liter octane

Solar PV system will save by 24 day = 288 liter octane

Solar PV system will save by 1 month = 288 liter octane

Solar PV system will save by 1 year = 3456 liter octane

Solar PV system will save by 10 year = 34560 liter octane

So after 10 year, 34560 liter octane can be saved by using solar PV Pump.

The price of 34560L octane is Tk.3110400/=

7.2.1 NPV Calculation of Solar PV Pump System and Gasoline Generator for 10 years

$$NPV = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_T}{(1+r)^T}$$

$$= C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

NPV (Net Present Value) for Solar PV Pump

NPV= 1308900+0/ (1+r) +0/ (1+r) ²+............................+0/ (1+r) ¹⁰

Let us consider

Battery (100Ah, Brand: Locus, Rahimafrooz) price per unit Tk. 7200/=

(Warranty for Battery: 5years)

So NPV (1st year) = 1308900

NPV (2nd year) = 1308900

....

....

NPV (6th year) = 1316100 (Including Battery Price)

....

....

NPV (10th year) = 1316100

So NPV=1316100 (After 10 years)

NPV (Net Present Value) for 5000W Gasoline Generator

Let us consider

1st year fuel cost = (1L Octane) = 55Tk. (In 2001) = 2L per day = 40150/= per year

2nd year fuel cost = (1L Octane) = 55Tk. (In 2002) = 2L per day = 40150/= per year

3rd year fuel cost = (1L Octane) = 63Tk. (In 2003) = 2L per day = 45990/= per year

4th year fuel cost = (1L Octane) = 63Tk. (In 2004) = 2L per day = 45990/= per year

5th year fuel cost = (1L Octane) = 70Tk. (In 2005) = 2L per day = 51100/= per year

6th year fuel cost = (1L Octane) = 70Tk. (In 2006) = 2L per day = 51100/= per year

7th year fuel cost = (1L Octane) = 75Tk. (In 2007) = 2L per day = 54750/= per year

8th year fuel cost = (1L Octane) = 90Tk. (In 2008) = 2L per day = 65700/= per year

9th year fuel cost = (1L Octane) = 95Tk. (In 2009) = 2L per day = 69350/= per year

10th year fuel cost = (1L Octane) = 100Tk. (In 2010) = 2L per day = 73000/= per year

Discount rate, r = 5%= 0.05

Maintenance cost in 2001 = 800Tk

Maintenance cost in 2002 = 800Tk.

Maintenance cost in 2003 = 900Tk.

Maintenance cost in 2004 = 950Tk.

Maintenance cost in 2005 = 1000Tk.

Maintenance cost in 2006 = 1100Tk.

Maintenance cost in 2007 = 1150Tk.

Maintenance cost in 2008 = 1200Tk.

Maintenance cost in 2009 = 1300Tk.

Maintenance cost in 2010 = 1400Tk.

$NPV = 72000 + (800+40150) / 1.05 + (800+40150) / (1.05)^2 + (900+45990) / (1.05)^3 + (950+45990) / (1.05)^4 + (1000+51100) / (1.05)^5 + (1100+51100) / (1.05)^6 + (1150+54750) / (1.05)^7 + (1200+65700) / (1.05)^8 + (1300+69350) / (1.05)^9 + (1400+73000) / (1.05)^{10}$

NPV = 72000 + 39000 + 37143 + 40422 + 38475 + 40703 + 38955 + 39929 + 44600 + 44156 + 45644

So NPV = 480827 Tk. (For 10 years)

NPV (1st year) = **111000**

NPV (2nd year) = 111000 + 37143 = **148143**

NPV (3rd year) =111000 + 37143 = 148143+40422 = **188565**

NPV (4th year) =111000 + 37143 = 148143+40422 = 188565+38475=**227040**

NPV (5th year) = 111000 + 37143 = 148143+40422
= 188565+38475=227040+40703=**267743**

NPV (6th year) = 111000 + 37143 = 148143+40422
= 188565+38475=227040+40703=267743+38955=**306698**

NPV (7th year) = 111000 + 37143 = 148143+40422

= 188565+38475=227040+40703=267743+38955

=306698+39929=**346627**

NPV (8th year) = 111000 + 37143 = 148143+40422

=188565+38475=227040+40703=267743+38955

=306698+39929=346627+44600=**391227**

NPV (9th year) = 111000 + 37143 = 148143+40422

= 188565+38475=227040+40703=267743+38955

=306698+39929=346627+44600=391227+44156=**435383**

NPV (10th year) = 111000 + 37143 = 148143+40422

= 188565+38475=277040+40703

=267743+38955

=306698+39929

=346627+44600=391227+44156=435383+45644=**481027**

Table 7.2
10 Years Cost Comparison for Gasoline Generator and Solar PV Pump System

