Estimation and analysis of Rooftop Solar PV Power system in Bangladesh

This thesis submitted to the Institute of Energy, University of Dhaka in the partial fulfillment of the requirement for the Degree of Masters Of Science in Renewable Energy Technology.

Submitted by:

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Exam Roll: 428

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MS in Renewable Energy Technology (RET)

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DECLARATION

I hereby declare that this thesis and work presented in it is my own generation and the result found from my own research.

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CERTIFICATE OF APPROVAL

I hereby recommended that the thesis prepared under my supervision by Mst. Juthika Azad , bearing exam roll – 428, entitled "**Estimation and analysis of Rooftop Solar PV Power system in Bangladesh***"* be accepted in partial fulfillment of the requirements for the degree of MS in Renewable Energy Technology(RET) from Institute of Energy, University of Dhaka. To the best of my knowledge and as per her declaration the whole work has been prepared by her and has not been submitted to anywhere else.

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February, 2016

Mst. Juthika Azad

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 rooftop solar system application also. Rooftop Solar systems are quite needing no fuel and require very little maintenance. Another advantage of PV system is: free energy, reliable power, flexibility and quick installation.

The aim of this thesis is to Estimate and analysis of Rooftop Solar PV System in Bangladesh and to be a participant to make Bangladesh the first Solar Nation.

Here discussed about solar photovoltaic system in Bangladesh both solar home system and rooftop solar power system. Broadly discussed about Rooftop solar power pv system. It's connection, it's metering arrangements etc.

The important part of the thesis is to estimate the total installed capacity in rooftop pv system in Bangladesh without considering limitations and with considering limitations.

At last to give some idea to calculate the installed capacity properly like site assessment, shading analysis, Financing Options, Legal and Regulatory Frameworks etc.

TABLE OF CONTENTS

CHAPTER - 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 cannot 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. Even if fuel is available within the country transporting that fuel to remote, rural village can be difficult .There are no loads or supporting infrastructure in many remote villages 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 (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. But still some problems have that make it uncomfortable to us. Its efficiency is so much low and the prices of its energy still so high. So in this paper we try to find way to make it comfortable.

1.1Solar energy 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).

1.2 Importance of Solar Energy

The main sources of world 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.

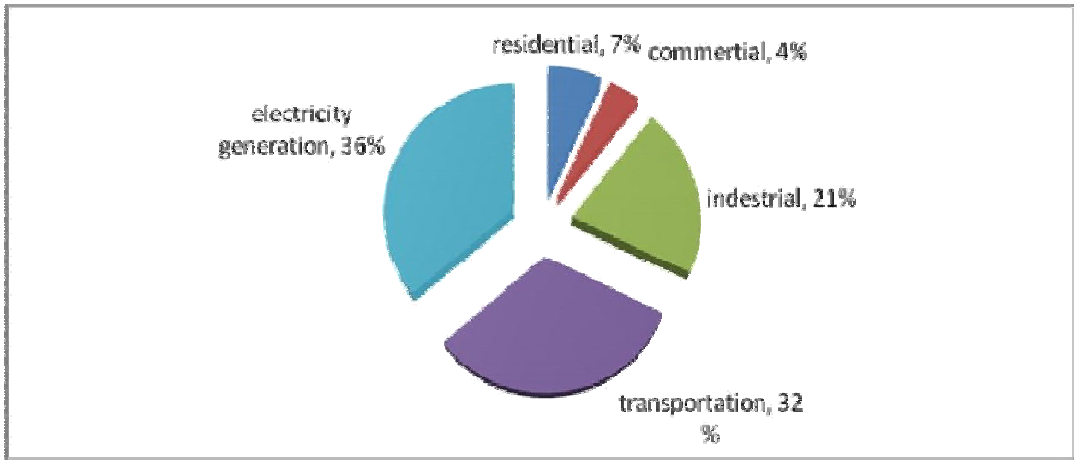


Figure1.1 Sources of carbon dioxide emissions [2]

Figure1.1 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. 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.

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 Emission.
3. Easy to install and use.
4. Noise free.
5. Less maintenance.
6. Source is unlimited.
7. There is no moving part, so its life is long

1.3 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 about green house effect environmental impact, cost, risk.

1.4 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. We started wondering about which countries have the most amount of installed solar systems. So we wanted to do a top ten list of the countries which uses the most solar energy (in Mega Watts, MW) in the world. We wanted to do this in a Letterman style but we think it's better to write a short note about each country pointing out its highlights and some interesting facts. [7]

This is the (unofficial) overview of the Top10 Solar PV installed capacity across the world, we keep it updated based on latest info from various sources. . [8]

Country	Latest Installed Capacity (GWp)	PV % of electricity consumption in country	Latest capacity update date
Germany	35.65	5.3%	31 Dec 2013
China	17.7	0.1%	31 Dec 2013
Italy	18	9%	31 Dec 2013
Japan	11.86	0.8%	31 Dec 2013
USA	11.42	0.3%	31 Dec 2013
Spain	5.1	2.8%	31 Dec 2012
France	4.67	0.9%	31 Dec 2013
Australia	3.159	1.2%	31 Jan 2014
Belgium	2.82	2.5%	31 Dec 2013
Czech Republic	2.0	3.1%	31 Dec 2012
Total of Top 10	112.4		

Country	Installed Capacity (GWp)	PV % of electricity consumption	Latest capacity update date
Greece	2.58	3.5%	31 Dec 2013
India	2.123	0.3%	31 Dec 2013
UK	1.845	0.5%	16 Feb 2014

1.5 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 [9]. 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. 1.2" in terms of the installed capacity .

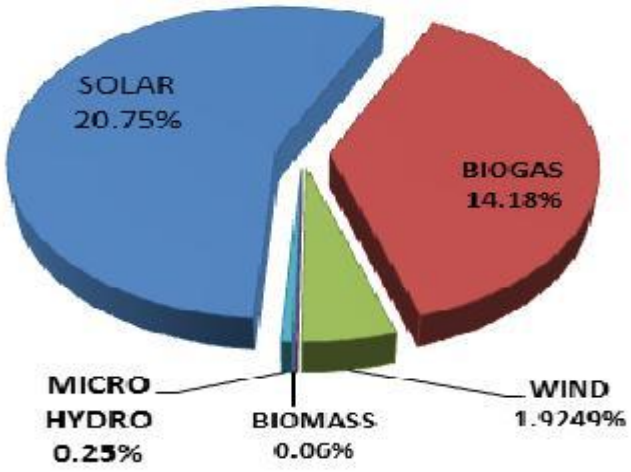
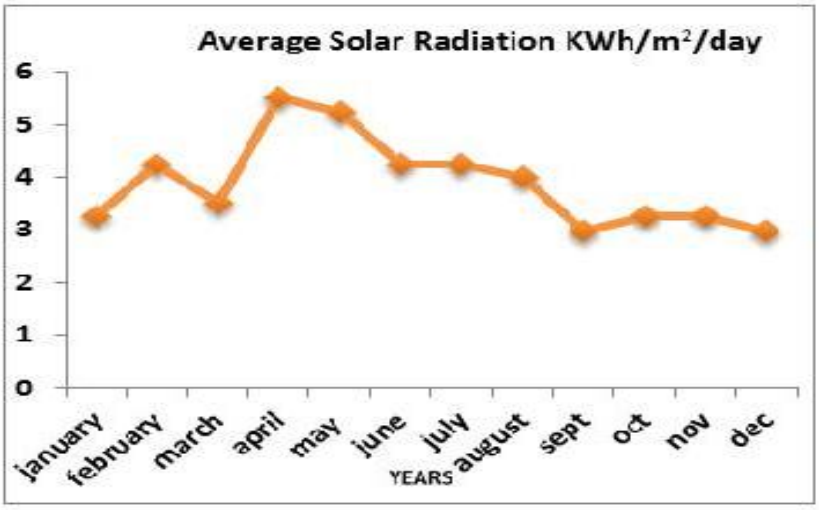


