Solar Photovoltaic based Integrated Renewable energy system size and cost for a 100 kW Solar mini grid in Sandwip, Chittagong.

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APPROVAL

This project titled "**Solar Photovoltaic based Integrated Renewable energy system size an cost for a 100 kW Solar mini grid in Sandwip Chittagong",** submitted by Md. Rezaul Karim to the Department of Electrical and Electronics Engineering, Daffodil International University , has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Scin Electrical and electronics Engineering and approved as to its style and contents .The presentation has been held on.

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ABSTRACT

The increasing demand of electric power and shortage of present energy resources lead today engineers and scientists to think about the alternative sources of energy, the sunlight is a potential sources for generating electric power. In recent years, it is increasingly used to generated power .The use of solar energy is attractive for solar home system application also. Solar home system are quite , need no fuel and require very little maintenance .Other advantage of a PV system are :free energy, reliable power, flexibility and quick installation.

I have discussed **Solar Photo-voltaic based Integrated Renewable energy system size and cost for a 100 kW Solar mini grid in Sandwip Chittagong.** Finally ,I have analyzed On-grid solar system design , installation, operation and maintenance .

The government of Bangladesh should take necessary steps for solar energy development of rural area .The government institute is “Infrastructure development company limited ”(edcol) established from 2003 to 2013 solar home system 20 luck and produce 100 MW electricity .We know that 70% people lived in rural area. So , this project is not sufficient for development in rural area. Sun is the source of all energy available in the world . The initial cost of the solar energy would be much higher but the experts believe that it would be a cost effective alternative to Other source.

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

Presently Global warming and climate changes effect is the burning issue all over the world. Bangladesh will be the most affected country in the climate changes effect round the world. There are so many causes of global warming. Among them power generation is the most remarkable one. We can not think about any development without power (Electricity). Finally, sources of conventional energy like Fossil fuel, Natural gas and Coal are limited. If we used them in the present rate it will be finished within the short time. So, there is no other way to think about environmental friendly renewable energy production sources. In Bangladesh context solar energy is the most effective source for renewable energy production.

Developing countries can them plummet .Even if fuel is available within the country transporting that fuel to remote ,rural village can be difficult .There are no load or supporting infrastructure in many remote village where transportation by animals is still common . Transportation by animals limits loads capacities and some loads , diesel generators ,for example may be impossible to bring to such locations.

The use of renewable energy is attractive for solar energy application in many developing countries. This technology, referred to as photovoltaic's(PV),converts the sun energy into electricity through electromagnetic means when PV module is exposed to sunlight .The solar radiation energy is converted into DC power and requires an inverter it into AC power.

1.2 solar energy attractive in Bangladesh

1.Bangladesh is situated between 20.30 – 26.38 degrees north latitude and 88.04 – 92.44 degrees east longitude.

2. Daily average solar insulation rate is 4 to 6.5 KWh per square meter.

3, Maximum amount of radiation is available on the month of March- April (6.5h) and minimum on December- January (4h).

1.3 Important uses of solar power

The main sources of world's energy generation are the fossil fuels (gas, oil, coal) and nuclear power plants. Due to the usage of fossil fuels, green house gases (CFC, CH4, O3, but mainly CO2) emit into the atmosphere. From the nuclear power plant, carbon is released in a small amount (90 grams equivalent of carbon dioxide per kilowatt hour).[1]

But the radioactive waste remains active over thousand years which is a potential source of environmental pollution.

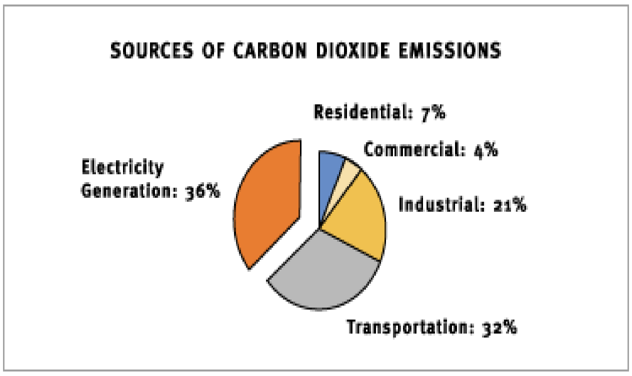


Figure1.1 Sources of carbon dioxide emissions[2]

Figure1 shows that electricity generation is source of the highest emission of carbon dioxide. So, production of this clean energy is actually contributing the highest towards global warming. Global warming as well as the environmental pollution is, in our times, the greatest environmental threat to human being .

On the other hand, there is an alarming energy crisis world wide as fossil fuel reserves decrease and the ageing power plants are going to close in near future. From the aspect of global warming and shortage of natural gas, scientists and engineers are looking for clean, renewable energies. Solar energy is the one of the best options. Because the earth receives 3.8 YJ [1YJ = 1024 J] of energy which is 6000 times greater than the worlds consumption. [3] Bangladesh is facing an acute shortage of energy. Natural gas is the main source of electricity generation in Bangladesh. But the limited gas reserves cannot fulfill the necessities of both domestic requirements and industrial and commercial demands, especially demands for electricity generation for long. Our present power generation capacity is only around 4200 MW whereas the total power requirement is 6000 MW. [4] So, we are able to generate only 70% of our total electricity demand. Due to this shortage of electricity not only we are facing load shedding across the country but also the industrial sector is badly affected. Resulting in reduced industrial output and diminished export earnings. There is a rising demand on the energy sector for rapid industrialization, urbanization, high population growth, increasing food production, rising standard of living etc. Solar energy could be a major source of power generation in Bangladesh. Bangladesh government plans to make it mandatory to install solar panel on rooftops of every multistoried and hi-rise building. As solar energy is one of the cleanest and simplest forms of energy, we can hope to find. Solar energy is readily available anywhere and everywhere in the earth.

It can be used it to generate electricity at the point of consumption. Solar powered building is based on this concept. Considering the above aspects, solar power option for the **Daffodil International University** campus is being studied in this work.

As finally we can say that for use of solar energy:

1. Source of Conventional Energy is Limited.
2. Production of power from conventional Energy causes CO_2 Emission.
3. Easy to install and use.
4. Noise free
5. Less maintenance.
6. Source is unlimited.
7. There is no moving parts, so its life is long

1.4 Potential of solar energy

There is a huge potential of solar energy. It is so huge that the total energy needs of the whole world can be fulfilled by the solar energy. The total energy consumption of the whole world in the year 2008 was 474 exajoule(1EJ=1018 J) or approximately 15TW(1.504*1013 W). [5]Almost 80%-90% of this energy came from fossil fuel. [6] From the sun earth receives 3,850,000 EJ of energy. [5] Which is equivalent to 174 petawattas (1 PW=1015 W). The earth does not hold all the energy, a part of it reflects back. After reflection earth receives 89 PW of energy. Of this huge amount only less than 0.02% is enough to replace the fossil fuel and nuclear power supply in the whole world at present. By this we can easily understand the great potential of solar energy. Considering green house effect, other environmental impact, cost, risk .

1.5 Top ten countries using solar power

Solar energy is becoming more and more popular among the grown and the growing countries. This is mainly because of government recognizing the energy problems and giving out more and more incentives for going solar, to both the general public and the corporations. The countries are starting to compete, to lead the renewable energy race in solar energy. I started wondering about which countries have the most amount of installed solar systems. So i wanted to do a top ten list of the countries which uses the most solar energy (in Mega Watts, MW) in the world. I wanted to do this in a Letterman style but i think its better to write a short note about each country pointing out its highlights and some interesting facts.[7] So here we go counting down….

10) India (120 MW)

9) France (272 MW)

8) China (305)

7) Belgium (363 MW)

6) Czech Republic (465 MW)

5) U.S (1650 MW)

4) Japan (2633 MW)

3) Spain (3386 MW)

2) Italy (4000 MW)

1) Germany (9785 MW)

1.6 Objectives of the project

1. To introduce Renewable Energy (RE) as an alternative solution for power generation.
2. Technology & know-how Transfer.
3. Practice and Product oriented Training.
4. Ref. of uninterrupted power supply.

1.7 Project Target

1.Promote Solar Energy Production and uses in Urban, Sub Urban, Rural, Agriculture & Industrial Sector.

2.Reference of uninterrupted power supply.

3.Reference of surplus power Transmission directly to Grid line.

4.Training to be Teacher & Technicians for Design, Installation, Repair and Maintenance of solar Energy Production system and equipment.

5.Formulate a Sustainable & suitable policy for solar power sale.

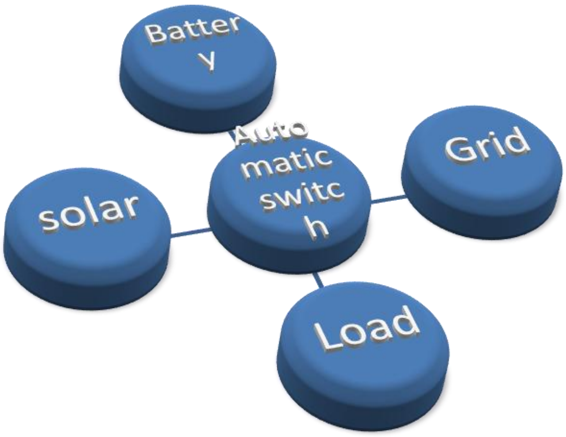


Fig 1.2 Ref. of uninterrupted power supply

CHAPTER TWO

Photovoltaic Technology

2.1 Solar panel

Solar panels produce electricity from sunlight. The first solar panel-powered satellite was launched in 1958 by Hoffman Electronics.

A solar panel consists of number of photovoltaic (PV) solar cells connected in series and parallel. These cells are made up of at least two layers of semiconductor material (usually pure silicon infused with boron and phosphorous). One layer has a positive charge; the other has a negative charge. When sunlight strikes the solar panel, photons from the light are absorbed by the semiconductor atoms, which then release electrons. The electrons, flowing from the negative layer (n-type) of semiconductor, flow to the positive layer (ptype), producing an electrical current. Since the electric current flows in one direction (like a battery), the electricity generated is DC.

2.2 Types of solar system design

There can be various types of solar system design. But there are three basic design consideration, they are-

1. Grid tie
2. Off-grid
3. Stand alone

2.3 Solar PV technologies

With the growing demand of solar power new technologies are being introduced and existing technologies are developing. There are four types of solar PV cells:

- Single crystalline or mono crystalline
- Multi- or poly-crystalline
- Thin film
- Amorphous silicon

2.3.1 Single-crystalline or mono crystalline

It is widely available and the most efficient cells materials among all. They produce the most power per square foot of module. Each cell is cut from a single crystal. The wafers then further cut into the shape of rectangular cells to maximize the number of cells in the solar panel.

2.3.2 Polycrystalline cells

They are made from similar silicon material except that instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers.

2.3.3 Thin film panels

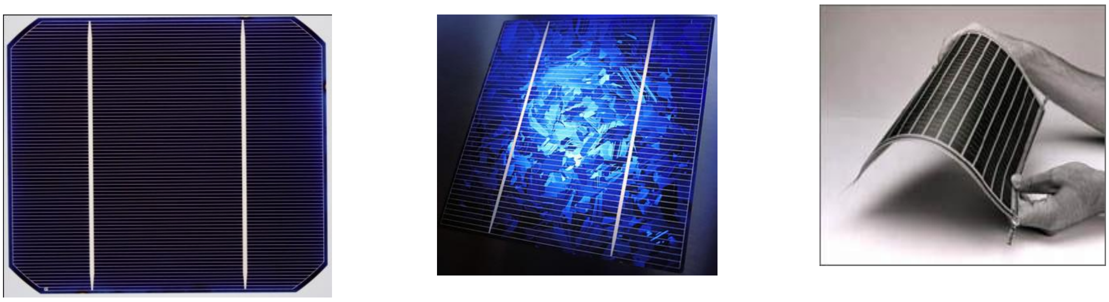
It is the newest technology introduced to solar cell technology. Copper indium dieseline, cadmium telluride, and gallium arsenide are all thin film materials. They are directly deposited on glass, stainless steel, or other compatible substrate materials. Some of them perform slightly better than crystalline modules under low light conditions. A thin film is very thin-a few micrometer or less.

2.3.4 Amorphous Silicon:

Amorphous silicon is newest in the thin film technology. In this technology amorphous silicon vapor is deposited on a couple of micro meter thick amorphous films on stainless steel rolls. [8] Compared to the crystalline silicon, this technology uses only 1% of the material. Table 1 below shows the efficiency of different types of solar cells.

Table 2.1 Efficiency of different types of solar cells

Cell type	Efficiency,%
Mono crystalline	12-18
Polycrystalline	12-18
Thin film	8-10
Amorphous	6-8



Monocrystalline Silicon ***Polycrystalline Silicon*** ***Amorphous Thin Film Silicon***

Fig 2.1 three types of solar PV cells

2.4 Components of a solar PV system

A typical solar PV system consists of solar panel, charge controller, batteries, inverter and the load. Figure 2.2 shows the block diagram of such a system.

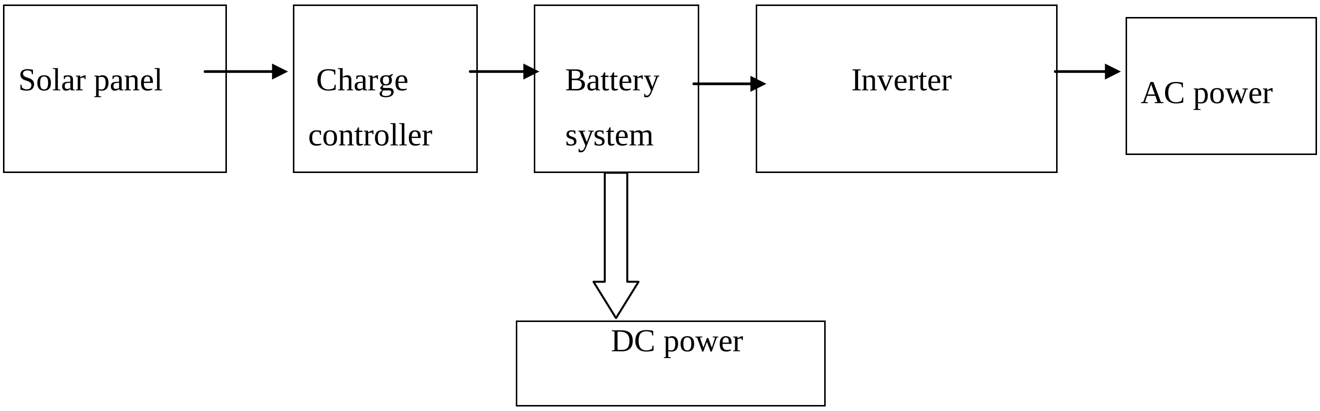


Figure 2.2 Block diagram of a typical solar PV system

2.4.1 Charge controller

When battery is included in a system, the necessity of charge controller comes forward. A charge controller controls the uncertain voltage build up. In a bright sunny day the solar cells produce more voltage that can lead to battery damage. A charge controller helps to maintain the balance in charging the battery. [9]

2.4.2 Batteries

To store charges batteries are used. There are many types of batteries available in the market. But all of them are not suitable for solar PV technologies. Mostly used batteries are nickel/cadmium batteries. There are some other types of high energy density batteries such as- sodium/sulphur, zinc/bromine flow batteries. But for the medium term batteries nickel/metal hydride battery has the best cycling performance. For the long term option iron/chromium red ox and zinc or manganese batteries are best. Absorbed Glass Mat (AGM) batteries are also one of the best available potions for solar PV use. [10]

2.4.3 Inverter

Solar panel generates dc electricity but most of the household and industrial appliances need ac current. Inverter converts the dc current of panel or battery to the ac current. We can divide the inverter into two categories. [11] They are-

- Stand alone and
- Line-tied or utility-interactive

2.5 Solar Generation Technology:

There are two possibilities to Generate power from Solar Energy.

2.5.1 Roof Top System – In this segment, you can install solar power plant on your roof, produce electricity in the day time and directly convert them into AC power and use for loads during day time or export to Grid and save on EB Bills. This system is most common for applications above 100 KW upto MW size. In this system, you can only use solar power when produced and not stored at all.

2.5.2 Off Grid System – In this segment, you can install solar power plant on your roof top, generate electricity and store it in the battery. The system functions in such a manner – the battery is charged priority by solar power and if not by EB power. When the battery is full, if the solar power is available – then the load is connected to solar power – even when EB power is available. When solar is not available, if the battery is full – the load is connected to EB power if available.

When both Solar and EB power is not available – the load is supplied from battery. Generally these systems are highly suitable for power cut situations and for capacities ranging from 1 KW to 100 KW.