Base Year 2001

Year	Gasoline Generator Cost (Tk.) Capacity: 2400W	PV Pump System (Tk.) Capacity: 2400W
2001	111000	1308900
2002	148143	1308900
2003	188565	1308900
2004	227040	1308900
2005	267743	1308900
2006	306698	1316100
2007	346627	1316100
2008	391227	1316100
2009	435383	1316100
2010	481027	1316100

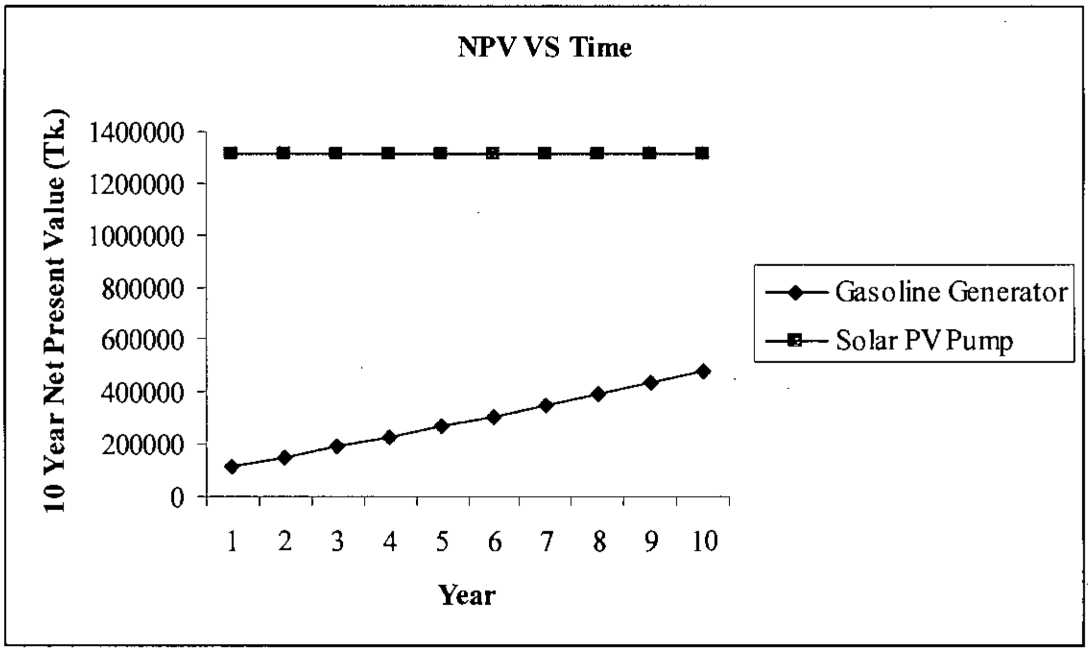


Fig. 7.3 NPV VS Time

7.2.3 Cost Comparison between an SPV and a typical diesel pump for 1 Hectare field cultivation

We know that, rice cultivation requires about 4 inch water over the field for 21 days.

1 Hectare= 107640 Sq. Ft.

1 hectare field requires = 107640*(4/12) CFT.

= 35880 Cft water

= 1016000 Liters water in 21 days.

= 48,381 Liters water /day

7.2.3.1 Solar Pump

Let's consider the case of an 1800 Wp SPV Pump.

TDH: 20 Meter

Capacity: 82,000 Liters/day

Cost: Tk.12, 25,000.

We know, 1 Hectare field irrigation requires 48,381 Liters water/day.

Our 1800 Wp SPV pump can irrigate 1.5 Hectare field per day.

Total Cost per hectare irrigation= Tk.12, 25,000

7.2.3.2 Diesel Pump

Let's consider a 16HP, $20m^3$ conventional diesel pump

Pump rating: 16 Hp

Assumption: 1KWH= 0.27Liter diesel

16HP= (16+16*5%)*0.746 KW

= 12.53 KW

1KW-Hr generation= 0.27 Liter diesel

12.53 KW generation= (0.27*12.53) Liter diesel

= 3.38 Liters diesel (consumption)

7.2.3.3 Hourly diesel consumption of a typical 16Hp diesel pump= 3.38 Liters

We know that, Diesel run irrigation cost/hectare= Tk.17, 199 in one crop.