Fig 1.2: Contribution of different implemented renewable sources in Bangladesh

1.6 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. [10]



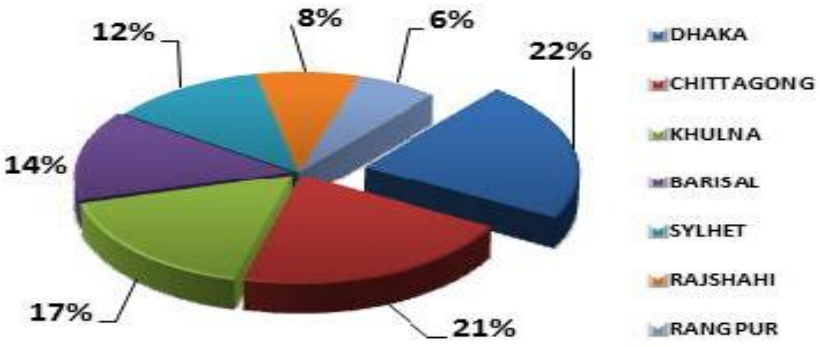


Fig 1.3: Monthly average solar radiation profile in Bangladesh

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 [11]. The amount is significant considering the upward trend of the number of SHSs (Solar Home System) installations in the country.

1.7 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 [12]. 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 [13]. 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 [14]. 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 [15].

1.8 Objectives of the thesis

The objective of the thesis is to learn about rooftop solar pv system with it's advantage and disadvantage.To know about the present condition of RPV in Bangladesh.To know about the future plan of the government about RPV in Bangladesh.And most importently to estimate the total installed capacity in Wp for all over the country.