2.6 Selecting the PV module

As we need huge power supply and we do not have huge area. So, we selected mono crystalline silicon module. Our module selection depends on cost and efficiency. The capital investment of solar PV panel is very high. Approximately, 60% of the total system installation cost is the price of module cost. We should consider the cost in order to get the best output of the money spent. Cost varies on efficiency of panel and the material has been used to make the PV panel. The cost of silicon solar cell is very high. In our design we used mono crystalline silicon cell. Efficiency of solar cell depends on the technology used. Silicon solar cell has the highest efficiency. Thin film has low efficiency, but they can be ideal for some applications. Another important consideration is temperature. Module efficiency decreases as the module temperature increases. When modules operating on roof, it heats up substantially. Cell inner temperature reaches to 50-70 degree Celsius. In high temperature areas, it is better to choose a panel with low temperature co-efficient. Considering the above factors, we have selected a module of Samsung brand.

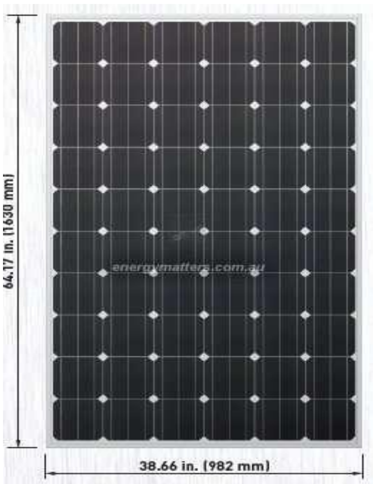


Figure 2.3 Samsung LPC250S solar module

Fig. 2.3 shows the Samsung solar module and the model is LPC250S. Its maximum output power is 250 watt. If irradiance is 1000 watts per meter square then the module's nominal power output is 200 watt if irradiance is 800 watts per meter square. The irradiance of Dhaka City is 694.04 watts per meter square. So we will get power less than 200 watts, approximately 173.51 watts. 25 years power output warranty is 80%. The panel efficiency is 15.62%. Short circuit current of the panel is 8.66A at standard test condition and 6.90A at nominal condition. [14]

2.7 solar energy system site considerations

One of the first things most home owners ask when considering a solar system is "Yeah, but will that work at my house?" This is soon followed by a litany of concerns such as to which way their house faces towards the sun, overhanging trees, too cold a climate and other factors. The good news is that both passive and active solar systems can work under a wide variety of conditions. Photovoltaic systems in particular tend to be much more site tolerant than most people suspect. Nonetheless, there are a number of site factors I should consider before deciding if solar is right for you, and if so what kind of solar system you should go with [1]. Here are a few things to consider:

2.7.1 Proximity to the Power Grid - If our home or home site is more than half a mile from the nearest power line you may want to consider going with an off-the-grid solar system using some combination of passive and active PV systems with batteries. Electric utilities can charge $50,000 or more to run a line to our home and battery systems with generators typically run far less than that.

2.7.2 Cost of Electricity - PV systems make particular sense in locations which have high electric rates. In the U.S states such as California have very high electric rates (20 to 30 cents per kilowatt hour).

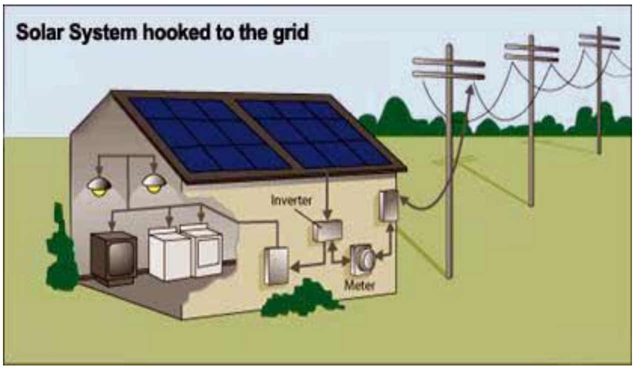
2.7.3 Financial Incentives - Many states have become very aggressive in providing financial incentives to homeowners who wish to install PV systems. California, New York, Colorado, Florida and Illinois are among the leaders in providing incentives.

2.7.4 Shade - Shade is always a factor in the use of photovoltaic systems. If you live in a heavily wooded area you may need to determine if the trees blocking the potential site for our PV panels can be removed or cut back. In denser neighborhoods trees may not reside within our property line and this might not be an option. In such cases, consider alternative locations for our panels. Sometimes a set of panels mounted on a tracking system in the back yard can accomplish as much as a roof mounted system.

2.7.5 Roof Direction and Pitch - While it is true that south facing roofs are better for locating solar panels, most systems still can produce strong output even if they do not face south. For example, if a roof is 45 degrees off of due south it will output only 4% less electricity than if it were placing perfectly south. Roof angles are also fairly robust when it comes to placing panels. Generally a 30% angle (7:12 roof pitch) is recommended. However a south facing roof with a strong 45% pitch (12:12) will produce only 3% less electricity than one facing a perfect 30 degrees.

2.7.6 Snow and Leaves - The impact of snow and leaves, in contrast, is often an underrated factor in the performance of PV systems. PV panels work best when they are kept clear of debris or snow. Even a small amount of obstruction can significantly impair their performance. This is why regular maintenance is always recommended to keep the panels clean.

2.8 SOLAR HOME SYSTEMS



For those homeowners who would like to achieve long-term energy independence solar photovoltaic (PV) systems using solar panels are one of the very best options. Solar energy systems for the home are relatively simple, last for decades and over the long term can save homeowners significant money, particularly in those states or countries that provide incentives for solar energy. Moreover, solar PV systems create no pollution and give off no hydrocarbon which makes them one of the best energy options from an environmental standpoint. They are definitely a home energy option i can feel good about. A key thing to remember with PV systems is that what they are harvesting is light energy, not heat or solar thermal energy. [2]

That means they work as well in colder climates as they do in warmer climates. All that matters is how much light a location gets and in most of the U.S. there is more than sufficient light on average for PV systems to be very effective. If i want to learn exactly how much light your location has during the year look at our section on solar maps. These will show you exactly how many hours of sunlight per day your area gets at different times of the year.

Photovoltaic systems (PV systems for short) are any energy generation systems that make use of photovoltaic cells. A photovoltaic cell is a cell which generates electricity directly from light energy. Photovoltaic cells come in many sizes, but most are 10 cm by 10 cm and generate a little more than half a volt of electricity. PV cells are bundled together in interconnected solar panels to produce higher voltages and increased power. A 12-volt solar panel typically used in home solar energy applications has 30 to 50 PV cells. And can generate anywhere between 80 to 200 volts of electricity. In a residential application multiple solar panels are strung together into one or more modules. The number of panels you need is a function of your energy use and the amount of space you have available on your southern facing roof.

2.9 Grid-Tied vs Off-the-Grid Systems

Photovoltaic systems for the home can generally be classified into those that are designed to make use of an existing electric grid(grid-tied system) or those that are designed for rural use where no electric grid is available(off-the-grid system). In a grid-tied system there is no need for a battery system to store the energy that the solar panels generate. Instead the power grid itself acts in a sense as a giant battery that uses any excess electricity that your solar panels may generate, and which you can draw from on cloudy days when there is insufficient sunlight to fully power your home.

We believe that grid-tied systems offer a number of advantages over off-the-grid PV systems. Overall they are less expensive than off-the-grid systems because they do not require either batteries or battery charging controllers. Because they require less equipment they are also much simpler systems to set up and use. They take less time to install and require very little maintenance. We also think they are far more efficient and environmentally friendly than off-the-grid systems. With a grid-tied system none of the energy your PV panels generate is wasted. On sunny days when your panels are producing more electricity than you are using the energy is transferred to the grid where it can immediately be used by others. In an off-the-grid system, once your batteries are fully charged, any excess electricity being generated by your panels has to be dumped to prevent the batteries from being overcharged. This results in wasted electricity.

However, in some situations, particularly in rural areas which have no grid, there may be no option other than to go with an off-the-grid system. For a home owner to pay the utility company to bring power lines into their property can cost upwards of $10,000 per quarter mile. For many owners of rural properties this makes hooking to the grid economically non-viable. Off-the-grid systems require more care and maintenance but can give a homeowner a strong sense of independence.

2.10 TRACKING SYSTEMS

Tracking systems are hardware devices usually used on pole mounted solar arrays to allow the positioning of the solar panels to follow the movement of the sun. This helps ensure that there is maximum exposure for the solar cells. A tracking system can increase the output of your PV system by up to 30% in the summer and 15% in the winter over non-tracked systems.

Tracking systems are usually classified as being either passive or active. In a passive system the tracker follows the sun from east to west without using any type of electric motor to power the movement. Instead the system rotates from a combination of heat and gravity. Because no external source of electricity is needed such systems are ideal for remote off-the-grid scenarios or use with water pumping systems where peak the peak demand is in the summer.

Tracking systems are also sometimes classified as to the number of axis they track against. Simple one axis systems rotate only left to right rather than in an arch. A two axis tracking system will track both left to right and up and down. This allows it more accurately to follow the true arch of the sun throughout the day.

Passive tracking systems have some limitations. First, they are somewhat susceptible to high winds which can throw the tracker off the proper direction. They can also be somewhat sluggish in getting moving in cold temperatures because they are mechanically rather than electronically driven.

Active tracking systems are powered by small electric motors and require some type of control module to direct them. They are similar in approach to the systems supporting giant TV dishes. Active systems require some electric power which can come from an external source or from the solar panels themselves depending upon the model.

The big question with trackers is whether or not the additional cost, of a tracking system, both initial cost and maintenance cost, is justified by the additional electric power they generate. Tracking systems require maintenance and add a good bit of complexity to the system simply because they have moving parts.

CHAPTER THREE

Solar Energy in Bangladesh

3.1 Physical Perspective of Renewable Energy in Bangladesh

Bangladesh situated in the north-eastern part of south Asia is among the world's most densely populated nations (1099 people/km2 in 2010) with a population of 162.20 million in 2011 . Energy, and more explicitly electricity, is a prerequisite for the technological development, higher economic growth and poverty reduction of a nation. The future economic development of Bangladesh is likely to result in a rapid growth in the demand for energy with accompanying shortages and problems. The country has been facing a severe power crisis for about a decade .

Out of various renewable sources hydropower, geothermal, solar, tides, wind, biomass, and bio fuel can be effectively used in Bangladesh . Solar energy is the most readily available and free source of energy in our country and traditionally solar thermal energy has been utilized in different household and industrial activities in Bangladesh. Several organizations have installed low capacity wind turbines, mainly for battery charging in the coastal region of Bangladesh. However, progress in the wind energy sector of Bangladesh is not impressive [10]. Micro Hydro Power Plants can be installed in the north-eastern hilly regions and in the existing irrigational canal system with a sufficient head. 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 . There are scopes of integrated small tidal power plants in the coastal regions. Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries like Bangladesh .

An agriculture based country like Bangladesh has huge potentials for utilizing biogas technologies. According to IFRD-there is potential of about four million biogas plants in our Country .

It is notable that Bangladesh Government has planned to produce 5% of total power generation by 2015 & 10% by 2020 from renewable energy sources like air, waste & solar energy . Based on the information obtained, a comparative scenario of the five leading renewable energy sectors of Bangladesh is illustrated in “Fig. 1” in terms of the installed capacity .

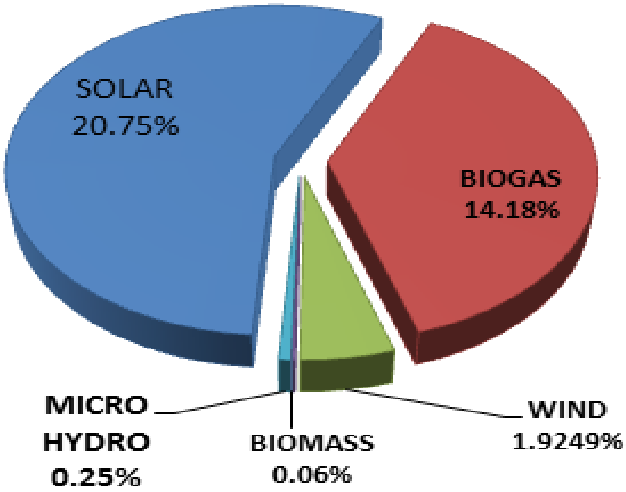


Fig 3.1: Contribution of different implemented renewable sources in Bangladesh

3.2 Present Status of Solar Energy in Bangladesh

Solar radiation varies from season to season in Bangladesh. So we might not get the same solar energy all the time. In "fig.2" the monthly average solar radiation pattern is shown. [17]

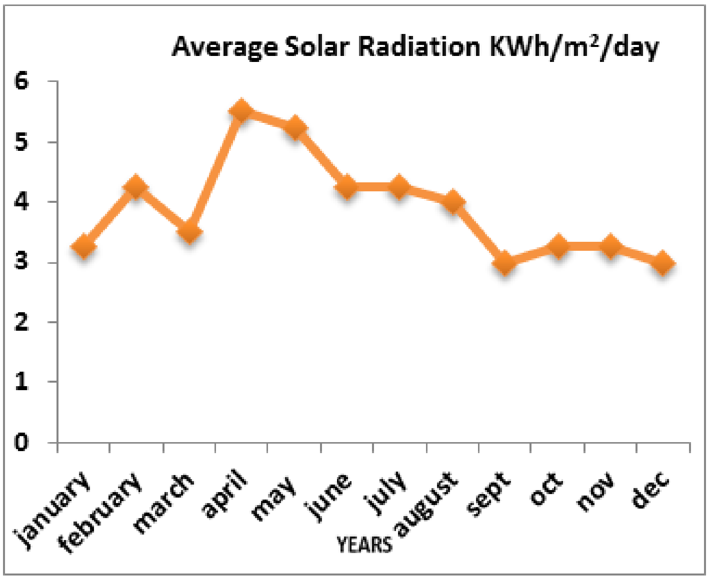


Fig 3.2: Monthly average solar radiation profile in Bangladesh

Daily average solar radiation varies between 4 to 6.5 KWh per square meter. Maximum amount of radiation are available in the month of March-April and minimum in December-January .
According to IDCOL, the total capacity of solar energy based installations in Bangladesh appears to be 20.75 MW [26]. The amount is significant considering the upward trend of the number of SHSs (Solar Home System) installations in the country.

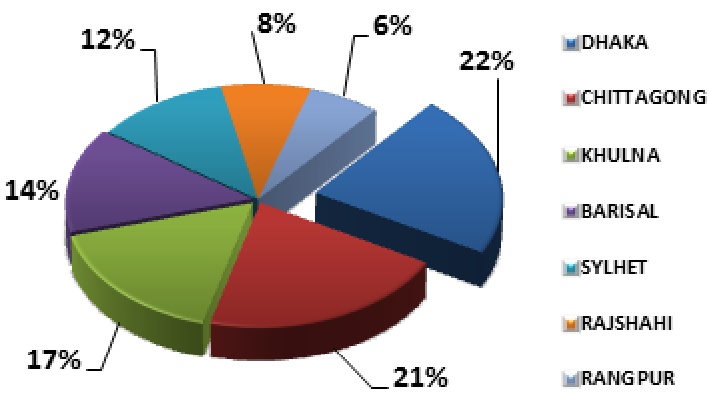


Fig 3.3: Distribution of the SHSs (Solar Home System) in seven divisions in Bangladesh

The “fig. 3” shows the approximate division wise SHSs installation. The figure illuminates that the distribution of the SHSs is highest in the Dhaka district whereas lowest in the newly formed district Rangpur.

3.3 Solar Energy source of Bangladesh

Solar Energy is a great source for solving power crisis in Bangladesh. Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east which is an ideal location for solar energy utilization [8]. At this position the amount of hours of sunlight each day throughout a year is shown in the following graph in the Figure-1 [17]. The highest and the lowest intensity of direct radiation in W/m² are also shown in the Figure-1 [17].

Figure 1. The amount of hours of sunlight in Bangladesh Infrastructure development company limited (IDCOL) has supported NGOs in installation of solar home systems (SHSs) and a total of 1,320,965 SHSs having capacity of about more than 36.5 MW have been installed upto February 2012 [18]. Bangladesh power development board (BPDB) has implemented an excellent Solar PV electrification project in the Chittagong hill tracts region. The Solar PV electrification has emerged as the most appropriate technological option for the electrification of these areas [19]. A 10 kW central AC solar PV system has been installed in one selected market in each of the three Rangamati district’s sub-districts. With these systems, the shops of that market have been electrified with normal AC electricity [20].