Diesel required per crop= 17,199/33= 521.18 Liters.

1crop= 90 days (on an average)

Diesel required per day= 521/90 Liters.

Diesel required per day = 5.79 Liters.

Diesel required per year = 5.79*2*90 Liters

Diesel required per year = 1042.2 Liters

7.3 Recommendation for a Suitable Solar Technology

As Bangladesh is a populated country and 80% of people are living in villages. So, solar home system in our country is more efficient and applicable now a day. Most of the organizations who involved in solar energy business are working with Solar Home System. By using this solar energy technology, we can save a rich amount conventional fuel.

CHAPTER-EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The monthly average solar radiation in Dhaka is found to be 4.24 kWh/m^2. Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east latitude which is a good location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available in the month of April-May and minimum in December-January.

The project envisages installing 929,169 SHSs all across Bangladesh between 2007 and 2015. The SHS will provide facilities for lighting, TV and radio and comprise of: (a) a Solar Module (10 to 120wp); (b) battery (47 Ah to 130 Ah); (c) Charge Controller; (d) fluorescent tube lights with special electronic ballasts; (e) mounting structure; (f) installation kit; and (g) cables and connecting devices. The capacity of individual SHS will vary according to consumer choice and demand. The cost of SHS would be recovered through monthly installments over a period of up to 4 years which will be within the affordable capacity of the targeted consumers. Upon full implementation in year 2015, the project activity will replace 20,075 kilo liters per annum of kerosene usage, equivalent to an emissions reduction of 48,380.75 tones CO2 per annum and 16,600,500 KWh/ year of electricity generation using diesel generators.

- There are quite significant untapped renewable energy resources in Bangladesh, although the utilization is minimal today.
- Remote & rural households and other establishments can benefit from off-grid services of RETs.
- The solar industry has begun to develop commercially. The popularity of PV is increasing.
- To harness the potential of RE, concerted effort is urgently needed.

8.2 Recommendation for a Suitable Solar Technology

The scope for solar energy in Bangladesh is bright. The rural home lighting market is growing robustly at the rate of 100% and the market for other customized solution is also developing. Rahimafrooz have been focusing on rural market in Bangladesh with potential of 1 Million households and so far all players have supplied SHS to 200,000 households.

At present, about 38% of the Bangladeshi population has access to electricity and per capita electricity consumption is about 133 kWh which is one of the lowest in the world. Nearly 75% of the population is rural and only about 30% of the rural households have access to grid electricity. The current rate of expansion in electrification is only about 400,000 new households gaining access every year and at such rate it would take more than 40 years to reach all households. Rural electricity access rates have to increase dramatically to accomplish the Government's stated goal of providing universal electricity access by 2020. Government has encouraged implementing off-grid renewable energy technologies, such as solar home systems (SHS) and micro-wind power systems in coastal areas and mini-hydro projects in the mountainous regions as a priority.

So, Solar Home System (SHS) Technology is very suitable for our country

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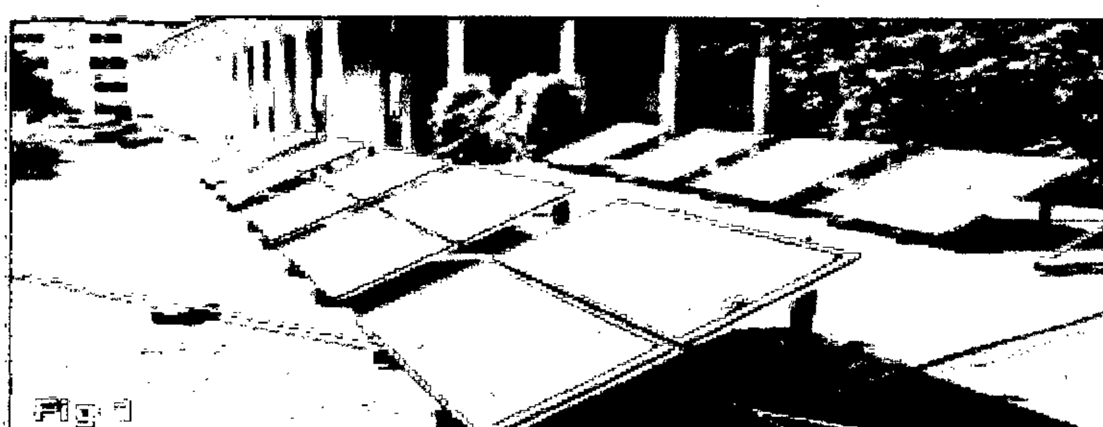
APPENDIX-A