CHAPTER – 2

SOLAR PHPTOVOLTIC(PV) SYSTEM

2.1 Connection of solar PV System

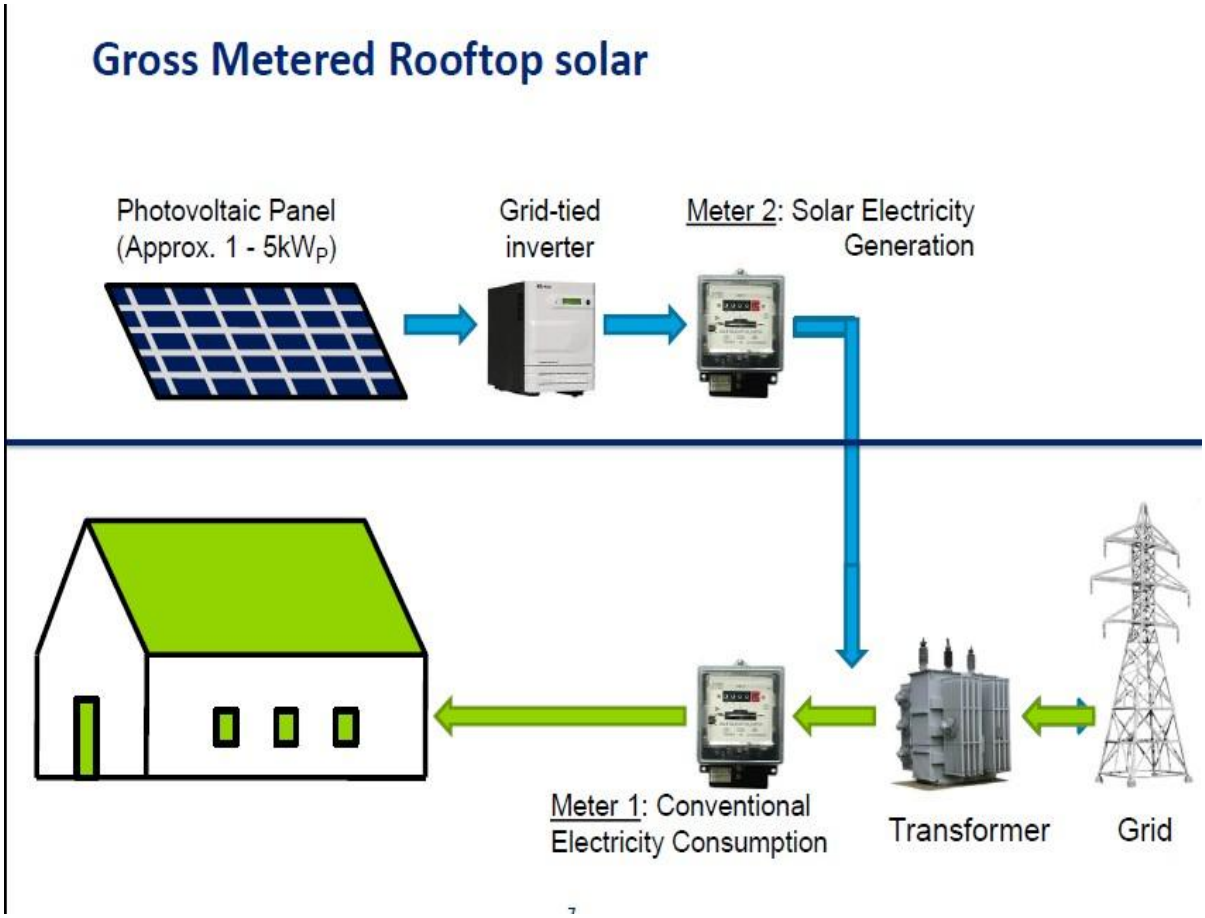


Fig: 2.1

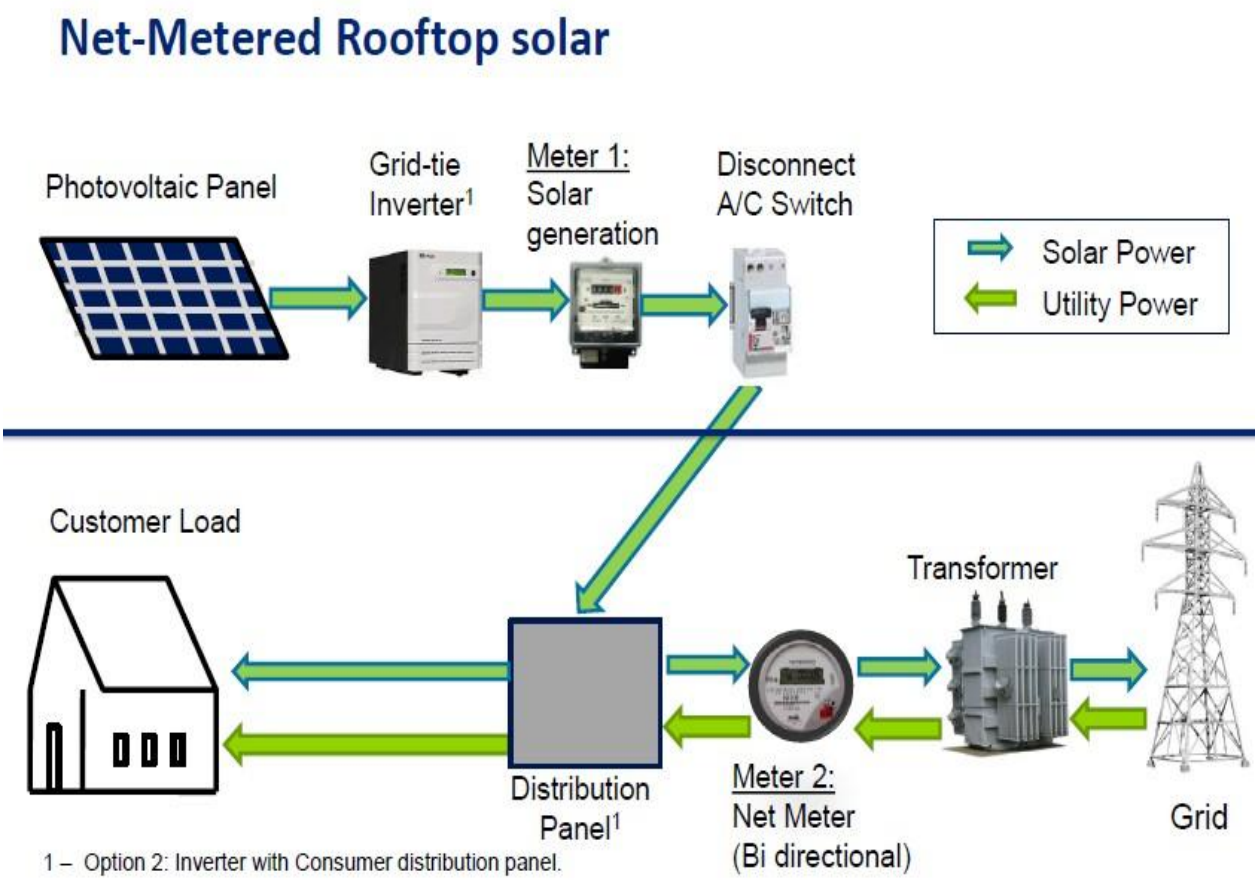


Fig:2.2[16]

2.2 Components of a solar PV system

A typical solar PV system consists of solar panel, charge controller, batteries, inverter and the load.

2.2.1 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. [17]

2.2.2 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. [9]

2.2.3 Inverter

An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC); the resulting AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse, and thus was "inverted", to convert DC to AC.

Figure2.3: Inverter designed to provide 115 VAC from the 12 VDC source provided in an automobile. The unit shown provides up to 1.2 Amps of alternating current, or just enough to power two sixty watt light bulbs

String inverter:

Figure2.4: String inverter

- Good look
- Available in small- and medium-sized PV power station
- User-friendly Interface
- Power level 1.5KW to 6KW

Power plant inverter:

Professional design for large-sized PV power station Transformer type and transformer less type

Satisfy different requirement, predigest design of power station

Figure2.5: Power plant inverter

A **grid-tie inverter** or a (GTI) is a special type of Inverter (electrical) that is used in a renewable energy power system to convert direct current into alternating current and feed it into the utility grid. The technical name for a grid-tie inverter is "grid-interactive inverter". They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications where utility power is not available.

Figure2.6: Inverter for grid connected PV

2.3 Solar Generation Technology

There are two possibilities to Generate power from Solar Energy.

2.3.1 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.

2.3.2 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.

2.4 Grid tide vs off-grid system

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.

2.5 Rooftop PV system

The Concept

Every building whether home, industry, institution or commercial establishment can generate some solar power by installing PV panels on the roof top. Sometimes this can be a BIPV(building integrated).

Some Key Benefits

- Photovoltaic roof-top installations at the tail-end of the grid can enhance grid-stability and reduce losses
- Savings in land requirement and costs
- Savings in development of new transmission infrastructure
- Creation of value from under-utilized /unutilized rooftops

•Good choice for distributed power generation system

•BIPV can enhance esthetics of buildings

2.6 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.

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.

2.7 Community Solar vs. Rooftop Solar:

Community Solar vs. Rooftop Solar: Which is right for you?

Community solar power is a good option for renters or home & business owners with unsuitable roofs to produce their own clean energy. In some rare cases, participation in a community solar

project may even be an alternative to rooftop solar where the property has a viable roof for installing solar panels.

"In some cases, participation in a community solar project may be an alternative to rooftop solar even where there the property has a viable roof for installing solar panels."

Community vs. Rooftop Solar Comparison Table

The table below examines the main differences between the two approaches to going solar. Keep in mind that program parameters and models vary between companies, so it is critical to understand precisely what deals are on offer in your area in order to be well-informed before making a decision.

COMMUNITY SOLAR	ROOFTOP SOLAR
Ownership Model: Participants may purchase or obtain financing for their share of project under ownership-based program 'Subscription-based' programs: System is owned by utility or the solar company and participants buy electricity at lower cost	You can own the system, finance it with solar loans, or sign up for a solar lease or PPA
Billing administered by utility, solar project administrator or combination of both. Benefits delivered via either: A. Virtual Net Metering credits on monthly electricity bill or B. Arrangement with community solar supplier whereby utility bill is reduced via solar credits and community solar developer sends separate bill (2 bills total)	Administered by utility. Benefits generally paid via solar Net Metering credits on participant's power bill or through avoided electricity purchase
Variable. Some allow easy entry and exit from programs; others require long-term contract comparable to rooftop solar lease	Solar lease/PPA, contracts are for 20-25 years
With both purchase and subscription, maintenance is the responsibility of the project developer/administrator.	If PV system is owned, you maintain the system. If leased, system maintenance is responsibility of solar company that owns the PV system.
Solar benefits unaffected by relocating if the participant remains in the same utility service area, Moving out of the utility service area may require an early termination fee.	If owned, systems add to sale price of house. If lease/PPA, may be taken over by next occupant (read more).
Can be built communal property (land or even	On roof or elsewhere on property owned by

roof) or third-party owned property. However, in most cases projects built as ground-mounted on open land for optimal solar access	the home or commercial property owner
Typical expected system life of system is 25-30 years, although some projects may extend longer	Typical expected system life is 25-30 years
As agreements are between customer and utility, any value associated with system (subscription or purchase) would not transfer to residents of the participants	Rooftop solar has been shown to improve property values
Best practice is for projects to be located in proximity to existing grid infrastructure and on otherwise unusable land (e.g. former landfill) to maximize environmental outcomes.	Rooftop solar makes use of otherwise 'empty' space and located close to point of power consumption (i.e. home or business).

CHAPTER – 3

ROOFTOP SOLAR PV POWER

Roof-top solar power systems provide energy for both office and households. This comes as an efficient alternative to supplement conventional grid energy and substitute usage of generators.