Table 3.1: SHS's installation up to February 2012 [21]

Partner Organization	Number of SHSs Installed
Grameen Shakti	750,657
RSF	199,209
BRAC	75,440
Srizony Bangladesh	54,011
Hilful Fuzul Samaj Kallyan Sangstha	32,630
UBOMUS	23,651
BRIDGE	19,148
Integrated Development Foundation	12,618
TMSS	11,787
PDBF	9,869
SEF	16,783
AVA	10,564
DESHA	9,593
BGEF	13,684
RDF	15,911
COAST	6,181
INGEN	8,487
NUSRA	5,543
RIMSO	7,651
Shubashati	6,798
REDI	4,933
GHEL	5,209
SFDW	4,981
PMUK	2,046
Patakuri	2,087
ADAMS	2,433
AFAUS	1,003
Xenergeia	252
Other	389
Total	**1,320,965**

3.4 Obstacles of Expansion of PV Technology in Rural Areas*:*

The major obstacles of rapid expansion of PV systems are as follows:

- The problem with this technology is that the expectations almost always outweigh what the systems could achieve. Most thought a simple system could power an entire household quite easily. But after everything was explained thoroughly the main problem of solar energy was its price.
- The lack of awareness about the PV technology requires long time, effort and money to familiarize the PV technology to the rural areas.
- Private sector companies and NGOs may find it very difficult to cover the initial cost of dissemination of the technology, the main hindrance bring the high cost of system due to high price of the PV module in international market and imposition of government taxes.
- An alternative to reach large number of rural households could have been developed with an easy financing system so that the buyers can pay the system price over a longer period of time (for example, 5 to 7 years). The implementing agency automatically requires soft fund to finance the customers, but source of soft finance is so far nonexistent.

o Usually people show a lot of enthusiasms for this new technology and a desire to observe it more closely for a longer period. Many persons come forward to negotiate terms under which they can procure a system for themselves. In fact, there was huge gap between the financial affordability of rural people and the price of solar system. So, a suitable marketing mechanism is always required to reduce the gap. Presently Grameen Shakti is offering four types of solar systems for household use. The brief descriptions of these are given in Table 3.

Table 3.2: Brief description of solar systems Types of Solar System[23]

Types of SHS	Usable Items	Package Price (Tk.)
75 Wp	6 lamp (8 Watt each) and 1 B&W TV	34,500
50 Wp	4 lamp (8 Watt each) and 1 B&W TV	22,000
40 Wp	3 lamp (8 Watt each) and 1 B&W TV	17300
30 Wp	2 lamp (8 Watt each) and 1 B&W TV	12500

The Grameen Shakti program made a cost analysis of the SHS taking the price of system, possible repairs, replacements, maintenance and depreciations. This led to several possible marketing strategies to be piloted by the program. Table 4 indicates the pricing options of SHS.

Table 3.3: Pricing Options for solar system[24]

Sl No.	Types of SHS	Cash-package price (Tk.)	Down payment (TK.)	Loan amount (TK.)	Monthly installment amount (36 installment)	Monthly installment amount (24 installment)	Monthly installment amount (12 installment)
01	75 Wp	34,500	5,865	28,635	1,034	1,432	2,625
02	50 Wp	22,000	3,740	18,260	660	913	1674
03	40 Wp	17,300	2,941	14,359	519	718	1317
04	30 Wp	12,500	2,125	10,375	375	519	951

3.4.1 Experience of Rural Electrification Board (REB) Project:

(a) Customers prefer standalone system mainly due to higher quantity of energy available from the system and for convenience; batteries need not to be brought to the charging station;

(b) Customers prefer relatively larger system (46 Wp and above);

(c) Charging stations may be considered as a failure. Customers do not like to frequently charge batteries from charging stations. It is very inconvenient to bring batteries from far flung areas. Many batteries have been damaged due over discharge.

3.4.2 Socio Economic Impact of Solar Energy:

Socio-economic development is the process of social and economic development in a society, which is measured with indicators, such as GDP, life expectancy, literacy and levels of employment. The electricity makes a significant impact on rural community from socio-economic perspective. Among different aspects of socio-economic impacts of rural electrification, some aspects are highlighted in this study.

Besides electrification other basic infrastructure development is necessary for positive socioeconomic impact on rural community. The degree of impact varies with the location of the study area, availability of basic infrastructure and mode of electrification in the local community. In this case the authors wanted to quantify the socio economic impact that solar energy usage has on Bangladeshi society, especially the rural one.

3.4.3 Lighting Facilities Before and After SHS :

Lighting and entertainment facilities usually available in a typical village before using the solar home systems in the study villages are given in the Table 5.1. It is shown that 35% of respondents are using some sort of kerosene lamps for their household lighting. On the other hand, 40% of the users use dry cell batteries for torch lights and radios. For watching TV, 15% of the participants use car-batteries.[25]

Table 3.4: solar home systems Lighting and entertainment facilities

Study Area	Kerosene Lamp	Dry cell Battery	Kerosene Pressure Lamp	Car Battery	Wick & Kerosene Lamp
Niz Mawna(Village)	39	36	-	9	6
Micro Enterprise	3	2	5	-	3
Barabo	9	8	-	3	1
Total Respondent	51	46	5	12	10
% of Respondent	77	70	8	18	15

After the solar home system installation, the scenario changed. Nobody was using kerosene pressure lamps and car batteries for lighting and entertainment purposes. Reduction of Kerosene was the main impact of the solar home system that results less pollution, less darkness, less hassle and in addition less work for cleaning kerosene lamps as well. Charging of the car batteries was more time consuming with respect to present situation whether charging was being done automatically remained connected with TV. Dry cell batteries were still common in use at night for torch lights to facilitate communication. Among the respondents, 5% were still habituated with kerosene lamps for lighting purposes in whole night.

3.4.4 Impact on Lifestyle:

The daily working activities changed after introducing of solar home systems in the stated study areas. Better quality of light provided opportunities for studying and refreshment as well as gossiping activities, for watching TV or listening to broadcast information and entertainment by the radio. It is shown from the Table 5.3 that at present children could study additional two and half (2.5) hours with this facility. Three household respondents made their opinion that their children's performance of study was better than previous. On the other hand, all respondents remarked that their evening working hours were extended.

Table 3.5: Number of Hours/day for Social Activities before and after SHS [25]

Social Activities	Number of Hours per Day		
	Before SHS	After SHS	Change
TV watching	2	4/5	+ 2/3
Listening radio	2	3	+1
Children studying	1.5	4	+ 2.5
Sewing	0	2	+ 2
Chatting	0	2	+ 2
Sleeping time	8/9	6/7	- 2

3.4.5 Income Generation Activities, Poverty, and Income Distribution:

There is a positive relation between the income generation and the exposure of people to sources of power in the rural areas. Income generation activities are created after acquiring the solar home systems in villages. The people engaged in doing business using traditional fuel now switch to solar light that results in more development of their business than before. Medical pharmacies in and mobile phone service centers are established due to installation of solar home systems. Tailoring machines are bought to earn some money.

Women become involved with income generation activities. Grocery shop owners who were using kerosene lamps for their business get working hours extended due to SHS.

As more and more income generating facilities and opportunities are created due to the introduction of solar energy in villages, solar energy has the potential to reduce poverty in rural areas. It can also play a role in balancing income distribution in a great way in a given village.

Table 3.6: Income Generation Activity Hours Before and After the SHS[25]

Income Generation Activities	Number of Hours		
	Before SHS	After SHS	Change
Sewing	0	1	+ 1
Tailoring (HH)	0	2	+ 2
Tailoring (Shop)	3	4	+ 1
Mobile phone business	0	12	+ 12
Grocery shop (Used Kerosene lamp)	2	4	+ 2
Grocery shop (Used Pressure Lamp)	3	4	+ 1
Furniture shop	1	3	+ 2
Pharmacy	0	3	+ 3

3.4.6 Impact on Household Assets:

Households acquire color television after the solar home system installation (Above table). Radio and cassette increases after the solar system installation. Mobile phone uses increases. Most popular item for the households is television. After installation of solar home system, in a survey by Md. Alam Hossain Mondal, the individual household TV increased to 52%, meaning that buying rate of TV was increased by 41%. Mobile phone was another interesting item for communication. Network was not available in the study villages, but eight of the SHS users out of total surveyed people were using mobile phones by using small antenna for getting network and they used the solar facility for charging. The telecommunication system was improved significantly due to SHS. In the rural area, people could communicate with their near and dear easily. The respondent could know the news of the country by watching TV and listening to radio.

3.4.7 Impact on Literacy and Education:

Solar energy in households like any other form of energy enhances opportunities for connecting to the world and education. People in a electrified village is much more prone to be educated as they learn to become more competitive by gaining access to developed areas. And solar energy helps people in study related areas in more than one can think of.

3.5 Prospect of Solar System in Bangladesh

a)Government Initiative[2] :

Government strategy emphasizes promoting off-grid options in areas that are unsuitable for grid expansion. It has made a good start by eliminating import duty on SHS in April 2000. The strategy emphasizes the pivotal role of well functioning rural systems for the Government’s off grid promotion strategy and endorses the approach to use well-functioning rural community based organizations (CBOs) to leverage grass-roots reach and establish credibility to improve electricity provision significantly.

The objective of this Clean Development Mechanism (CDM) project is to contribute to sustainable development through the provision of renewable solar electricity to households not connected to the electricity grid and thereby reduce the Greenhouse Gas (GHG) emissions by displacing kerosene and diesel use for lighting and off-grid electricity generation.

The project will contribute to the sustainable development of Bangladesh with a particular emphasis on the rural population, which is generally poorer. In addition to reducing GHG emissions, the project would have significant other social, economic and environmental benefits. Bank's involvement in supporting this project is therefore considered highly appropriate.

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.[26]

Upon full implementation in year 2015, the project activity will replace 20,075 kilolitres 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.

The project will be implemented by Grameen Shakti (GS) which develops, introduces and popularizes renewable energy technologies for sustainable energy solutions, particularly Solar PV systems, aiming to reduce poverty, improve living standards and protect the environment.

Over the last decade GS has installed about 77,000 SHS with combined capacities of 15.8 MW and more than 1,650 SHSs are installed each month. It has also set up 120 offices for service delivery and performance monitoring, and has a research unit for improvement of the overall efficiency of the system and ancillaries. GS is currently serving more than 275,000 beneficiaries through its 120 offices spread over 58 districts of Bangladesh.

3.6 Status of Application of PV Technology in Bangladesh

In Bangladesh, the applicability of standalone SHS is more than others. The remote and scattered clusters of rural households make the SHS more appropriate for electrification.

IDCOL is the main financing organization in the renewable energy sector and it contributes in dissemination of renewable technology through partner organizations in Bangladesh. So far 116,448 SHSs have been installed by different NGOs throughout Bangladesh and a target of installation of 200,000 SHSs will be implemented by the year 2009. Besides NGOs, government organizations like the REB have installed 3521 SHSs in Bangladesh under different renewable energy projects26. Till January, 2005, the total PV installation capacity of the Bangladesh Power

Development Board (BPDP) was 56 kWp in the Chittagong hill tracts region and it is expected to install around 150 kWp in near future. The Local Government and Engineering Department (LGED) so far installed 35.6 kWp solar installations in Bangladesh. It is to be mentioned that for both the BPDB and LGED, the total PV installations include various applications like SHS, centralized solar electrification, solar water pumping and others. The centralized solar electrification programs are implemented by some government organizations with the assistance from donor organizations. So far six centralized solar electrification projects were implemented in Bangladesh and they were implemented by the BPDB and LGED. These projects were implemented to determine the viability of the centralized PV technology for remote rural electrification.

3.7 Potential market for PV technology

Bangladesh has a potential market for utilization of PV technology for off-grid electrification purposes. According to a market survey (funded by World Bank) in 1998, there is an existing market size of 0.5 million households for SHSs on a fee-for-service basis in the off-grid areas of Bangladesh. In most of the developing countries it has been observed that households spend no more than 5% of their income for lighting and usage of small appliances. According to that about 4.8 million rural households in Bangladesh could pay for a solar home system. It is estimated that 10,000 rural markets and commercial centers which are about 50% of all rural markets in the country are electrified by conventional grid electricity. The centralized PV system has good electrification potential for the off-grid rural markets and commercial centers. In off-grid rural markets and commercial centers, the electricity is mainly provided from private owned diesel generator operators and it has been found that 82% of them are interested in marketing SHS in surrounding areas if favorable financing arrangements are available (World Bank, 2000). Different government and non-government offices, health centers, schools, banks, police stations etc in the off-grid areas use traditional means of lighting like lantern, candles, kerosene wick lamps etc or they have their own diesel generator set. These offices have separate budgets for electricity which can be used for electrification through PV technology. The estimated short to midterm market potential of the PV technology in Bangladesh is about 60 MW. This estimation considers the various applications of PV technology like pumping, signaling, telecommunication besides conventional rural electrification. The chart 1 shows the relative distribution of the projected existing market for SHS within the administrative divisions of Bangladesh.[27]

Chart 1: Projection of the SHS Market in Bangladesh

The estimation of market potential is based on operating experience of other developing countries like India, Sri Lanka where PV technology is techno-economically attractive for different applications irrespective of high initial cost of solar installations. This market potential is determined on short to midterm basis however the actual market potential is dependent on the price of the solar PV system. The commercialization and widespread application of solar electrification depend on the potential of the market in the context of socio-economic condition, attitude and preference of people and above all the energy usage pattern in the rural area.

3.8 Impact of Further Growth in Solar Energy Sector on Present Power Distribution System

Today's Bangladesh is featured with load shedding problem and now, people in Bangladesh are living with some worst load shedding memories. As Bangladesh is a densely populated country, things should have been changed before any depressing thing emerges. Though solar power is not new in Bangladesh, people yet are not using it as a pure alternative of load shedding problem. In Bangladesh, Grameen Shakti is popular for awareness and implementation of solar power in some rural areas.

In Bangladesh, power demand amounts to 5500 megawatt unofficially and 4600 megawatt officially. But the power plant under Power Development Board (PDB) can generate only around 3600 megawatt (mw).Now, with the gas crisis, the PDB cannot generate 500 to 800 mw.Earlier in April 2009, PDB had all the gas supply it needed and it could generate a record 4200 mw power just for one day. It has been proved by many researches that Bangladesh is not suitable for wind or coal power because of high cost. Thus solar power is the only alternative[28]

According to the interview with Grameen Shakti, it has been revealed that, initially, people were simply interested in how the sun could provide electricity but now, with different awareness program generation, from 1996 to till now, Grameen Shakti has been successful to make people understand and thus is succeeded in installing solar power system in many rural areas of Bangladesh. From the secondary sources provided by Grameen Shakti, following statistics about installation of solar home system has been found.

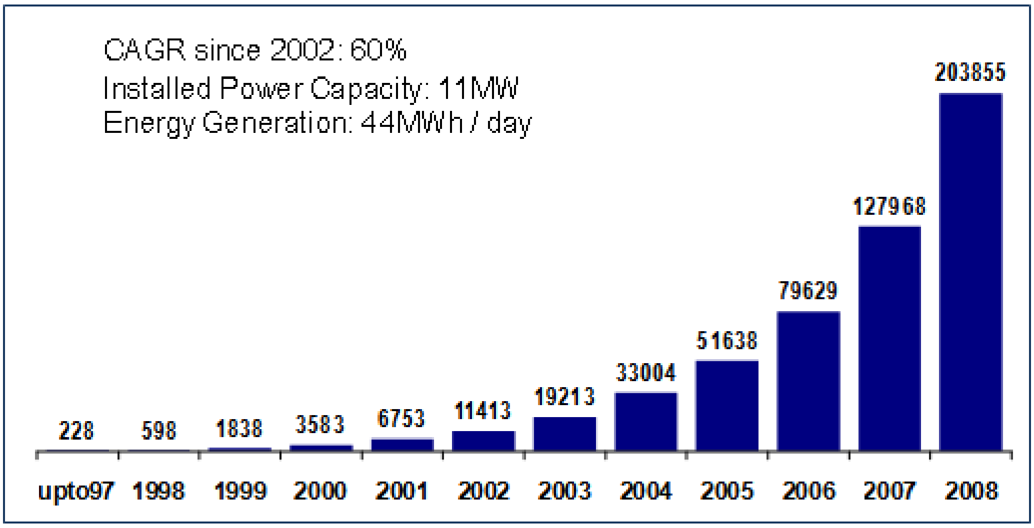
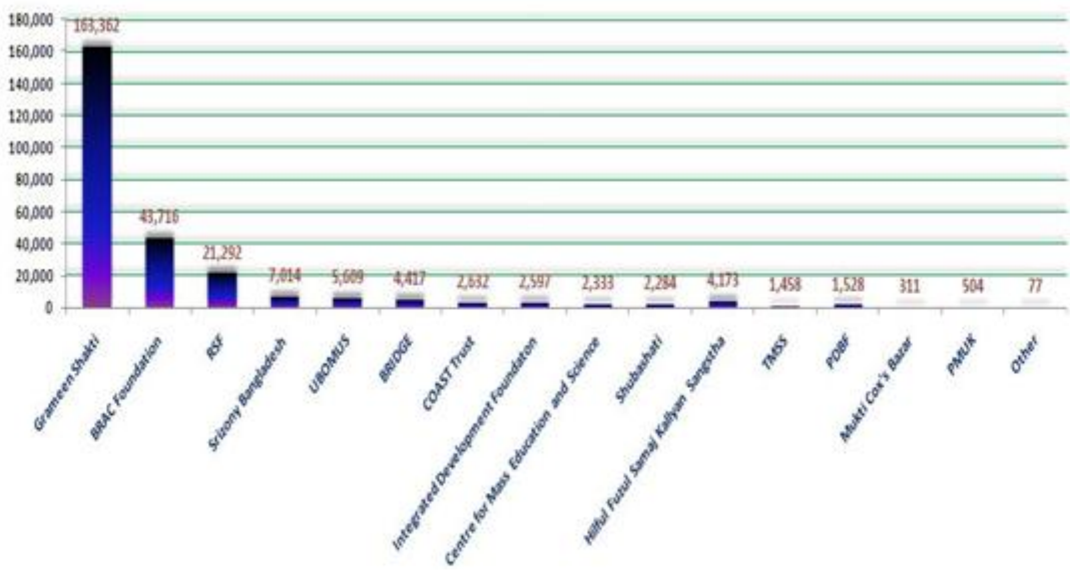


Chart 2: Growth of Solar Users

According to the above graph, up to 2008, cumulatively more than 0.2 million solar home system has been installed in rural areas of Bangladesh. According to Grameen Shakti, solar home system (SHS) is very popular in market place as micro utility.50 Watt systems can rent lights to 3 more shops. Also, SHS helps to replace kerosene. A 40 watt system can replace about 20 Tk. kerosene cost per day. Average installments are per month Tk515.