Rooftop grid connected photovoltaic system costs with life cycle

System Size (kW)	System Price (Tk.)	Annual Energy Generated Q kWh	Life Cycle (Yrs)
1.1 kW	6,60,000	1806.75	20
2 kW	10,22,000	3285	20
3 kW	14,91,000	4927.5	20
5 kW	24, 78,000	8212.5	20
6 kW	29,68,000	9855	20
10 kW	49,56,000	16425	20
24.5 kW	1,10,00000	40241.25	20

Source: RERC, DU



Rooftop grid connected photovoltaic system at the Renewable Energy Research Centre (RERC), University of Dhaka.

APPENDIX-B

Costing of Solar PV System (SHS) for GRAMEN SAKTI Project

SL	System Capacity (W)	Usable Items	Machine Supplied by GS	Package Price (Tk.)
1	30	2pcs 6W Lamp	1pc 30W Panel, 1pc 47 Ah Deep Discharge Battery, 1pc Charge Controller, 2pcs 6W Lamp, 1pc Structure	**18,000**
2	40	3pcs 6W Lamp & 1pc 14" B&W TV	1pc 40W Panel, 1pc 55 Ah Deep Discharge Battery, 1pc Charge Controller, 3pcs 6W Lamp, 1pc Structure	**22,500**
3	50	4pcs 6W Lamp & 1pc 17" B&W TV	1pc 50W Panel, 1pc 80 Ah Deep Discharge Battery, 1pc Charge Controller, 4pcs 6W Lamp, 1pc Structure	**27,900**
4	60	5pcs 6W Lamp &1pc 14" B&W TV	1pc 60W Panel, 1pc 100 Ah Deep Discharge Battery, 1pc Charge Controller, 5pcs 6W Lamp, 1pc Structure	**31,500**
5	65	5pcs 6W Lamp & 1pc 17" B&W TV	1pc 65W Panel, 1pc 100 Ah Deep Discharge Battery, 1pc Charge Controller, 5pcs 6W Lamp, 1pc Structure	**33,500**
6	75	5pcs 6W Lamp & 1pc 17" B&W TV	1pc 75W Panel, 1pc 130 Ah Deep Discharge Battery, 1pc Charge Controller, 6pcs 6W Lamp, 1pc Structure	**38,400**
7	80	7pcs 6W Lamp & 1pc 17" B&W TV	1pc 80W Panel, 1pc 130 Ah Deep Discharge Battery, 1pc Charge Controller, 7pcs 6W Lamp, 1pc Structure	**40,000**

APPENDIX-B-1

SL	System Capacity (W)	Usable Items	Machine Supplied by GS	Package Price (Tk.)
8	85	8pcs 6W Lamp & 1pc 17" B&W TV	1pc 85W Panel, 1pc 130 Ah Deep Discharge Battery, 1pc Charge Controller, 8pcs 6W Lamp, 1pc Structure	**42,500**
9	120	10pcs 6W Lamp & 1pc 17-20" B&W TV	1pc 120W Panel, 2pc 100 Ah Deep Discharge Battery, 1pc Charge Controller, 10pcs 6W Lamp, 1pc Structure	**62,800**
10	130	11pcs 6W Lamp & 1pc 17-20" B&W TV	1pc 130W Panel, 2pc 100 Ah Deep Discharge Battery, 1pc Charge Controller, 11pcs 6W Lamp, 1pc Structure	**65,000**

Panel Prices

Panel Capacity (W)	Price (Tk.)
130	34,600/=
120	31,900/=
85	22,600/=
80	21,300/=
75	20,000/=
65	17,300/=
60	16,000/=
50	13,300/=
40	10,700/=