The first key rooftop project installed at the Prime Minister's office. From then onwards, various government institutions and the private sector have embraced solar solutions as a form of alternative form to meet the partial energy required.

Flush / Flat Mounting Options:

Mounting options for all flat-roof types

Mounting options for all flat-roof types

Many solar rail and clamp mounting options

Gravel and tar roofs

Membrane roofs

Tilt-Up Penetrating Mount Options:

Most popular tilt-up mount

Non-penetration options for membrane roofs

With or without thermal separation

Virtually any flat roof

Solar panel "roof penetrating systems”

Non-Penetrating Mounting Options:

Low-cost ballast-mounted solar systems

Easy installation

No penetrations required

Consideration for all flat-roof solar projects

3.1 RPV potential And Growth

Benefits of Roof top PV

At national level, reduces requirement of land for solar Power. It reduces need for additional transmission infrastructure

For consumers, it

–Reduces the dependency on grid power.

–Mitigates diesel generator dependency.

–Long term reliable power source.

–Day Peak load Demand

–T&D and conversion losses as power is consumed at the point of generation.

Most suitable for commercial establishments

–Max generation during peak usage time.

–Solar power cost is close to the commercial power cost.

–Solar power cost is fixed for 25 years

Concerns with Rooftop PV

Power quality: DISCOMs are apprehensive about the quality of the power being injected into their distribution grids. This is mainly to do with flicker, harmonics and DC injection.

Safety: Utilities are rightly concerned about the safety of their personnel, especially while working around the possibility of the formation of an unintentional island from the operation of the distributed solar PV systems.

Low voltage distribution grid: They are also concerned about the impact on the LV distribution grid (voltage levels, power factor, higher wear and tear of equipment, etc.) from high penetration of a large number of distributed solar generators.

Transaction Costs: Another logistical worry for utilities is the significantly higher transaction effort in terms of metering, inspection and certifications

Two Significant Classes of Concern

Technical: Grid-integration challenge with likelihood of

– Reversal of power flows across the LT network.

– Breach of voltage regulations with tail-end generation feed

– Erratic behavior of LV protection systems

Commercial: Utility likely to have certain valid long-term concerns

Loss of consumers / reduction in revenue in net-metering /captive operation.Regulators don't often factor in compensate for the cost of grid support provided to distributed generators.

3.2 RPV Connection

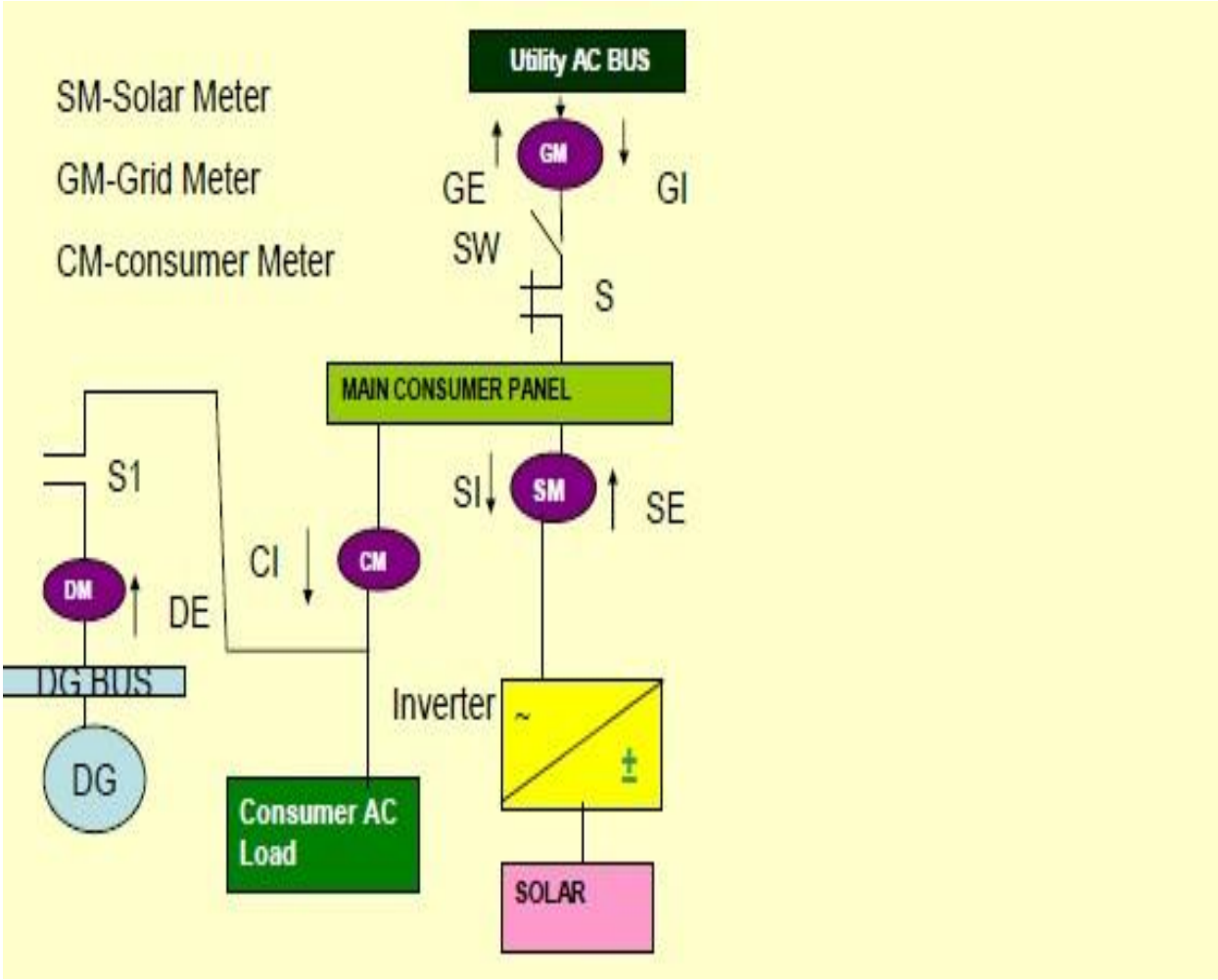


Fig:3.1 Grid Interactive Solar PV System With Full Load battery backup Battery Backup

Grid Connected Solar Energy Project Development

Globally, grid-connected solar project has followed 2 broad routes:

• **Utility driven solar project development:**

Large MW-scale centralized solar projects developed to meet renewable purchase obligations (RPO) of the utilities either developed by utilities themselves or by third parties for their procurement.