To promote solar energy among rural people, different organization such as Brac, RahimAfrooz is coming forward with SHS program. Following graph shows the number and name of organizations installed solar system in different areas[29]



3.9 Market Share of Solar Energy Providers

With a view to developing renewable energy resources to meet 5% of total power demand by 2015 and 10% by 2020,Bangladesh government has already declared solar panel as duty free in the upcoming budget of 2009-2010.Government in every year has been providing facilities so that people can use solar energy. Following graph shows the number of SHS installed in different divisions of Bangladesh up to December 2008. Thus, though not million or billions of SHS yet, current number of SHS installation is providing backup to the current power demand as the country's population is increasing

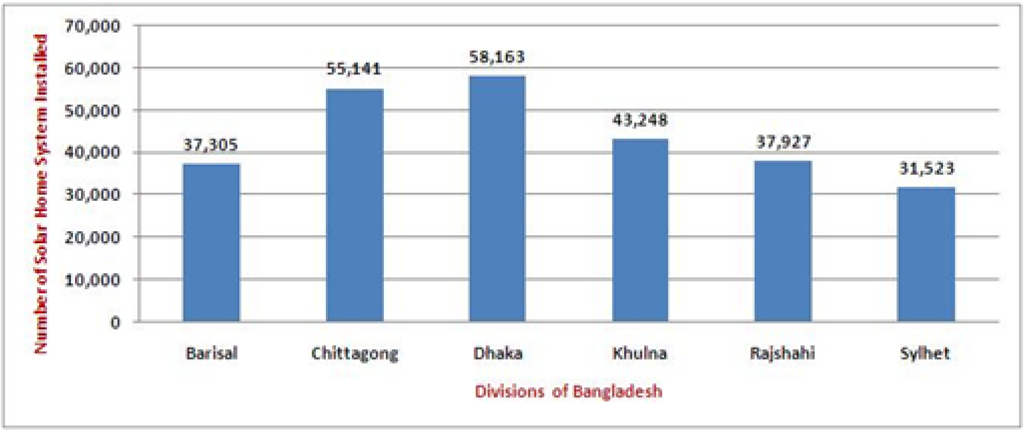


Chart 4: Division wise installations of SHSs (21 December 2008)

From the above graphs, it is clear that, using solar energy is getting importance and day by day, the number of installation is increasing .Dipal Chandra Barua, managing director,Grameen Shakti said that, it is his dream to empower 75 million people through renewable energy technologies and Grameen Shakti has selected its vision for 2015 which includes a whopping 7.5 million solar home system to be installed and a massive 100,000 green jobs to be created[30]

Further growth in the solar energy sector has a great impact on the present power system in Bangladesh. Solar power system is lessening the burden on gas, fulfilling country's power demand and decreasing the amount of other resource consumption such as kerosene. Solar power can be used to electrify computer centres and other workplace also. Solar power is harmless for environment and human being. Thus the further growth of solar system may reduce this massive load shedding by providing harmless continuous energy supply. If not full, the solar energy system installation can meet almost half of the electricity demand in Bangladesh which is the urgent need for the country. Another thing is, solar energy is renewable means as sun is not a miser in disseminating its light. Thus there will be no shout for electricity one day if our country can implement a Solar Bangladesh Concept as Mr. Dipal Barua's dreams will come true.

3.10 Recommendation of solar energy in Bangladesh

Providing electricity for meeting lighting needs of households and rural markets can bring several positive impacts including improvement of quality of life and increasing in income and employment opportunities. So, rural electrification through solar energy is a model to the users is that they are free from the responsibility of maintaining the system. The risk of the whole system has been avoided with the involvement of local community in management. Demonstration of solar energy system has been successful to create interest among the rural people and demand from other location also observed.

Following are the recommendations that might be applied for smooth growth of rural electrification through solar energy:

- Rural people in Bangladesh are not aware of the solar energy technology. Therefore demonstration is necessary to reach the information to this group.
- Appropriate financial arrangement is necessary for the rural people to afford the system. This may include payment in installment, fee for services and other suitable modes.
- Users training has great impact as the users can do trouble shooting of minor problems like replacing fuse, adding distilled water, replacing bulbs etc. This may avoid technician call and increase system reliability.
- Solar systems with different options should be available to the consumers so that they can choose themselves according to their demand.
- Technician training is essential for ensuring the local technical support as well as to make the project sustainable.
- Women also should be invited for training, as they are the main users of the systems.
- They can also pay attention for maintenance.

CHAPTER FOUR

Sandwip 100 kW Solar Mini Grid Island

4.1 About Sandwip

It is situated at the estuary of the Meghna River on the Bay of Bengal and separated from the Chittagong coast by Sandwip Channel. It has a population of nearly 350,000. There are as many as fifteen different wards, 62 mahallas and 34 villages on Sandwip Island. The entire island is 50 kilometers long and 5-15 kilometers wide. It is located at the north-eastern side of The Bay of Bengal, nearby the main port city of Chittagong. It is bounded by Companiganj on the north, Bay of Bengal on the south, Sitakunda and Mirsharai, and Sandwip Channel on the east, Noakhali Sadar, Hatiya and Meghna estuary on the west. About three hundred ships of salt per year were loaded for export from Sandwip's port. It also had a shipbuilding industry. The Turkish president Solaiman Demirel came to Chittagong in 1994 and imported a gun ship from Sandwip port.[31]

Fig 4.1: Sandwip Upuazila, Chittagong, Bangladesh

4.2 Description about Sandwip 100 kW Solar Mini Grid Island

The Sandwip Island, has a population of 400,000, is detached from Chittagong mainland by a channel of about 75 kilometers. Located along the south eastern coast of Bangladesh, the island is 50 kilometres long and 5.15 kilometres wide. There are 15 unions in Sandwip.Because of its position and inaccessibility there is no possibility of grid electrification service in this area in the distant future. Sandwip is an upazilla with very high literacy rate and remittance earnings from the United States and Middle Eastern countries.

The island, however, has a dynamic population with various public and private service offerings providing support to the general public including educational institutions, health service centers, small and medium enterprises, etc. Despite shortage of reliable and consistent supply of electricity, use and willingness of use of various loads have been found in this region i.e. computers, printers, scanners, photocopy machine, refrigerators, color television, etc.

At present, the electricity demand of general shops in the markets of Sandwip are served by diesel micro-grid run by several diesel generator operators who provide services for about 5 to 8 hours per day. Besides, several diesel generators are used by several shop owners for captive consumption. Average tariff rate being charged to the customers by the diesel operators currently range between BDT 53 per kWh[1] and BDT 60 per kWh. Bangladesh Power Development Board also has diesel generator that supplies electricity to mainly government offices.

Several non-government organizations (NGOs) have been providing off-grid electrification solution in the household levels through 'solar home system[2]' units in Sandwip under a program run by state-owned financial institution named Lighting Rural Bangladesh "LRB". LRB was established by the Government of Bangladesh to catalyze the development of private sector infrastructure and renewable energy project. [32]

Observing the demand patterns in the commercial areas, the NGOs came up with an idea of installing a 100-kW solar based power station in an optimal location from where electricity will be dispatched through a distribution line. Construction of such a system would cost at least BDT 5

[1] kWh, kilowatt-hour, is a unit of energy equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time.

[2] Solar home system is a small power unit(ranging between 10 Wp to 130 Wp) consisting of solar PV module, battery, charge controller installed in a household for running different loads e.g. lights, DC fan, black and white TV.

crore and the consortium of the NGOs could afford up to 20% of the project cost. The NGOs recognized that the Project would require extensive concessionary financing support and technical assistance.

When shared the project idea with LRB, it expressed its interest to extend soft loan and arrange grant support for implementing the Project. As per its lending policy, LRB could extend 10 years loan with a grace period of 2 years at an interest rate of 6% per annum and only interest is required to be paid during the grace period. The construction period of the Project is expected to be only 4 months.

The NGOs formed a Project Company called PGL for implementing the Project with individual shareholding. It has been decided that PGL will inject the equity first and will start the construction works. The expected financial closing of in the Project has been planned on 31 December 2012 and the expected drawdown of the loan will be as shown the following table:

	30-Jan-13	**28-Feb-13**	**28-Apr-13**
Percentage of drawdown	**20%**	**40%**	**40%**

LRB decided to require the loan to be repaid semi-annually following annuity method.

Later, LRB approached one of its multilateral financing sources and one of them agreed in-principal to extend the required grant support. The grant amount would be up to the amount required for making the Project financially viable. However, it cannot exceed 40% of the project cost.

Now, the challenge has been turned out to be identifying the customer base with stable demand pattern, identifying the project location, and designing an optimal mix of debt, equity and grant ensuring the viability of the Project and suitable return to the project sponsors.

After rounds of survey for electricity demand in different areas, five adjacent areas have been found to have stable demand pattern. The areas are Enam Nahar Market, Malekmunsir Bazar, Khontarhat, Panditerhat, and Boktarhat.Three categories of potential customers have been identified for supplying electricity in these areas as mentioned in the following table:

Customer	**Total number of potential customers**	**Total number of targeted customers**
Small shops	478	390
Health care	5	5
Schools	5	5

Currently there are about 11 diesel generator operators supplying electricity to the proposed project areas during day and night hours at prices ranging between Tk. 52.6/kWh and Tk. 73/kWh.

When interviewed, the potential customers expressed a great deal of interest for availing the electricity connection immediately. 70% of the targeted customers have been expected to be acquired in the first year and the remaining 30% in the second year.

Total electricity consumption among the targeted areas was studied to be 137,977 kWh of which 110,125 kWh was estimated to be sourced from solar energy source. The remaining portion of the demand will be served by diesel generator.

The Project will produce electricity through solar micro-grid. The solar PV modules are the main power generation system that is operational during daytime. The other main equipment and accessories include inverter, diesel generator, batteries. About 60 kW of the PV modules will be directly connected to 6 mini central inverters which will convert from DC[3] to AC[4] power at 220V and supply to the micro-grid distribution line at all times. Three phase configuration of the AC distribution line will be configured through the multi-cluster box, which is the interface for all connectors and control. The unused portion of the power in the distribution line will be stored into the batteries through 12 bidirectional inverters in 4 clusters. During daytime additional 40 kW PV power will be stored into the same battery bank through DC battery chargers. When the grid power is not available, mainly during evening hours, the plant will use power from the battery bank. During the periods of lesser solar radiation, and on cloudy days, backup power will be provided by the 40kW diesel generators.[32]

Tariff would be charged in the form of one-time connection fee and regular electricity tariff. The electricity tariff will be set at Tk. 35 per kWh. The connection fee will vary depending on the type of the customer as shown in the following table:

Customer type	Connection Fee (BDT)
Small shop	4,000
Health centre	6,000
School	6,000

The electricity tariff is expected to be increased by 5% from the third year of operation.

The full technology of the Project will be supplied by ABC Systems on a turnkey basis. As per the arrangement, ABC Systems will procure, install and commission the Project and after implementation, will hand over the Project to PGL. ABC Systems will also provide technical assistance during the first year of operation and will train the technical team of PGL. The equipment would cost about BDT 4.25 core. ABC Systems will charge a technical assistance fee of BDT 28.66 lac. The transportation costs have been assumed to be BDT 7.25 lac and other accessories will cost about BDT 33.5 lac.

The O & M cost of the Project in the first year has been estimated to be 1% of the project cost excluding technical assistance fee, which is BDT 4.76 lac. The O & M cost is expected to increase by 5% per year from the second year onwards. The annual insurance cost will be BDT 95,000. Per unit diesel requirement was identified to be BDT 0.17 liter/kWh and diesel price was BDT 45 per litre. Price of diesel has been expected to increase by 5% per year.

The economic life of the Project is estimated to be 20 years. The battery bank, however, is to be replaced in 7^{th} and 13^{th} year at a cost of BDT 1.12 core. The technical assistance fee is to be amortized in five years.

The applicable income tax rate would be 37.5%. There is, however, provision for tax holiday of 15 years for encouraging power generation in the private sector.

Recognizing the economic value of the Project, LRB is looking for a minimum IRR of 9.00% and minimum NPV of BDT 2 crore.PGL, however, expects to receive an equity IRR of 20%.

As a thumb rule, LRB allows minimum DSCR to be 1.2x. In this case, the DSCR could go down as low as 1.17x.With the cost of equity being 9%, the weighted average cost of capital (WACC) has been found to be 4.5%. LRB and PGL decided to use the WACC as the discount factor for calculating NPV. Consider 360 days in a calendar year.

4.3 Over view of 100 KW solar mini grid project at a glance

Name of the Projec : 100 kW Solar Mini Grid, Enamnahar , Sandwip, Chittagong

Project Area : 0.6 Acre

Project Cost : BDT 57.71 Million

Financed By : IDCOL, kfW-Germany and World Bank

Loan 30% : Tk 17.31 Million

Grant 50% : Tk 28.86 Million

Equity 20% : Tk 11.54 Million

Proposed Electricity Supplied Area : Enamnahar Bazar, Malek Munsir Bazar, Khontar Hat & Ponditar Hat.

Proposed Length of Distribution Line : 4 kilometer

Proposed Number of Consumers : Commercial Shop- 390, Health Center- 5 & School- 5

Technical Assistance : Prokaushali Sangsad Limited (PSL), Dhaka, Bangladesh

Technology Supplied : Energy Systems (BD) Ltd, Asantys Systems (Germany)

Hardware Details : Solar Module- Kyocera , Inverter- SMA Solar Technology AG, Germany Battery- Hoppecke, Germany

Introducing PGEL Management :

Asma Huque, Chairman
Johirul Alam, Managing Director
Bimal Kumar Chandra, Director
Alauddin Ahmed, Director
Didarul Alam, Director

4.4 Sandwip Solar Plant Technology in Bangladesh

The system design is based on AC-coupled bus concept. The main idea is to provide direct solar energy to the consumer via an AC bus through converters, when the converter energy (radiation) meets with the energy demand. Surplus will be charged via a so called "sunny island" charger into the batteries.[32]

The size of the solar micro-grid project under consideration is 100 kW accompanied by 40 kW Diesel. The solar micro-grid is given in Figure 4.2, which is a combined operation of several sub-systems.

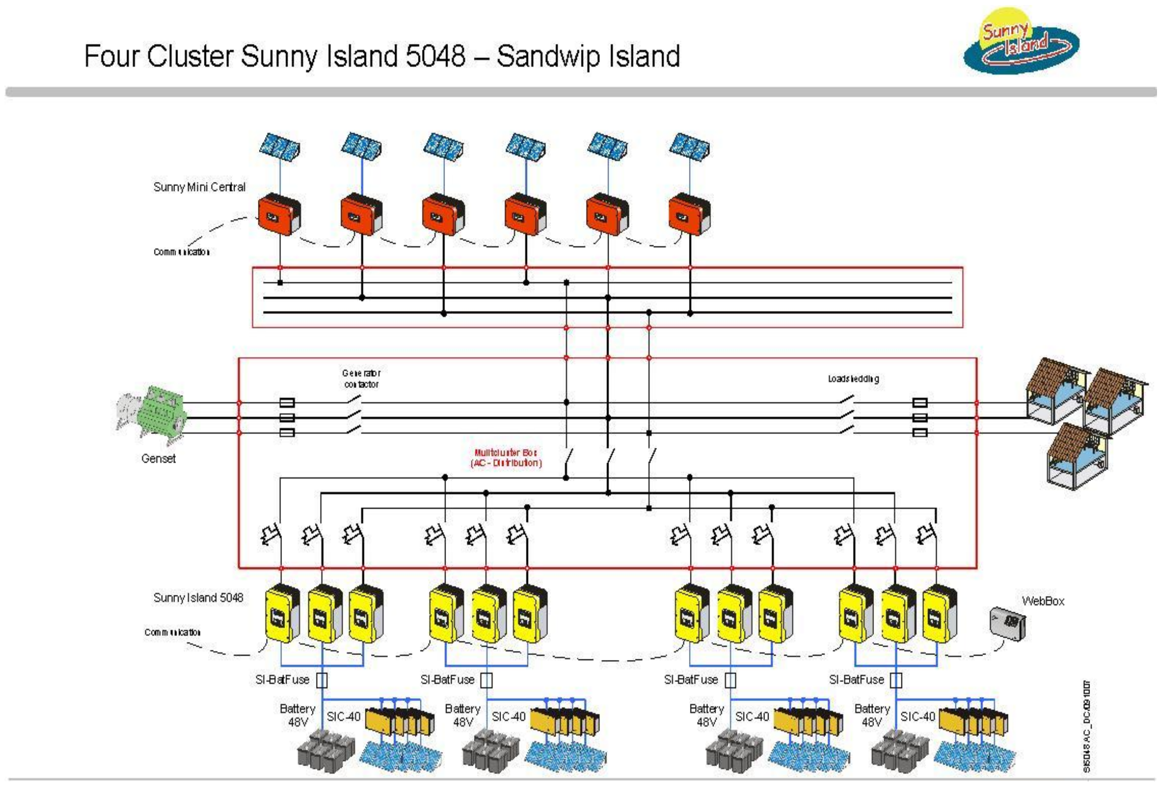


Figure 4.2 Solar Micro Grid Layout using Four Cluster Sunny Island

4.4.1 List of major Equipments

Table 4.1 : major Equipments list

Equipment	Supplier	Country of Origin
Photovoltaic Module	Kyocera	Japan (Assembled in China)
Inverter	SMA Solar Technology AG	Germany
Battery	Hoppecke	Germany
Grid Inverter	SMA Solar Technology AG	Germany
Sunny Web box & Battery Fuse	SMA Solar Technology AG	Germany

4.4.2 Supplier Details

SMA solar Technology AG.SMA is world's largest producer in this segment and has a product range with the matching inverter type for any module type and any power class. This applies for grid tied applications as well as island and backup operation. The Sunny Mini Central produced by SMA already has an efficiency of over 98%, which allows for increased electricity production. SMA's business model is driven by technological progress. Due to its flexible and scalable production, SMA is in a position to quickly respond to customer demands and promptly implement product innovations. This allows the Company to easily keep pace with the dynamic market trends of the photovoltaic industry.