Charge Controller Price

Capacity (A)	Price (Tk.)	Made by
10	800	GS
5	1200	Germany

APPENDIX-B-2

Costing of Solar PV System (SHS) for RAHIMAFROOZ Project

SL	System Capacity (W)	Usable Items	Machine Supplied by GS	Package Price (Tk.)
1	20	2pcs 7.5W FTL & 2 pcs LED lamps	1pc 20W PV Module, 1pc 45 Ah Deep Cycle Solar Battery, 1pc Charge Controller, 2pcs Luminaries, 1pc Structure	**17,000**
2	40	1/3pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 40W PV Module, 1pc 55 Ah(12V) Deep cycle solar Battery, 1pc Charge Controller, 3pcs Luminaries, 1pc Structure	**27,300**
3	50	2/4pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 50W PV Module, 1pc 80 Ah(12V) Tubular plate solar Battery, 1pc Charge Controller, 4pcs Luminaries, 1pc Structure	**34,000**
4	60	3/5pcs 6W Lamp &1pc 14"/17" B&W TV	1pc 60W PV Module, 1pc 85 Ah(12V) Tubular Plate Solar Battery, 1pc10A, 12V Charge Controller, 5pcs Luminaries, 1pc Structure	**42,100**
5	75	4/6pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 75W PV Module, 1pc 100 Ah(12V) Tubular Plate Solar Battery, 1pc 10A, 12V Charge Controller, 6pcs Luminaries, 1pc Structure	**47,500**

APPENDIX-B-3

Costing of Solar PV System (SHS) for MICRO ELECTRONICS LTD. Project

SL	System Capacity (W)	Usable Items	Machine Supplied by GS	Package Price (Tk.)
1	20	2pcs 7.5W FTL & 2 pcs LED lamps	1pc 20W PV Module, 1pc 45 Ah Deep Cycle Solar Battery, 1pc Charge Controller, 2pcs Luminaries, 1pc Structure	**18,000**
2	40	1/3pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 40W PV Module, 1pc 55 Ah(12V) Deep cycle solar Battery, 1pc Charge Controller, 3pcs Luminaries, 1pc Structure	**30,300**
3	50	2/4pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 50W PV Module, 1pc 80 Ah(12V) Tubular plate solar Battery, 1pc Charge Controller, 4pcs Luminaries, 1pc Structure	**45,000**
4	60	3/5pcs 6W Lamp &1pc 14"/17" B&W TV	1pc 60W PV Module, 1pc 85 Ah(12V) Tubular Plate Solar Battery, 1pc10A, 12V Charge Controller, 5pcs Luminaries, 1pc Structure	**54,100**
5	75	4/6pcs 7.5W FTL &1pc 14"/17" B&W TV	1pc 75W PV Module, 1pc 100 Ah(12V) Tubular Plate Solar Battery, 1pc 10A, 12V Charge Controller, 6pcs Luminaries, 1pc Structure	**52,500**

APPENDIX-C

Costing of Solar PV Pump System from RAHIMAFROOZ

Pump Sizes

Serial	Pump Size	Average Water Output (in Liters at 50m head)
1	600W Solar Pumping System	10,800
2	900W Solar Pumping System	16,400
3	1200W Solar Pumping System	24,100
4	1800W Solar Pumping System	35,000
5	2400W Solar Pumping System	45,000

Pump Prices

Serial	Pump Size	Installation & Commissioning Per System
1	300W Solar Pumping System	4,62,400
2	600W Solar Pumping System	5,80,900
3	900W Solar Pumping System	7,26,000
4	1200W Solar Pumping System	8,37,000
5	1800W Solar Pumping System	10,72,000
6	2400W Solar Pumping System	13,08,900

Please note that, the above prices are approximate. Wiring, pipe, structure & other installation costs will be estimated after site visit.

Bore-hole for submersible pump will be provided by customer.

APPENDIX-C-1

Costing of Solar PV Pump System from MICRO ELECTRONICS LTD

Pump Sizes

Serial	Pump Size	Average Water Output (in Liters at 50m head)
1	600W Solar Pumping System	11,000
2	1200W Solar Pumping System	25,000
3	1800W Solar Pumping System	36, 000

Pump Prices

Serial	Pump Size	Installation & Commissioning Per System
1	600W Solar Pumping System	6,20,000
2	1200W Solar Pumping System	9,00,000
3	1800W Solar Pumping System	11,00,000

Please note that, the above prices are approximate. Wiring, pipe, structure & other installation costs will be estimated after site visit. Bore-hole for submersible pump will be provided by customer.

APPENDIX-D

Costing of Solar Hot Water System from RAHIMROOZ

SL	Description	Total Price In Taka
1	GPSOL 47-1500-15, 110 LPD DP Super Conducting Solar Water Heaters based on evacuated Tubes, including the following- a. Heat collector plate b. 110 Liter Capacity insulated water Tank c. Mounting base of the collector plate d. Fittings for the collector plate & system's water tank etc.	40,000.00
2	Transportation & Installation Charge inside Dhaka	5,000.00
Total Taka: Forty Five Thousand only.		**45,000.00**

*** Please note that, the customer has to arrange the connection of the water heater to the existing pipe-eater system of the site.