•Customer driven solar project development:

Small-scale decentralized projects developed by electricity consumers on their own premises. Interest fueled by the declining cost of solar energy, fiscal incentives like feed in tariffs (FiT's), net metering and tax rebates, coupled with the increase in the cost of grid based conventional energy. Several hybrids of the above routes have emerged in specific markets, depending on the regulations, market opportunities and role of intermediaries. These are roof tops and BIPV opportunities

3.3 Metering Arrangement

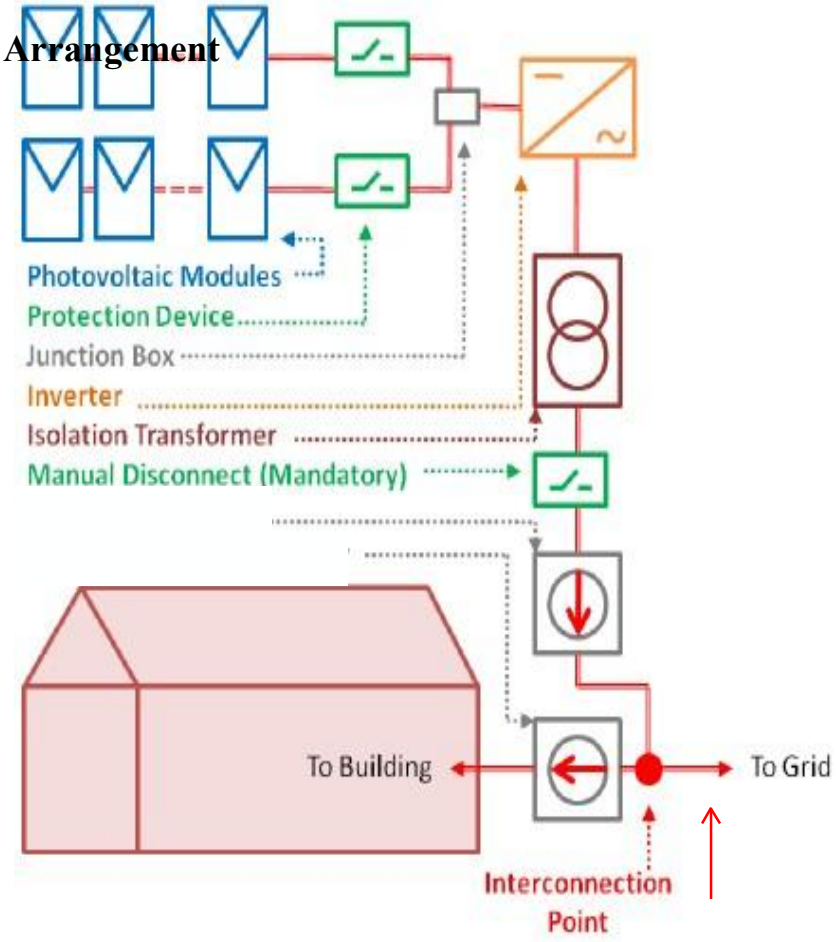


Fig: 3.2 Connection philosophy of a feed-in meter interconnection system

The three metering interconnection scheme is applicable where a separate feed in tariff is allowed for feeding of solar electricity into the grid. Energy is easily accounted for in this case through a dedicated feed-in meter(solar meter). Such schemes are popular in some European Countries including Germany.

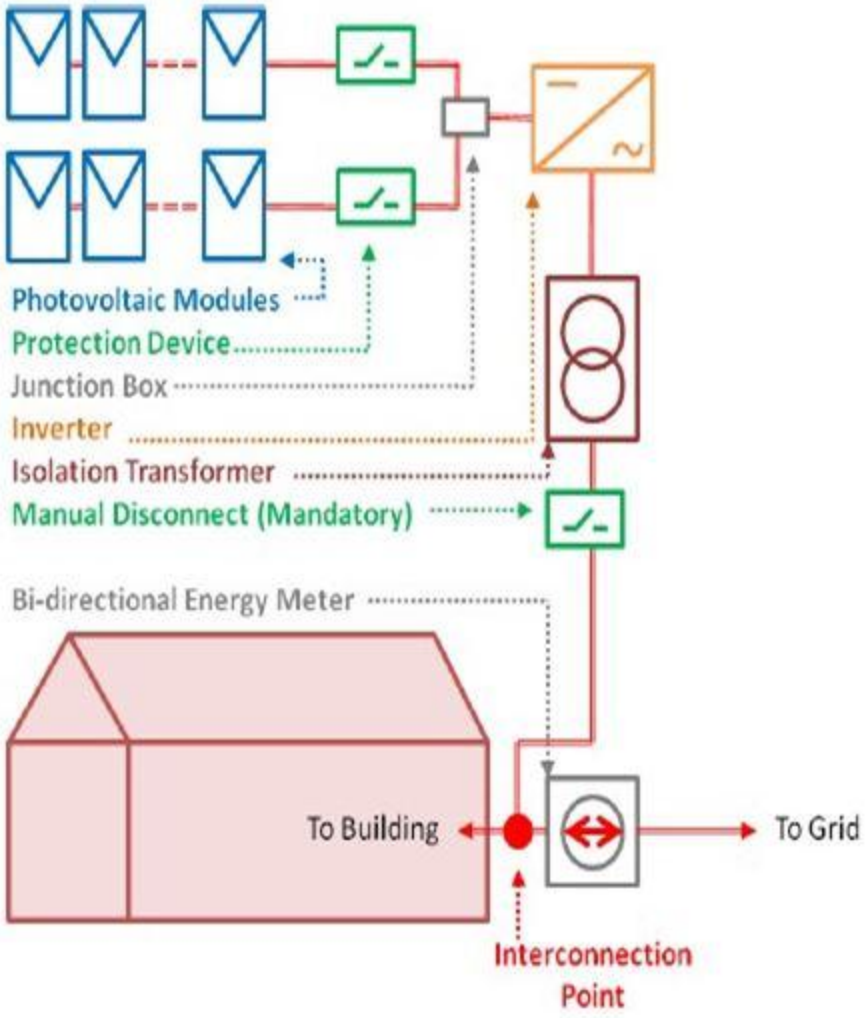


Fig: 3.3 Connection philosophy of a net metering interconnection system

The net metering system is applicable where conventional electricity and solar electricity are treated as same tariff. As the cost of solar electricity is higher than conventional electricity, such a net metering scheme has to be supported with additional subsidies to the developer. Such schemes are popular in some Countries including USA and Japan.

Locations of meters

Generating Station : On all outgoing feeders

Consumer Meter: Directly connected to any other system (Inter-State or Intra-State Transmission system.

Schedule: Meters shall meet the following requirements of Accuracy

Class: Interface meters : 0.2S

Consumer meters : Up to 650 volts - 1.0 or better, Above 650 volts and up to 33 kilo volts - 0.5S or better[16]

BERC Regulations need to incorporate appropriate metering system for rooftop PV and should clarify :

Whether separate metering (Export/Import) arrangement or single meter with separate registry for Export/Import be insisted, requirements for Main Meter/Check Meter/Standby meter, if any, Metering Location, Meter Accuracy Class for Consumer meter, Solar meter and Discom interface meter Meter type, Meter Sealing Meter Reading. What facilities the meter should be capable of - data storage, ToD slot- wise, time-block, communication facility etc.