Kyocera is one of the leading PV module suppliers of the world. In IDCOL Solar Home System Program more than 80% modules are supplied by Kyocera and the performance of these modules is quite satisfactory.

Hoppecke is one of the leading battery manufacturers in Germany. This company has been developing and producing batteries since 1927.HOPPECKE is now the specialist for industrial battery systems, and at the same time the largest manufacturer in European ownership.

4.4.3 Description of Major Equipments

a)Photovoltaic (PV) Module:

The PV Module is polycrystalline and highly efficient. There will be 324 nos. of 200Wp and 240 nos. of 135 Wp PV Modules. The PV Module is expected to be procured fromKyocera.

The major features of the proposed PV module model KC200GH-2Pare as follows:

Particulars	Model KC200GH-2P
Maximum Power (Pmax)	200Wp (+10%/-5%)
Maximum Power Voltage (Vmp)	26.3V
Maximum Power Current (Imp)	7.61A
Open Circuit Voltage (Voc)	32.9V
Short Circuit Current (Isc)	8.21A

b)Inverter:

Inverters used in the Project will be of two types:

i) Grid inverter

ii) Inverter

i) **Grid Inverter:**

It consists of the following:

- Multi cluster box
- Bidirectional Inverter
- Battery Main Switch

c) Multi Cluster Box:

There will be 1 no. of multi cluster box. The model used is SMA MC Box-12.3 Option Code 30001 (include:3: 4 Multicluster Piggy- Back RS485 and CAN Bus).

c.1) Major Features:

- 3-phase Multicluster-Box for the easy installation of stand-alone and hybrid systems with Sunny island 5048 up to a power range of 110 kW.
- Completely wired and equipped with a main connector for PV and wind turbine systems.
- Connection for a maximum of 4 clusters consisting of three SunnyIsland 5048 devices each.
- Integrated generator and load-shedding contactor.
- The communication cables necessary for the installation are included

d)Bidirectional Inverter:

There will be **12 nos. of bidirectional inverter. The model used is SMA SI 5048** Option Code 0031.

d.1) Major Feature:

- Bi-directional battery inverter for setting 3-phase stand-alone systems
- Modularly extendable
- Multicluster operation
- High efficiency
- Intelligent battery management for maximum battery lifetime
- Charge level calculation
- Excellent overload capability
- Integrated display and control panel
- Integrated protective functions, DC fuse
- Output: short-circuit proof
- Operating temperature range: -25 °C ... +50 °C
- Continuous charging current of the battery at 25 °C for 100 A battery type: lead NiCd, battery capacity 100 - 10,000Ah

i)Battery Main Switch:

There will be 4 nos of battery main switch and the model used is SMA BATFUSE-B.03 Option Code 30. The main features are as follows:

- 1-pole NH 1 battery fuse as a load disconnecting switch for up to 3 SunnyIslands
- 6 DC input ports (2 x Battery an 4 x Sunny Island Charger)
- 1 x auxiliary voltage output with 8.6 x 250
- A fuse plug with 6 additional replacement fuses for SunnyIsland 5048

ii)Inverter

There will be **6 nos. of inverter. The model is SMA SMC 11000TL-11** Option Code 8000x1

ii.a) Main Features:

- Inverter for the feeding-in of solar electricity into the low-voltage grid in grid-parallel operation
- Transformer-less with all current sensitive failure current monitoring unit
- Opti-Cool cooling concept - maximum output up to 40°C ambient temperature
- Integrated display; suitable for indoor/outdoor mounting
- SMA Grid Guard grid monitoring
- Electronic Solar Switch (ESS) circuit-breaker: integrated protective functions
- Input: thermally monitored varistors, ground fault monitoring, reverse polarity prevention via short-circuit diode
- Output: short-circuit proof (current regulation).

e) Charger (DC)

There will be 16 nos. of chargersof Model: SMA SIC 40-MPTOption Code 000. Main features of the charger are as follows:

- MPP solar charge controller.
- Automatic regulation and single point of operation from SunnyIsland
- Up to four devices can be connected in parallel, modularly extendable, active MPP tracking, efficiency > 98 %, suitable for indoor and outdoor installation due to IP65, fanless. Integrated protective functions: short-circuit / reverse polarity / overload / excessive or insufficient voltage / overheating and undercooling; operating temperature range: - 25°C … +60 °C;
- Battery type: lead;charge control IuoU process

f) Sunny Web box &Battery Fuse (Communication Kit)

There will be one communication kit of model SMA Sunny WebBox Option Code 2001. The main features are as follows:

- Multi-functional data logger and communication center for setting parameters
- System monitoring, remote diagnostics, archiving data and visualization of up to 50 inverters
- The data is automatically transferred to Sunny Portal if desired
- The Sunny WebBox is easily operated using a web interface
- The data is accessed using a SD card or the integrated FTP server

g) Deep Cycle Industrial Battery

System requirement 48V, of 12000 Ah total will be met with series and parallel connection of 2V of 96 nos. of industrial batteries. Battery banks with tubular plate industrial batteries of 48 Volt (made up of 2V units) 12000 Ah total is proposed for 100 kW PV system. Due to the tubular configuration of the positive plate, these batteries are designed to withstand deep discharge and have a longer life. The proposed batteries are manufactured in Germany, with a service warranty of 10 years. Technical Specifications of the batteries are given below.

Rated Voltage	: 2V
Battery Capacity	: 3000Ah@10hr
Plate Type	: Positive Plate Tubular
Brand	: HOPPECKE

Diesel Generator

40 kW Diesel generator will be used. The model will be selected later.

h) Tariff Comparison

Table 3.2 the average tariff rate being charged by these existing operators are as given below:

Diesel generator operators	Average tariff rate (BDT per kWh)	Average tariff of the diesel generator operators (BDT per kWh)	Effective tariff of the Proposed Project (BDT per kWh)
Operator-1 Brothers Computer	52.60	64.91	30.52
Operator-2 Ripon	66.21		
Operator-3 Bazar Committee	72.83		
Operator-4 Laik	72.83		
Operator-5 Afsar	60.09		

Table 3.3 Project Debt Facilities

Facility	Amount (BDT million)	Interest Rate	Tenor	Grace	Repayment
Term loan	17.31	6% p.a.	10 years	2 years	Annuity; In 16 (sixteen) semi-annual installments

i) Operating Expenses Assumption

Expenses of the Project include the following:

- Utility
- Salary and allowances
- General and administrative expenses
- Insurance cost

4.5 Utility expenses:

Diesel and lubricating oil will be required to run the diesel generator. Pricing and requirement of these are as follows(calculation follow):

A general 5% cost escalation has been considered in each of these cost items.

4.6 Salary and Allowances:

5% yearly increment has been considered for each of the employees

Table 4.6: Depreciation and Amortization

Depreciation	**No of years**	**Rate**
Plant, Machinery & Equipment	20	5%
Building and Civil Construction	20	5%
Battery	7	14%
Amortization		
Technical assistance	5	20%

4.7 Total project cost

Total cost of the proposed Project has been estimated to be BDT 57.71 million.

Table 3.7 Budgeted Project Cost in Sandwip

Particulars	**Project costs in TK**
Land and Land Development	1258078
Civil Construction	2400736
Equipment	
-Solar Modules (100 kW)	
-Grid Tie, SI Inverter	
-Backup Diesel Generator – 40 kW	
-Accessories	
-Batteries – 48 V, 18000 Ah	
	38348295
Transportation	727146
Distribution & Others	
-Distribution Line (5 km)	
-AC Household Meters	
-Control Room, Structure & Others	
	2850874
Import Duty & Clearance Cost	7404193
Technical Assistance	3133653
Contingency (3% of capital cost)	1587025
TOTAL PROJECT COST	**57710000**

CHAPTER FIVE

Result and Discussion

5.1 2012 daily diesel use in liter in sandwip and per unit cost

The Sandwip Island, has a population of 400,000, is detached from Chittagong mainland by a channel of about 75 kilometers. Located along the south eastern coast of Bangladesh, the island is 50 kilometres long and 5.15 kilometres wide. There are 15 unions in Sandwip.Because of its position and inaccessibility there is no possibility of grid electrification service in this area in the distant future. Sandwip is an upazilla with very high literacy rate and remittance earnings from the United States and Middle Eastern countries. We are calculated 2012 diesel per unit cost and solar individual cost .At last we are get total Sandwip total cost and per unit cost from this project.

Total Diesel Use in May Month= 513 Liter, Running hours=513/9=57 hours
Energy Produce=57*32=1824 KWh, Per liter 70 Tk , So 513 Liter=513*70=35910 Tk
Per Unit Cost =35910/1824=19.68 Tk

Total Diesel Use in Jun Month= 437.4 Liter, Running hours=437.4/9=48.6 hours
Energy Produce=48.6*32=1555.2 KWh, Per liter70 Tk , So 437.4 Liter=437.4*70=30618
Per Unit Cost =30618/1555.2 =19.68 Tk

Total Diesel Use in July Month= 494.55 Liter, Running hours=494.55 /9=50.35hours
Energy Produce=50.35*32=1611.2 KWh, Per liter 70 Tk , So Liter=494.55 *70= 34618.5
Per Unit Cost =34618.5 /1611.2 =21.48Tk

Total Diesel Use in August Month= 474.75 Liter, Running hours=474.75/9=52.75hours
Energy Produce=52.75*32=1688 KWh, Per liter 70 Tk , So Liter=474.75 *70= 33232.5Tk
Per Unit Cost =33232.5/1688=19.68Tk

Total Diesel Use in Sep Month= 235.35 Liter, Running hours=235.35 /9=29.75hours

Energy Produce=29.75*32=952 KWh, Per liter 70 Tk , So Liter=235.35*70=16474.5 Tk

Per Unit Cost =/=17.30Tk

Total Diesel Use in Oct Month= 407.25 Liter, Running hours=407.25 /9=50.75 hours

Energy Produce=50.75 *32=1624 KWh, Per liter 70 Tk , So Liter=407.25*70=28507.5 Tk

Per Unit Cost =28507.5 /1624 =17.55Tk

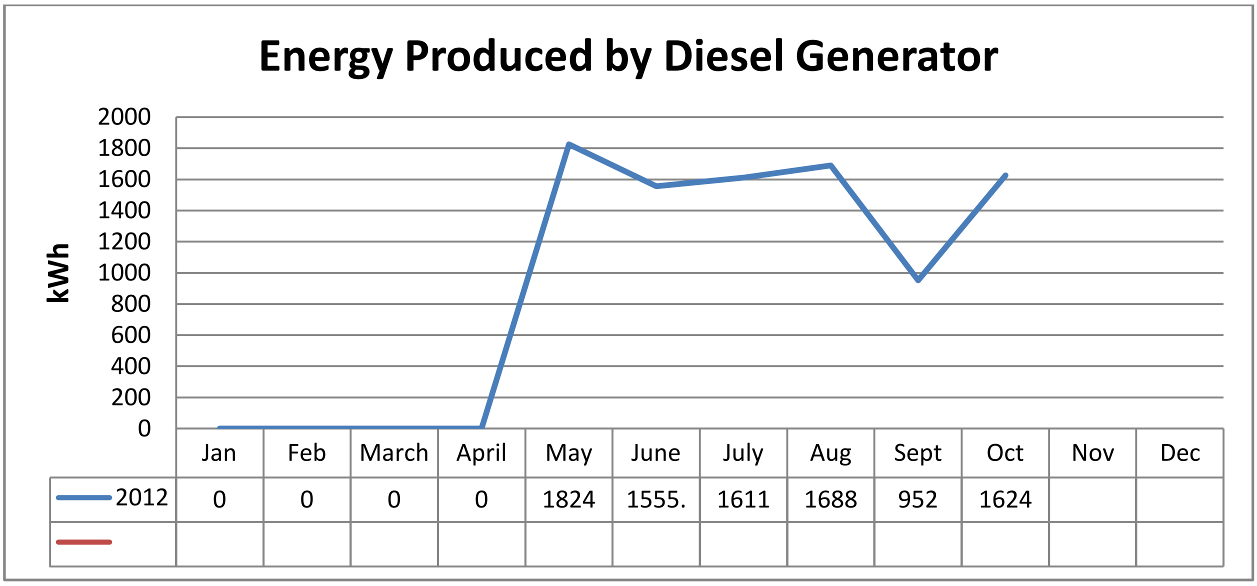


Fig 5.1 energy produced by diesel generator

Table 5.1 fuel cost

Month	May	Jun	July	Aug	Sep
Use fuel in Liter	513	437.4	494.55	474.75	235.35
Energy produce in KWh	1424	1555.2	1611.2	1688	952
Fuel cost, TK/KWh	19.68	19.68	21.48	1968	17.30
Fixed Cost	825000				

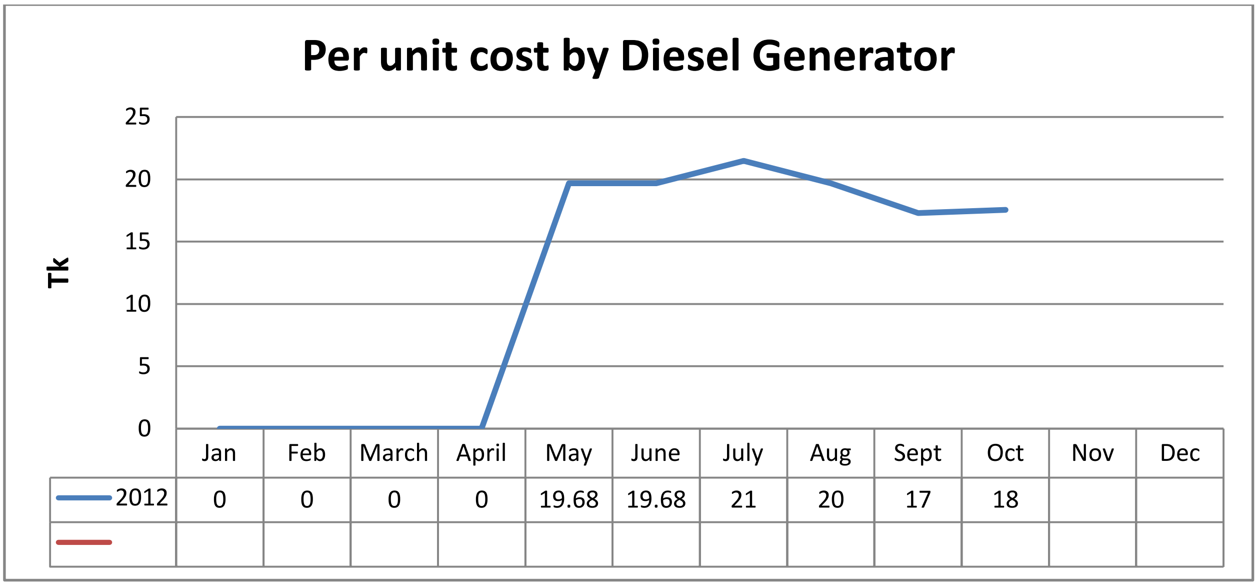


Fig 5.2 per unit cost diesel generator

5.2 Plant factor calculation:

Mar= 11601.93KWh , Apr= 9796.7 KWh , May= 10053.83 KWh, Jun=9842.42KWh

July= 9739.23 KWh, Aug= 12051.75KWh, Sep=7106.32KWh, Oct=5391.4KWh

So, Plant factor for month of Mar=(total KWh/100*total month of day*24)*100

=(11601.93/100*31*24)*100

=15.59%

Plant factor for month of Apr =(total KWh/100*total month of day*24)*100

=(9796.7/100*28*24)*100

=14.57%

Plant factor for month of May =(total KWh/100*total month of day*24)*100

=(10053.83/100*31*24)*100

=13.51%

plant factor for month of Jun =(total KWh/100*total month of day*24)*100

=(9842.42/100*30*24)*100

=13.67%

plant factor for month of Jul =(total KWh/100*total month of day*24)*100

=(9739.23 /100*31*24)*100

=13.09%

plant factor for month of Aug =(total KWh/100*total month of day*24)*100

=(12051.75/100*31*24)*100

=16.19%

plant factor for month of Sep =(total KWh/100*total month of day*24)*100

=(7106.32 /100*30*24)*100

=9.86%

plant factor for month of Oct =(total KWh/100*total month of day*24)*100

=(5391.4 /100*30*24)*100

=7.48%

Table 5.1:Plant Factor,2012

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
PF%	15.59%	14.57%	13.51%	13.67%	13.09%	16.19%	9.86%	7.48%