3.4 Present Status of RPV In BD

Government has set up the goal of providing electricity to all by 2020 and to ensure reliable and quality supply of electricity at a reasonable and affordable price. Sustainable social and economic development depends on adequate power generation capacity of a country. There is no other way for accelerating development except to increase the power generation by fuel diversification. Development of Renewable Energy is one of the important strategies adopted as part of Fuel Diversification Program. In line with the Renewable Energy policy 2009, the Government is committed to facilitate both public and private sector investment in Renewable Energy projects to substitute indigenous non- renewable energy supplies and scale up contributions of existing Renewable Energy based electricity productions. The Renewable Energy Policy envisions that 5% of total energy production will have to be achieved by 2015 and 10% by 2020[18]. To achieve this target, GOB is looking for various options preferably Renewable Energy resources. Under the existing generation scenario of Bangladesh, Renewable Energy has a very small share to the total generation. The share of Renewable Energy exceeds more than 1% till now. The present

Government is placing priority on developing Renewable Energy resources to improve energy security and to establish a sustainable energy regime alongside of conventional energy sources. Government has already launched *"500 MW Solar Power Mission"* to promote the use of Renewable Energy to meet the increasing demand of electricity[18]

Implemented Projects:

Prime Minister's office: The first key rooftop project installed Rahimafrooz Solar was at the Prime Minister's office. From then onwards, various government institutions and the private sector have embraced solar solutions as a form of alternative form to meet the partial energy required. Rahimafrooz is a major player in the development of rooftop solutions and systems installer for Bangladesh.[19]

Bangladesh Bank: Bangladesh Bank has installed a solar system on the rooftop of it's main building to reduce pressure on the demand for electricity.: Dhaka, March 30 (bdnews24.com) – Bangladesh Bank (BB) has installed a solar system on the rooftop of it's main building to reduce pressure on the demand for electricity.The central bank governor Atiur Rahman inaugurated the launch of the solar system, which is installed at a cost of more than Tk 1 crore on Tuesday.The solar system comprising 116 panels will provide electricity for 171 lights at the governor's office, one guest room, board room and the main conference room during the day, and boundary wall lighting at night.The solar system, expected to last about 20 years, has an 8 kilowatt capacity.The governor said that use of solar energy in domestic and offices can reduce pressure on national grid and can directly help in protecting the environment.He also said that the central bank will consider providing lone facility for its staff to install solar system for domestic use.[20]

Bangladesh Secretariat: Rahimafrooz Renewable Energy has installed a 50kilowatt-peak (kWp) Grid-Tied Solar Project on the rooftop of the Bangladesh Secretariat. Dhaka Power Distribution Company Limited (DPDC) is buying electricity from the plant. This is the first power purchase contract with a solar plant and a milestone for rooftop solar applications in the country. According to the agreement, the 50kWp project will be directly added to the national grid through an inverter. The DPDC will pay Tk19.95 per unit for 20 years to buy power from the project.[19]

BBS: The government has installed the biggest solar power plant on the rooftop of the Bangladesh Bureau of Statistics building in Dhaka. The plant, with a 200 kWp generation capacity, equivalent to lighting up 5,000 bulbs of 40 watts, meets a significant portion of the building's demand for electricity. The solar plant was installed by In Gen Technology Limited. [21]

Under BPDB: The plant comprising 670 panels of 300 watts will meet around 40 percent of the electricity demand of the building in Agargaon popularly known as Parishankhyan Bhaban, according to Akhtar Hamid Khan, chief executive of InGen Technology. The 11-storey building requires around 500 kwp electricity a day to run lights, fans, air conditioners, computers and data servers, he said. "Of the total, around 200 kwp will come from the solar plant."The solar plant has a grid-tie system to connect the electricity generated from renewable sources to the main power grid. The plant, expected to last about 20 years, can save electric bills worth around Tk 4.5 crore and fuel costs worth Tk 16 crore during the period, he said.

Major solar PV systems implemented by BPDB in the fiscal year 2010-2011 are as follows:

- 32.75 kWp at WAPDA Building, Motjheeel.
- 2.82 kWp at Chairman Banglo, BPDB.
- 6 kWp at Agrabad Bidyut Bhaban, Chittagong.
- 1.8 kWp at Cox's BPDB Rest House.

Major solar PV systems implemented in the fiscal year 2011-2012 are as follows:

- 37.5 kWp Solar Roof Top System on15th floor of Bidyut Bhaban. .

- 3 kWp at Khagrachori BPDB Rest House.

Ongoing Projects

- 650 KWp (400 kW load) Solar Mini Grid Power Plant at remote Haor area of Sullah upazila in Sunamgonj district under Climate Change Trust Fund (CCTF) on turnkey basis.

- 8 MW_p Grid Connected Solar PV Power Plant at Kaptai Hydro Power Station,at Rangamati on turnkey basis.

- 3 MW_p Grid Connected Solar PV Power Plant at Sharishabari, Jamalpur on IPP basis.

- 30 MW_p Solar Park Project adjacent to new Dhorola Bridge, Kurigram on IPP basis.

- Solar Street Lighting Projects in seven (7) City Corporations of the country.

N.B Installation of Solar Roof Top Systems in all BPDB offices across the country is a continuous process. More than 223 kW_p solar PV systems have already been installed and installations of about 407 kW_p solar PV systems are under planning/implementing stages.[22]

Projects under Planning

- Conversion of existing 37.5 kWp Solar System installed on the rooftop of Bidyut Bhaban into 37.5 kWp Grid Tied Solar System

- Conversion of existing 32.75 kWp Solar System installed on the rooftop of WAPDA Bhaban into 32.75 kWp Grid Tied Solar System

- Rehabilitation of 10 KWp Solar Power Plant at the Barkal upazilla sadar of Rangamati district.

- BPDB has planned to install Grid Connected Solar PV Power Plant on IPP basis such as-
  i) 1 MW Grid Connected Solar Power Plant at Regional Training Centre (RTC), Rajshahi.
  ii) 500 kWp Grid Tied Solar System at 33/11 kV substation's compound of former Hajigonj Electric Supply, Chandpur.
- BPDB has planned to install Solar Mini Grid Power Plant on turnkey basis under Climate Change Trust Fund (CCTF) at remote and inaccessible areas such as-
  i) 500 kW Solar Mini Grid Power Plant at Swandip Upazila of Chittagong district.
  ii) 500 kW Solar Mini Grid Power Plant at Thanchi Upazila of Bandarban district.

- BPDB has planned to implement Solar Park Projects on IPP/PPP basis under the Roadmap of ADB's 500 MW Solar Power Mission such as-
  i) Rangunia 60 MW Solar Park Project on IPP basis at Karnafuli river side, Rangunia, Chittagong
  ii) 40-45 MW Solar Park Project adjacent to Bangabandhu Bridge,Tangail and Sirajgonj area.
  iii) 2-3 MW Solar Park Project adjacent to PGCB Grid Sub-station compound, Ishwardi.
  iv) 1-2 MW Solar Park Project adjacent to PGCB Grid Sub-station compound, Jhenaidaha. [22]

3.5 Government Program:

The World Bank has offered to loan the Bangladeshi government $78.4 million in order to finance 480,000 solar home systems. This huge solar home systems project aims to install about 7,000 photovoltaic systems in Bangladesh every month. If it achieves this rate, it will be the largest of its kind in the world.[23]

There are already 3 million home solar systems in the country, and they were installed because the World Bank provided the support. “Together, the government of Bangladesh and the World Bank is scaling up a program that delivered development results for millions of rural Bangladeshis This is a proven model that works. Investing in electricity in rural areas empowers both men and women, leading to increased income and growth opportunities, and reducing poverty,” said acting head of World Bank Bangladesh, Christine E. Kimes.

Nearly 60% of the Bangladeshi people do not have access to grid-connected electricity. The government has set a goal of 100% citizen access by 2021. Millions of people’s lives have been impacted in Bangladesh because of the addition of more solar PV power.[23]

Bangladesh aims to be world’s 'first solar nation':

DHAKA, Bangladesh (Thomson Reuters Foundation) - Residents of Islampur, a remote village in the northern Bangladeshi district of Naogaon, were stunned one night last summer when the darkness was suddenly illuminated by electric lights coming from a village home.The owner of the house, Rafiqul Islam, is one of around 15 million Bangladeshis whose homes are now powered by solar home systems, or SHS, under a government scheme to provide clean power to communities with no access to grid electricity.[24]

The Bangladeshi government aims to provide electricity to all of the country’s households by 2021. With financial assistance from the World Bank and other development partners, it plans to generate 220 megawatts of electricity for around 6 million households by 2017 through the solar home system programme. [24]

Each solar home system uses a solar panel installed on the roof of an individual home. A 250 watt panel can produce up to 1 kilowatt of power a day.

BD Generate 2,000MW By 2020 From Renewable Sources:

Bangladesh has been working with a target to produce 2,000MW of electricity from renewable sources by 2020.

State Minister for Power and Energy Nasrul Hamid announced this while presiding over a session of the two-day 6th ministerial meeting of International Renewable Energy Agency (IRENA) on the last day yesterday.

The meeting, which was held in Abu Dhabi of the UAE, began on Saturday.

Representatives from 150 countries participated in the meeting although the IRENA has 145 members, according to a message received in Dhaka sunday.

The IRENA is an intergovernmental organisation that supports countries in their transition to a sustainable energy future. Reducing carbon emission and promoting energy conservation is also its core area of work.

The 6th ministerial conference reviewed the progress of different countries in renewable energy use and also their mid-term plans for 2016 and 2017.

It also discussed different areas of renewable energy, including solar, biomass and hydro wind, to ensure their sustainable use across the globe.

Nasrul Hamid said Bangladesh has formed Sustainable and Renewable Energy Development Authority (SREDA) as part of its frantic move to increase the share of renewable energy in power generation.

“But the unaffordable price of renewable energy has been a major barrier to the way of Bangladesh’s move to increase the renewable energy’s stake in total electricity generation,” he added.[25]

Rooftop solar plants planned for all govt. buildings :

The rooftops of government buildings, including Gono Bhaban, will soon be decked in solar panels, turning them into solar energy plants.

“We have decided to install a solar plant on the rooftop of all district government buildings including Gono Bhaban,” Power Division Secretary Monowar Islam told the Dhaka Tribune.

He said measures were being taken to utilise the rooftops of different government offices to install solar panels for power generation, adding that power sector officials have to pay more attention to generating electricity from renewable energy.

The first solar plant in a district government building, a green response to the fuel crisis, will be installed in Jamalpur. The government will identify appropriate buildings in all districts within a month with the help of the Public Works Department. Rahimafrooz Renewable Energy has installed a 50kilowatt-peak (kWp) Grid-Tied Solar Project on the rooftop of the Bangladesh Secretariat. Dhaka Power Distribution Company Limited (DPDC) is buying electricity from the plant.

This is the first power purchase contract with a solar plant and a milestone for rooftop solar applications in the country. According to the agreement, the 50kWp project will be directly added to the national grid through an inverter. The DPDC will pay Tk19.95 per unit for 20 years to buy power from the project.

The government has installed the biggest solar power plant on the rooftop of the Bangladesh Bureau of Statistics building in Dhaka. The plant, with a 200 kWp generation capacity, equivalent to lighting up 5,000 bulbs of 40 watts, meets a significant portion of the building's demand for electricity. The solar plant was installed by InGen Technology Limited. In addition to this, the government-run 57 kilowatt plant at Kaliakoir Hightech Park, a 50 kilowatt plant on the rooftop of the Bangladesh Bank main building and the privately owned 100-kilowatt plant in Sandwip are the country's three other big solar power plants. According to sources, more than 4 million solar home systems (SHS) are now generating more than 155 MW of solar power.[26]

Govt. set to buy power from solar panels on rooftops:

The government is set to purchase power to be generated from solar panels to be set up on rooftops of houses in urban areas. Such power will be added to the national grid. With an aim to popularise solar power in urban grid zones, the government has finalised a policy draft on such purchase

technically called 'feed in tariff' (FIT) system, officials have said. As per experts' estimate under the FIT system, at least 500 megawatt power would be generated every year. Md Shafique Uddin, Director of the Renewable Energy Division, the Bangladesh Power Development Board (BPDB) said the government, as a part of its renewable energy policy against the backdrop of global warming situation, is going to adopt the system to encourage people to invest money in installing solar plants at their house premises or on rooftops. He said, "We have finalised the draft and a further study is going on and it would be submitted to the higher authority shortly." Dipal Chandra Borua, President of the Bangladesh Solar Renewable Energy Association (BSREA), said along with the FIT, the government may also adopt net metering system under which the generated power could be diverted to the grid with a payment system. Mr Borua said the net metering may also encourage the urban people to invest in generating solar power on their rooftops and in house premises. Solar power is becoming the fastest-growing energy source in Bangladesh. According to sources, more than 3.3 million solar home systems (SHS) are now generating more than 150 megawatts of solar power. Apart from the SHS, more than 100 solar irrigation pumps (SIP), mini grids, street lamps, based transceiver station towers for mobile operators and other sources are generating more than 50 megawatt electricity. With supports from the world's different financial institutions, solar power in Bangladesh is becoming popular changing the socio- economic status in the rural areas. This has replaced 200,000 tons of kerosene and heavy fuel oil having an estimated value of US$ 250 million per year, sources in the renewable energy sector said. According to the Infrastructure Development Company Limited (IDCOL) sources, more than 3.3 million SHS have generated 150 megawatt electricity till August 2014 in remote and rural off-grid zones. This has marked a 58 per cent growth per year. The BPDB official said, "We have taken a few solar power mega projects in different districts to generate 50 megawatt electricity within 2017."

Abu Md. Iqramul Hasan, monitoring officer of the IDCOL said, "We have a target to finance 6 million SHS by 2017, with an estimated generation capacity of 220 MW of electricity."The IDCOL, the BPDB and other public and private institutions are likely to produce more than 300 megawatt solar power both in rural and urban areas by 2017. The IDCOL started solar renewable energy programme in 2012 with credit and grant support from the World Bank. Later, GIZ, KfW, ADB, IDB, GPOBA, JICA, USAID and DFID came forward with additional financial support for expansion of the IDCOL's SHS Programme. Mr. Hassan said currently more than 65,000 SHSs are

now being installed every month under the programme with average year-to- year installation growth of 58 per cent. The BPDB official also said along with formulating the FIT, they are moving ahead in setting up a 30 megawatt solar power plant on the bank of the river Dharala and several small plants in different parts of the country. He said under the FIT policy, the government will purchase solar power from private entrepreneurs at a certain price for supply to the national grid. [27]

Public Offices Under Roof Top Solar Coverage By Two Years:

Government is interested to increase the use of renewable energy. All public offices will be under roof top solar coverage by next two years. Engineer Musharraf Hossain, Minister of Ministry of Housing and Public Works, said this in a workshop titled "Solar Roof top –its Viable Option for Bangladesh" in the city arranged by SUSTAINABLE & RENEWABLE ENERGY DEVELOPMENT AUTHORITY.