Plant factor calculation for 2013

January= 9932.84 KWh, February=8896.08KWh, Mar= 10115.2 KWh ,

Apr=13268.95 KWh , May= 8091.5 KWh, Jun=12098.46KWh , Sep= 11898.46KWh

Month	January	February	Mar	Apr	May	Jun	Sep
PF%	13.35	13.29	16.21	18.42	12.48	16.80	16.52

Plant Factor,2013

In the above table shown that Plant Factor for 2012 and 2013.In the primary position 2012 for the Solar Plant in Sandwip Plant Factor was not Satisfactory But recent year 2013 Plant factor increase more and satisfactory. It is the great Important factor for the Solar Plant in Bangladesh

5.3 Per unit Sandwip solar plant calculation:

100 KW Solar Plant in Sandwip

Total Cost = 57710000 TK

Total Generation =100KW*365D*25yr*5.5h*0.8

=4015000 KWh,

Per unit Generation cost

=57710000/4015000

= 14.37TK

Plant Capacity =Solar +diesel (back up)

=100KW+40KW

=140KW

Max Demand =0.1

Average Load =Max Demand*Plant Capacity

=0.1*140

=14KW

Energy produce Per Year

=14*8760

=122640 KWh

Total project Cost =5771000 TK

Interest and Depreciation

=6.7%

=(6.7/100)*57710000

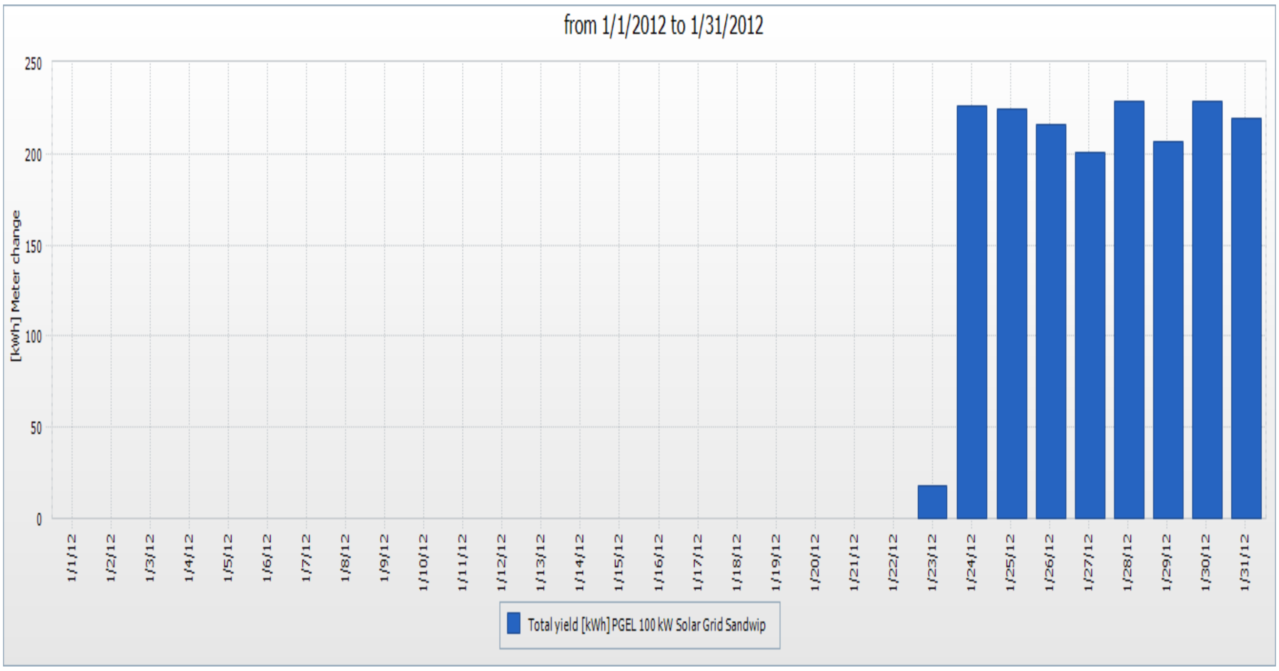
=3866570 Tk

Energy cost per KWh

=3866570/122640

=31.53 Tk

2012 daily energy yield (kWh) with curve month of Jan



2012 daily energy yield (kWh) with curve month of Feb

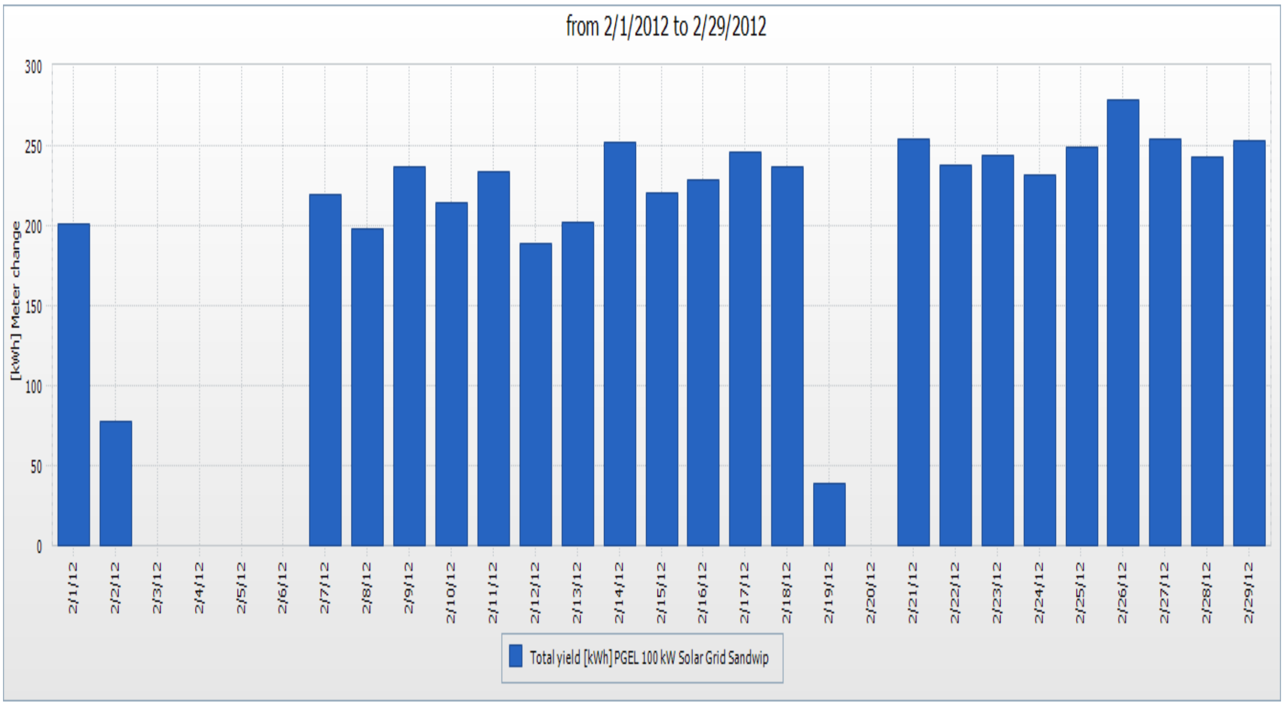
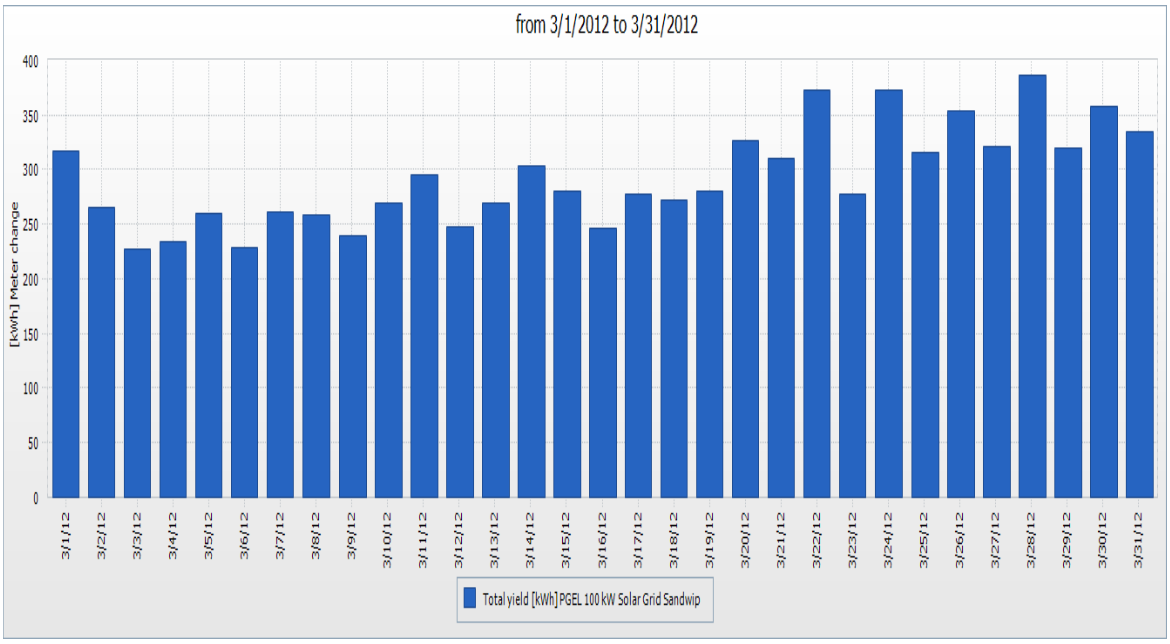


Fig 5.3 :2012 daily energy yield (kWh) with curve month of Jan,Feb

2012 daily energy yield (kWh) with curve month of Mar



2012 daily energy yield (kWh) with curve month of Apr

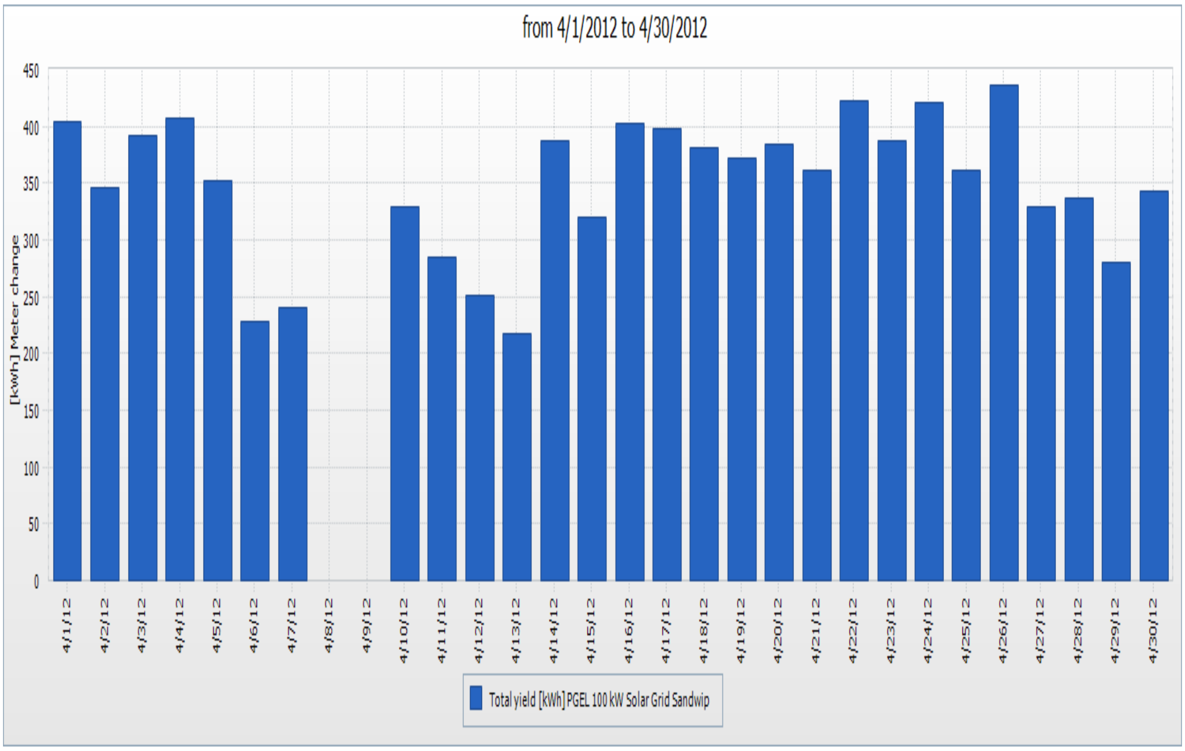
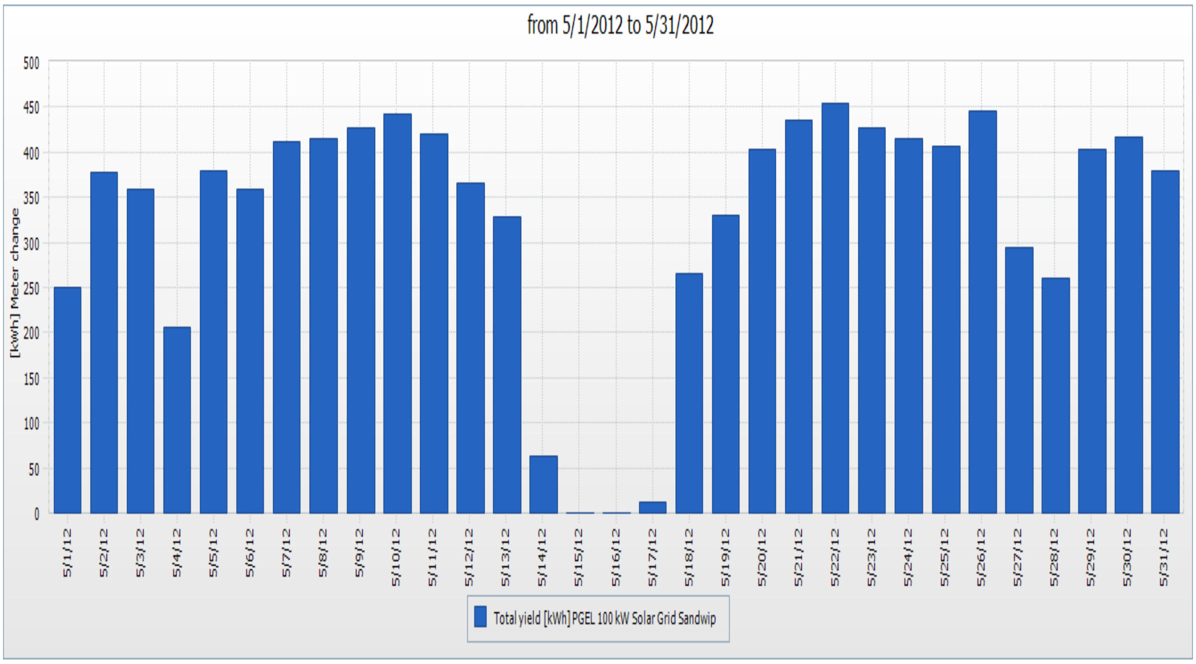


Fig 5.4 :2012 daily energy yield (kWh) with curve month of Mar,Apr

2012 daily energy yield (kWh) with curve month of May



2012 daily energy yield (kWh) with curve month of Jun

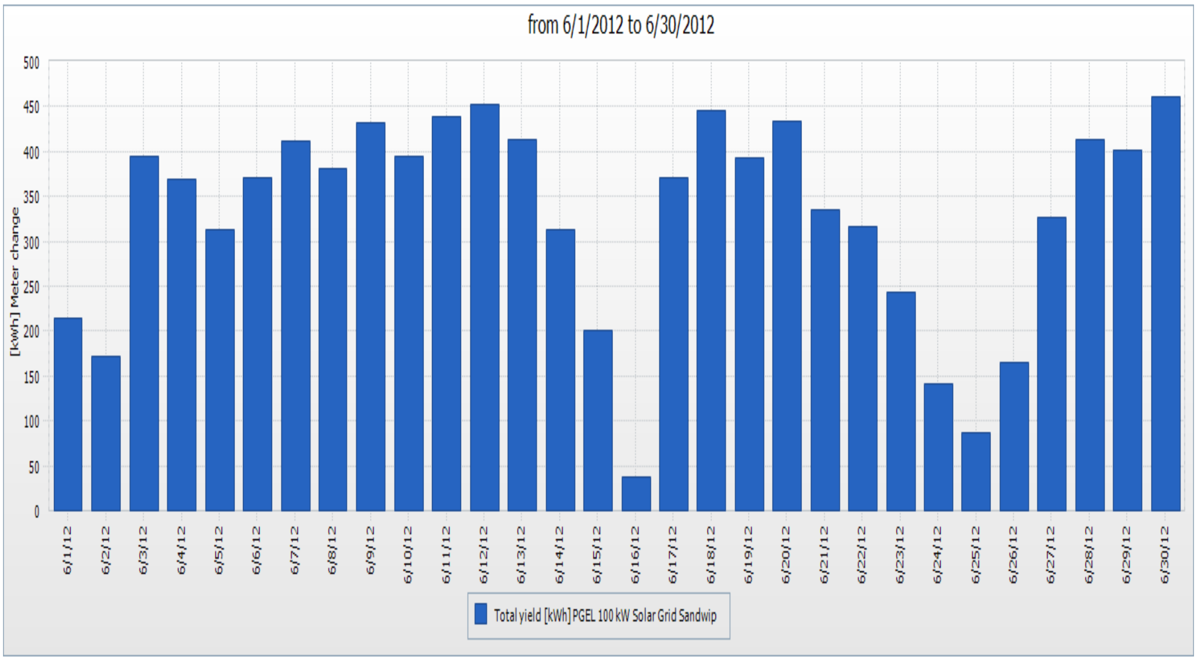
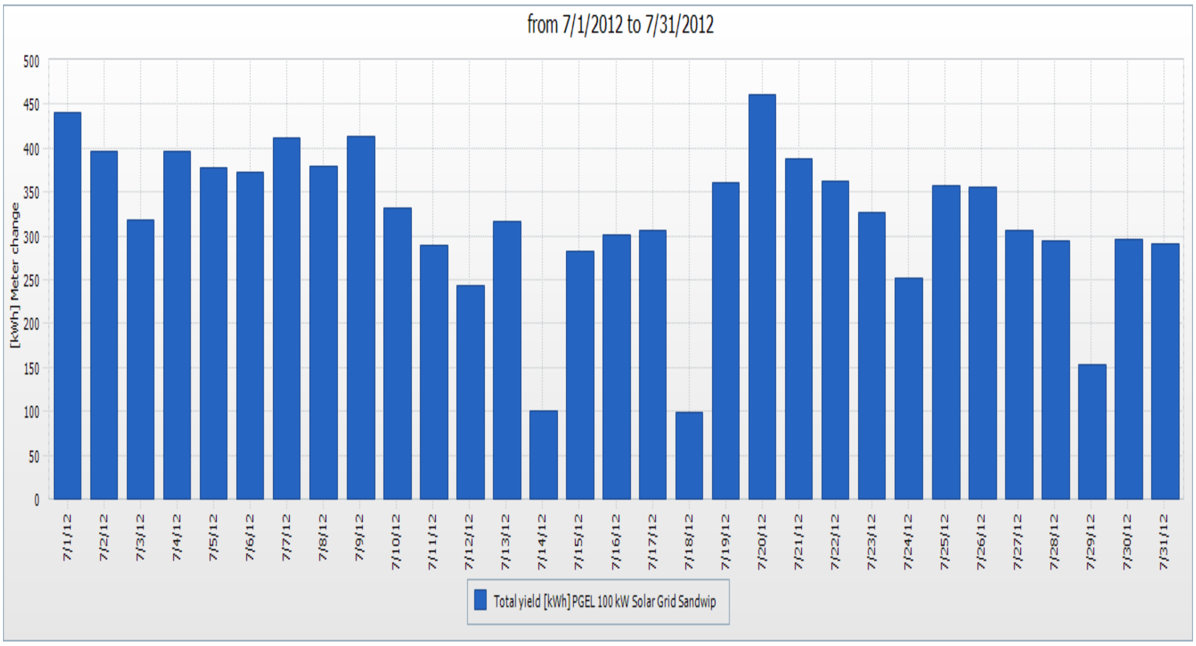


Fig 5.5 :2012 daily energy yield (kWh) with curve month of May,Jun

2012 daily energy yield (kWh) with curve month of July



2012 daily energy yield (kWh) with curve month of Aug

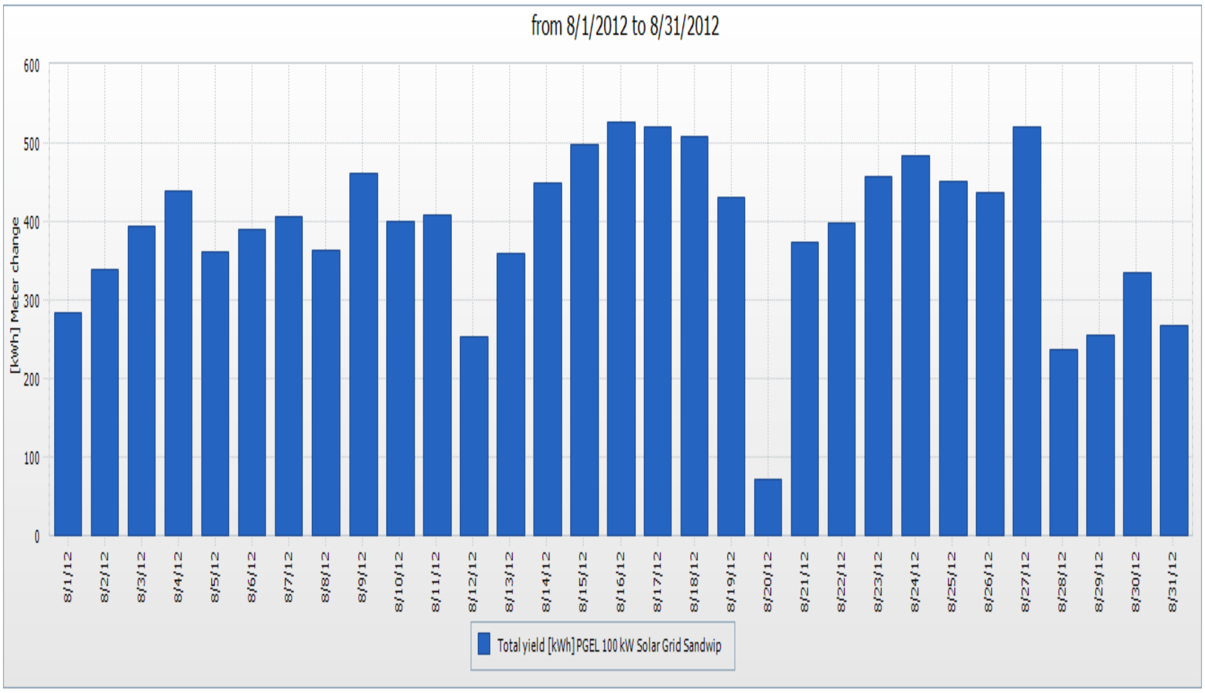
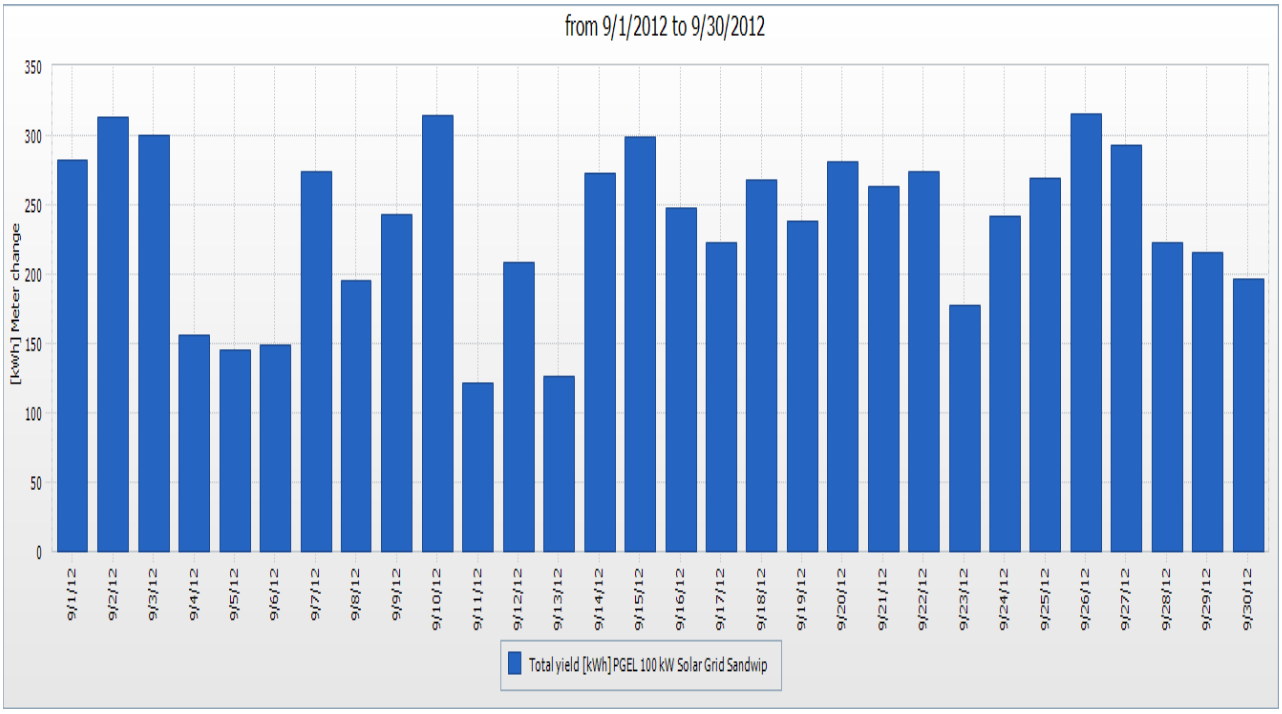


Fig 5.6 :2012 daily energy yield (kWh) with curve month of July,Aug

2012 daily energy yield (kWh) with curve month of Sept



2012 daily energy yield (kWh) with curve month of oct

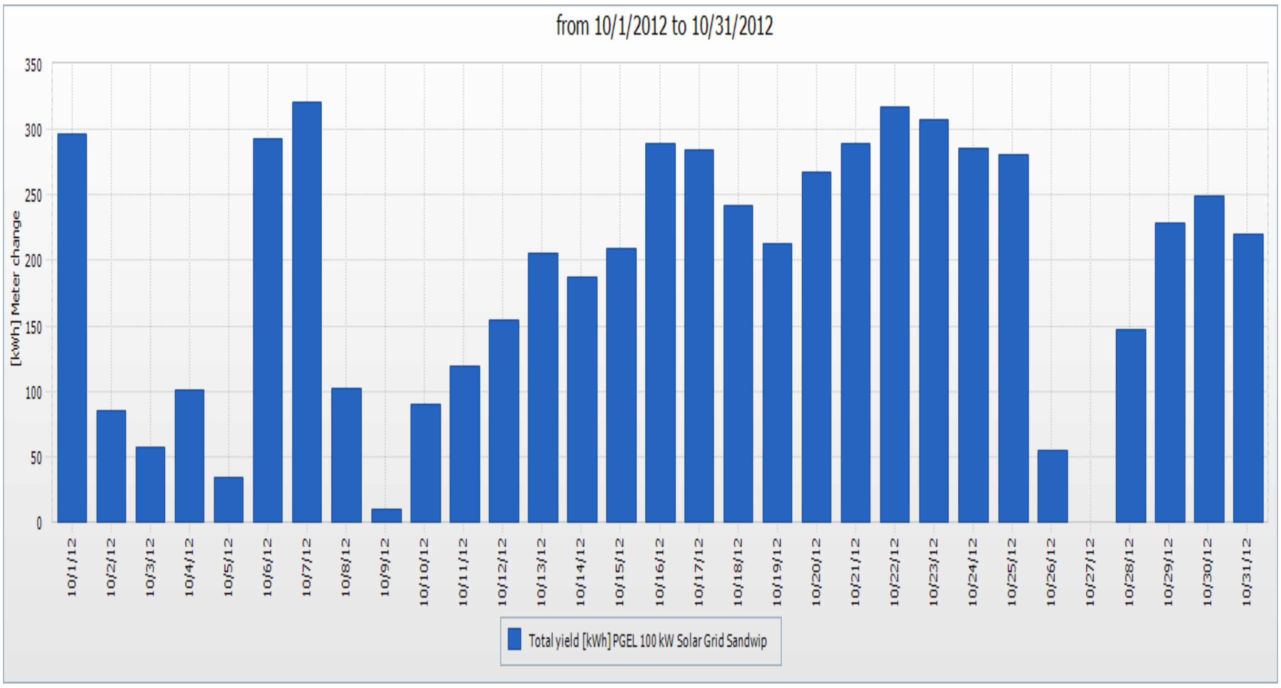
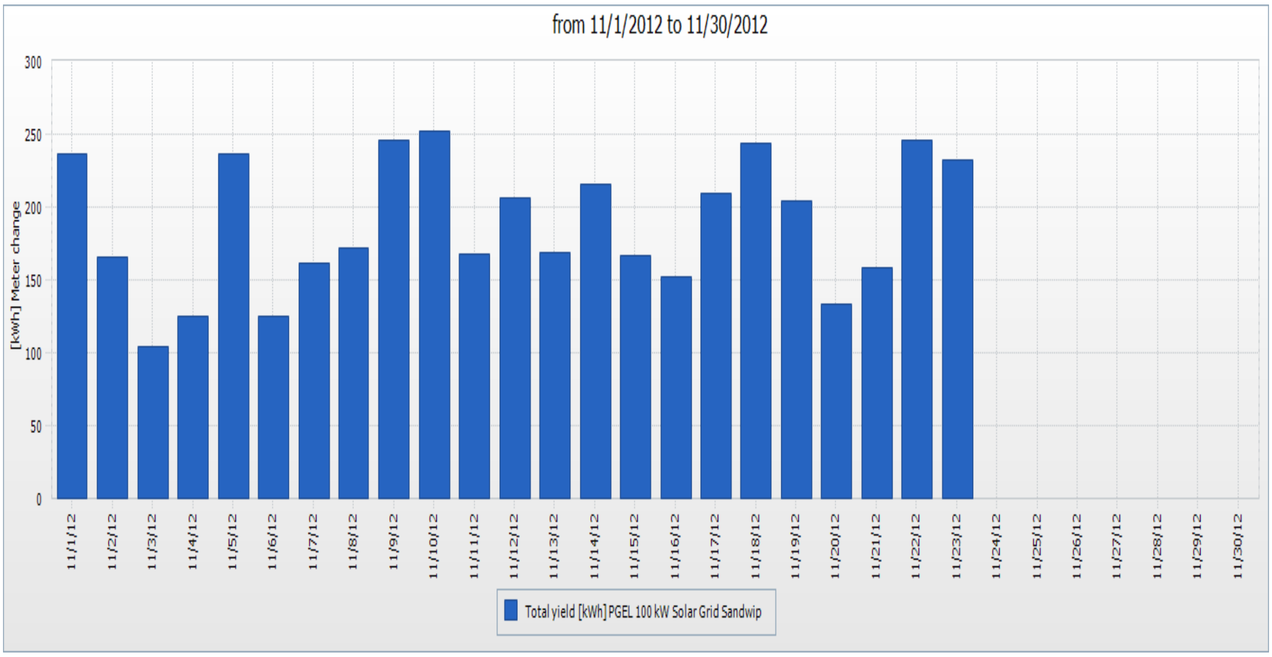


Fig 5.7 :2012 daily energy yield (kWh) with curve month of Sep,Oct

2012 daily energy yield (kWh) with curve month of Nov



2012 daily energy yield (kWh) with curve month of Dec

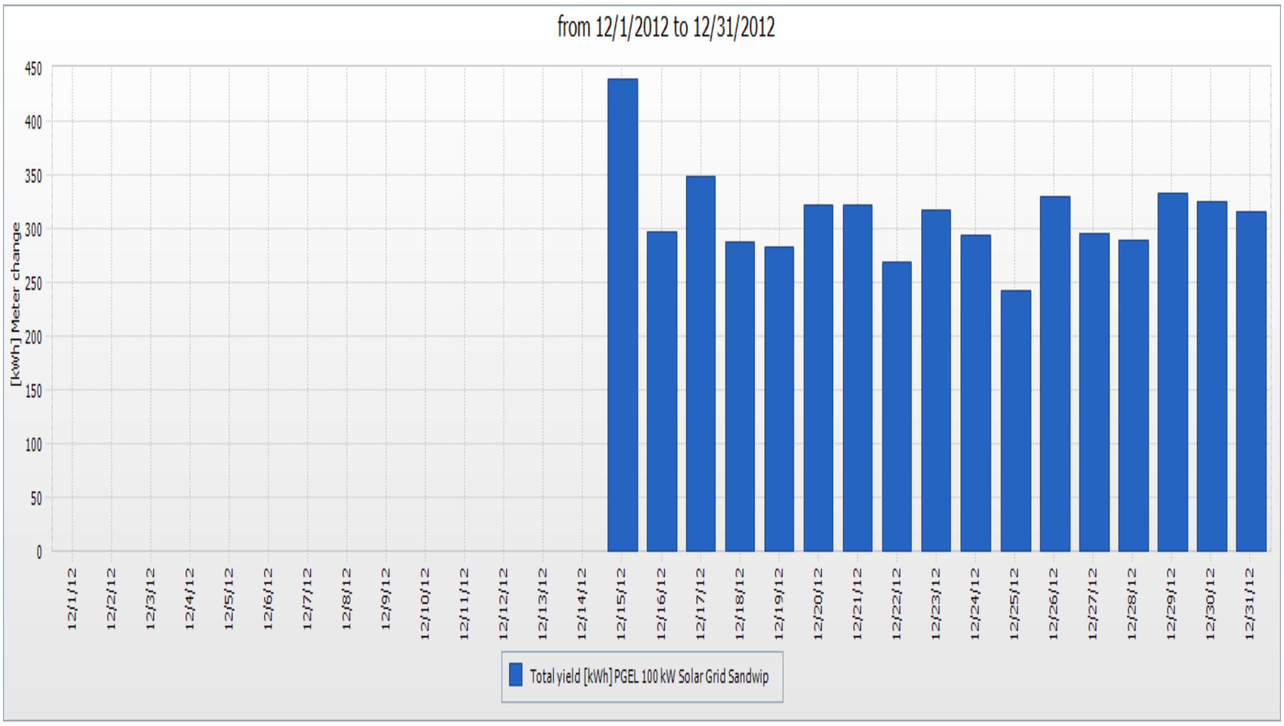


Fig 5.8 :2012 daily energy yield (kWh) with curve month of Nov,Dec

5.4 discussion

Environmental friendly Solar Energy will become the most important and cost-efficient energy source, if we are able to-

- Formulate a suitable & sustainable policy to sale surplus renewable energy to govt./grid.
- Converted our lights from conventional to low consumption LED lamps.
- Capacity build-up among the Technicians who are able to Calculate, design, install, repair and maintain the solar system.
- Govt. subsidy or long term low interest loan for solar system installation.
- Stable grid line & calculate actual shortage of power that we can generate from solar.

On September 29, 2010 the power plant came into operation and the first consumer is a local cooperative bank followed by the local police station, hotels and commercial shops. High quality and reliable grid power supply is being used for computers, lights, fans and other appliances instead of polluting Diesel generators.

The most interesting part of this solar power plant is that 60 percent of the total 100 kW can be directly fed into the three phase line through grid tied inverters during daytime. This will serve local offices, schools and households and other user during daytime. Excess energy from this power supply will go to the battery bank. In addition, remaining 40 percent of the energy will be stored in high quality battery bank for the night, when the market is in peak demand

Barriers for Sustainability of Alternative Energy Technologies:

- High initial cost
- Dependence on the weather
- lack of awareness
- Lack of established high-volume supplier-dealer chains.
- High prices of the components.

Conclusion

Conclusion:

We are facing fuel shortage for electricity generation and in the near future the whole world going to face the same scarcity because of world's limited fuel stock. So worldwide renewable energy demand and research are rising and our government also taking steps for green energy. So, I choose solar energy for DAFFODIL INTERNATIONL UNIVERSITY .

Prokaushali Sangsad Limited (PSL) has provided technical assistance in power generation from nation's first solar mini grid of 100 kW in the remote island of Sandwip, Chittagong. Part of the world that makes headlines with natural disasters is now the proud owner of the largest single solar installation in the country. Energy Systems of Bangladesh in association with Asantys Systems of Germany, has completed the turnkey installation of this power plant. IDCOL has financed the power plant with grant and loan from KfW of Germany.

Plant Factor is great demand for any solar Plant in Bangladesh. In chapter Five shown that Solar plant calculation. In this chapter for 2012 solar plant factor was decrease but for 2013 solar Plant Factor more increase.we can say that possibility and sustainability solar plant building in Bangladesh

Purobi Green Energy Limited, a private company is distributing solar power through a mini-grid to meet the daily demand of a rural market of Sandwip. About 400 consumers are expected to get electrification service on a daily basis by paying monthly bills through electric meters. Using state of the art hardware for power generation and control, this plant will be totally self operated with direct power from the solar modules for daytime use, and reliable energy storage for the night.
As a small developing country Bangladesh faces monumental challenge in the energy sector and not having a clear and transparent energy policy and a strong energy strategy is the main reason of this struggles and a comprehensive strategy is needed to overcome these resistances. However, Bangladesh can consider a systematic and coherent approach to meet the strategic needs. The Government must consider sustained economic and social growth in the country, while making strategic moves. Besides, judicious and optimal utilization of available energy sources is must.

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APPENDIX A

Table A.1 2012 daily energy yield (kWh)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	201	316	404	250	214	440	282	282	296	236	0
2	0	77.54	265	346	378	271	396	339	312	85.44	166	0
3	0	0	227	391	258	395	318	392	303	97.20	104	0
4	0	0	234	407	206	368	396	438	356	100	125	0
5	0	0	260	352	279	312	377	306	144	34.17	236	0
6	0	0	228	228	358	370	372	399	148	293	125	0
7	0	218	260	240	412	412	411	405	373	121	167	0
8	0	197	358	0	414	481	479	382	194	12.45	172	0
9	0	237	239	0	426	431	412	461	242	9.65	246	0
10	0	213	279	328	441	393	331	399	314	89.83	251	0
11	0	233	295	284	423	438	298	408	121	119	168	0
12	0	189	248	251	365	451	242	252	208	154	206	0
13	0	201	269	216	328	413	316	398	126	205	179	0
14	0	251	303	387	62.61	313	100	448	272	196	215	0
15	0	220	280	320	0.02	201	282	496	298	208	166	438
16	0	228	245	402	0.04	37.08	301	526	247	289	152	296
17	0	245	278	397	12.68	371	306	520	223	284	209	448
18	0	236	272	380	265	445	99.43	509	267	242	243	287
19	0	38.63	280	372	329	393	359	430	237	212	204	283
20	0	0	327	383	403	434	461	71.34	281	267	133	322
21	0	254	310	361	435	335	398	373	262	288	198	322
22	0	237	372	481	453	316	361	397	253	317	245	69
23	18.26	244	277	386	426	242	325	457	177	307	232	316
24	226	231	373	420	414	140	251	484	241	285	0	293
25	224	248	315	361	406	87.27	256	450	268	280	0	242
26	216	278	354	436	445	165	250	536	315	55.02	0	329
27	200	254	322	329	294	327	306	521	393	0	0	255
28	228	242	386	337	260	412	293	337	223	147	0	298
29	206	252	319	279	402	400	153	255	215	228	0	332
30	228	0	357	343	417	461	253	334	196	249	0	324
31	219	0	334	0	378	0	291	268	0	219	0	315

Table A.2 Solar Load Curve (2012)

Hr	Jan		Feb		Mar		Apr		May		Jun	
	Max 28/01/12	Min 23/01/12	Max 26/02/12	Min 19/02/12	Max 28/03/12	Min 06/03/12	Max 26/04/12	Min 13/04/12	Max 22/05/12	Min 17/05/12	Max 30/06/12	Min 25/06/12
00-01	1.34	0	.84	.18	1.22	.99	1.46	.28	1.22	0	.61	.72
01-02	.64	0	.75	.27	1.08	.89	1.32	.40	.68	0	.64	.69
02-03	.51	0	.71	.28	1.02	.68	1.20	.34	.83	0	.63	.60
03-04	.18	0	.70	.30	.99	.76	1.08	.36	.78	0	.60	.59
04-05	.21	0	.64	.39	.47	.78	1.02	.48	.68	0	.59	.57
05-06	.21	0	.47	.46	.83	.61	1.21	.76	.77	0	.60	.48
06-07	.40	0	1.19	.81	2.58	1.33	4.51	2.04	4.33	0	1.12	2.87
07-08	3.5	0	6.49	6.10	12.11	7.06	15.08	.56	13.9	0	6.24	14.21
08-09	17.23	0	16.25	20.41	25.26	14.89	28.04	.13	21.02	0	14.88	16.58
09-10	28.87	0	35.46	16.283	35.68	13.48	36.39	27.17	22.67	0	20.34	18.07
10-11	36.26	0	34.23	0	41.77	12.38	43.52	27.22	24.68	0	31.13	22.45
11-12	16.67	0	21.81	0	40.68	13.40	28.23	12.56	25.12	0	23.77	20.19
12-13	10.28	0	22.76	0	30.95	9.99	18.73	10.11	25.01	0	25.25	19.31
13-14	7.49	0	10.19	0	18.58	9.61	17.68	6.15	20.31	0	23.39	16.45
14-15	5.54	0	7.78	0	13.60	8.44	15.98	6.18	27.34	0	28.10	30.95
15-16	6.30	0	9.22	0	14.34	9.54	16.22	18.83	20.90	0	19.54	20.35
16-17	9.53	0	11.46	0	17.24	10.95	18.14	10.44	21.13	0	20.09	16.58
17-18	13.22	0	14.08	0	18.98	13.09	17.45	11.53	21.27	0	21.92	17.82
18-19	17.11	0	20.92	0	23.64	18.69	22.99	17.64	25.31	0	28.90	22.44
19-20	16.52	0	20.31	0	24.46	18.55	26.02	17.99	29.54	0	30.37	28.14
20-21	14.35	0	18.02	0	20.46	16.90	23.45	14.63	27.45	.220	26.54	26.16
21-22	8.76	11	12.99	0	13.25	12.04	18.22	10.88	20.54	1.50	16.84	20.41
22-23	5.72	6	7.74	0	8.79	7.01	13.63	7.19	14.98	.60	12.84	13.98
23-00	2.20	4	4.99	0	6.98	3.82	11.27	5.28	12.44	.61	1.15	11.90

Solar load Curve (2012)

hr	Jul		Aug		Sep		Oct		Nov		Dec	
	Max 20/07/12	Min 14/07/12	Max 27/08/12	Min 20/08/12	Max 26/09/12	Min 10/09/12	Max 11/10/12	Min 9/10/12	Max 22/11/12	Min 3/11/12	Max 15/12/12	Min 25/12/12
00-01	.60	.22	.75	14.36	0	0	0	0	0	0	0	.07
01-02	.63	.37	.42	11.43	0	0	0	0	0	0	0	.03
02-03	.68	.46	.74	0	0	0	0	0	0	0	0	.09
03-04	.66	.26	.76	0	0	0	0	0	0	0	0	.07
04-05	.70	.42	.74	0	0	0	0	0	0	0	0	.01
05-06	.91	.55	.80	0	.050	0.11	0	0	0	0	0	.01
06-07	3.01	2.16	3.91	0	2.03	2.82	0	1.19	.44	1.43	0	.02
07-08	15.14	5.8	15.25	0	15.03	12.77	.07	4.20	4.29	4.23	0	.55
08-09	27.25	3.08	29.54	0	25.71	31.41	2.00	.94	17.46	7.45	0	2.97
09-10	30.69	.88	39.84		43.31	34.32	4.54	.48	26.53	8.08	30.05	4.90
10-11	44.55	14.06	37.63	0	47.92	39.73	8.89	.12	36.50	16.32	33.01	11.42
11-12	47.63	15.55	25.39	0	49.36	41.62	32.72	.12	41.88	17.95	35.83	12.89
12-13	43.99	14.77	27.53	1.06	42.62	49.70	15.46	.12	42.90	12.81	36.31	16.79
13-14	33.33	8.54	25.54	1.04	34.50	46.59	23.23	.12	38.16	12.08	31.11	25.51
14-15	16.38	2.38	21.30	0	31.54	30.49	20.78	.14	24.38	11.58	18.22	20.91
15-16	21.59	3.58	21.53	1.111	16.86	15.38	6.23	0	10.28	9.88	11.95	11.36
16-17	16.44	4.39	22.15	.54	5.01	8.06	3.19	3.04	2.28	2.17	13.47	12.87
17-18	18.22	1.64	23.65	.21	.88	.94	1.23	0	.10	.150	20.79	19.94
18-19	21.30	1.13	28.97	.16	0	0	0	0	0	0	24.31	25.83
19-20	26.20	1.15	30.83	.29	0	0	0	0	0	0	24.30	24.70
20-21	23.38	1.13	29.84	.35	0	0	0	0	0	0	21.16	20.24
21-22	18.49	1.13	22.76	.34	0	0	0	0	0	0	15.16	13.88
22-23	12.75	13.08	14.49	.40	0	0	0	0	0	0	11.42	19.50
23-00	3.03	1.24	1.99	.43	0	0	0	0	0	0	2.70	2.45

Table A.3 2012 daily diesel use in liter

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					0	0	0	56.25	0	9		
2					0	94.5	0	9	0	54		
3					0	0	0	27	0	49.5		
4					0	0	0	0	0	49.5		
5					0	0	0	0	27	49.5		
6					0	0	0	0	27	0		
7					0	0	0	20.25	0	36		
8					0	0	0	36	18	20.25		
9					0	0	0	18	0	0		
10					0	0	0	0	0	0		
11					0	0	0	0	22.5	0		
12					0	0	31.5	45	0	0		
13					0	0	0	45	36	0		
14					90	0	104.4	9	0	0		
15					103.5	41.4	41.4	20.25	0	0		
16					103.5	103.5	27	9	0	9		
17					103.5	0	18	9	13.5	9		
18					22.5	0	81	9	0	9		
19					0	0	22.5	9	4.5	9		
20					0	0	0	108	0	108		
21					0	0	0	0	0	0		
22					0	0	0	0	0	0		
23					0	31.5	0	0	22.5	0		
24					0	0	40.5	0	22.5	0		
25					0	103.5	20.25	0	18	0		
26					0	45	0	0	0	0		
27					36	18	0	0	18	0		
28					36	0	0	45	18	45		
29					18	0	99	0	20.25	0		
30					0	0	0	0	0	0		
31					0	0	9	0	0	0		

2013 Daily energy yield (kWh)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	336	297	321	442	336	351			239			
2	333	348	302	481	424	423			231			
3	332	294	347	462	465	473			131			
4	328	342	335	474	211	457			213			
5	341	316	378	480	240	459			283			
6	332	341	313	500	190	454			228			
7	387	319	364	490	229	385			468			
8	230	320	308	494	205	181			485			
9	351	283	378	504	0	340			481			
10	315	341	343	481	0	455			452			
11	299	292	342	453	0	432			398			
12	308	345	0	444	437	442			498			
13	326	226	0	411	391	483			480			
14	313	377	0	320	362	450			485			
15	318	346	0	156	250	466			466			
16	329	283	0	211	168	466			466			
17	304	233	409	403	419	485			450			
18	313	411	449	266	378	480			483			
19	303	340	404	495	433	498			442			
20	324	297	466	454	389	398			251			
21	308	322	421	430	206	452			432			
22	325	281	424	314	189	481			455			
23	301	332	431	518	44	485			340			
24	322	300	482	410	0	464			481			
25	297	345	406	493	224	228			385			
26	315	327	410	501	457	283			454			
27	312	357	426	489	319	213			459			
28	318	315	487	415	339	131			357			
29	310	0	452	407	303	131			373			
30	314	0	251	442	202	231			423			
31	308	0	454	0	277	239						

2012 daily diesel use in liter in sandwip and per unit cost

May	June	July	August	September	October	Unit	
35910	30618	34618.5	33232.5	16474.5	28507	TK	
513	437.4	494.6	474.8	235.4	407.2	lit	70 Tk /liter, Diesel uses per month
57	48.6	50	52.8	29.8	50.8	hr	9 lit/hr, Running hour per month
1824	1555.2	1611.2	1688.0	952.0	1624.0	kWh	32 kW/hr, Energy production per month
19.6875	19.6875	21.4862	19.6875	17.30515	17.55357	TK	per unit cost

Plant Factor calculation for 2012

March	April	May	June	July	August	September	October	
11601.93	9796.7	10053.8	9842.42	9739	12052	7106	5391	KWh
15.59	14.57	13.51	13.67	13.09	16.19	9.86	7.48	PF%

Plant Factor calculation for 2013

January	February	March	April	May	June	September	
9932.84	8896.08	10115.2	13268.95	8091.5	12098.46	11898.46	KWh
13.35	13.29	16.21	18.42	12.48	16.80	16.52	PF%

Per unit Sandwip Solar Plant Calculation

57710000 TK Total cost

4015000 KWh Total generation

14.37 TK Per unit generation cost

140 kW Plant Capacity (solar +Diesel)

122640 kWh Energy produce per Year

3866570 TK interest and Depreciation

31.53TK Energy Cost per KWh