Advisor to the Prime Minister for Power and Energy Tawfiq e elahi, Secretary of Power Division Monowar Islam, Engineer Muhammad Mohiuddin and the members of other stake holders were present in the Work shop.

To increase the use of solar power the government is trying to install solar panel at the roof top of the all houses. Thus installation of solar panel at the roof has been mandatory for new every electricity connection. Nowadays only 20 MW is generating rooftop with solar panel.

Science last 5 year government executed many things to increase the use of renewable energy. Such as took initiative to install 160MW capacity wind power plant as well as wind mapping in 13 places; formed SREDA by approving "SREDA act 2012"; generating 411MW of electricity from Renewable Energy resource which is 3.6 per cent of countries total generation; installed 40 lakhs solar home system; established 262 solar irrigation pumps and gradually transforming diesel run pumps into solar pump.

Type Capacity

Solar Home System 150 MW

Solar Irrigation 2 MW

Solar Roof top(resident) 16 MW

Solar Roof top(office) 4 MW

Solar Mini grid 1 MW

Total 173 MW

Source: SREDA

Since the reserve of natural gas is depleting rapidly we need to take a look to the alternative source like solar. We have a plan to give grid connection to Sandip Island very soon though the people of the Island presently are using solar power, he said.

The present Government is placing priority on developing Renewable Energy resources to improve energy security and to establish a sustainable energy rule alongside of conventional energy sources.

The Renewable Energy Policy envisions that 5 per cent of total energy production will have to be achieved by 2015 and 10 per cent by 2020. To achieve this target, GOB is looking for various options preferably Renewable Energy resources. Under the existing generation scenario of Bangladesh, Renewable Energy has a very small share to the total generation. The share of Renewable Energy exceeds more than 1 per cent till now.[28]

CHAPTER - 4

RPV MARKET IN BANGLADESH

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]

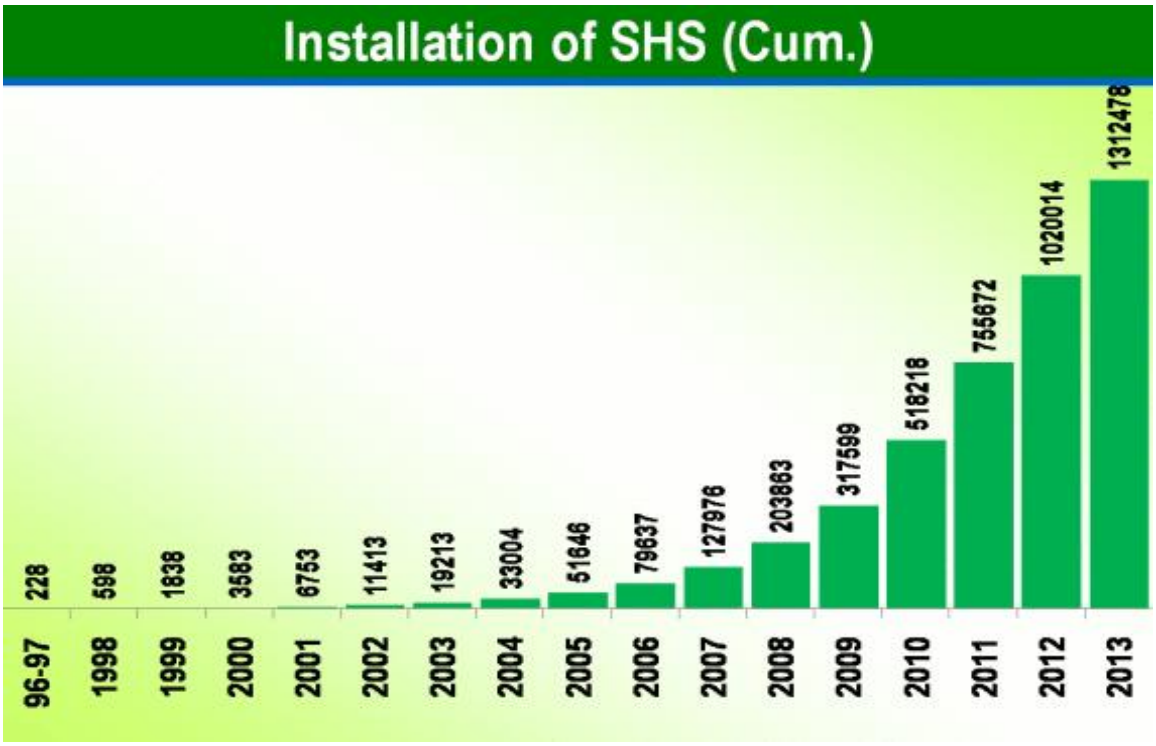
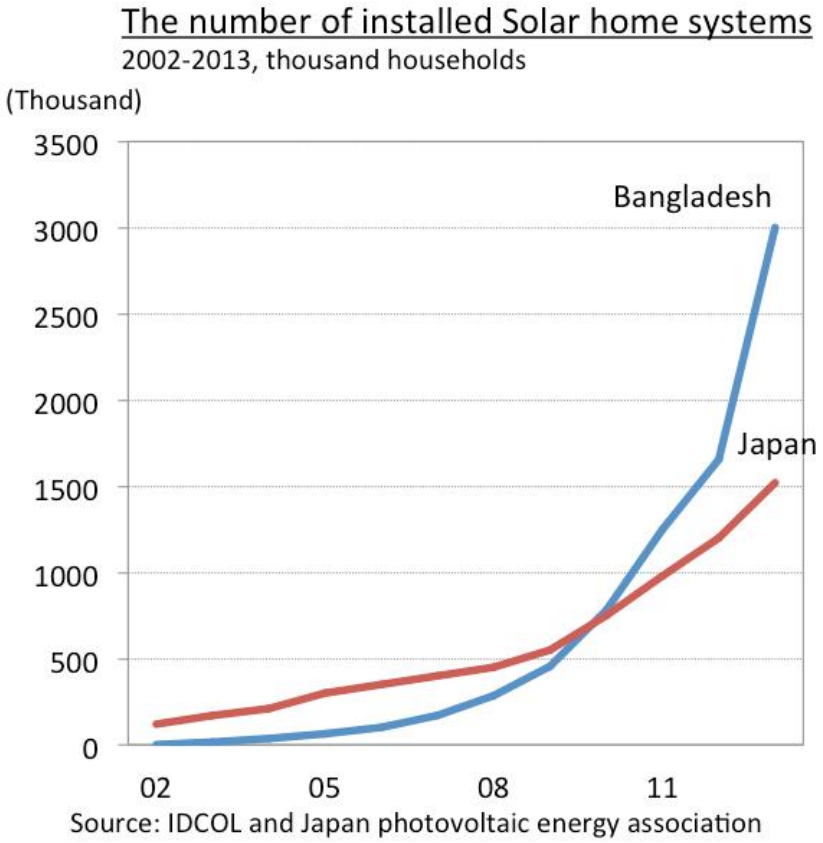
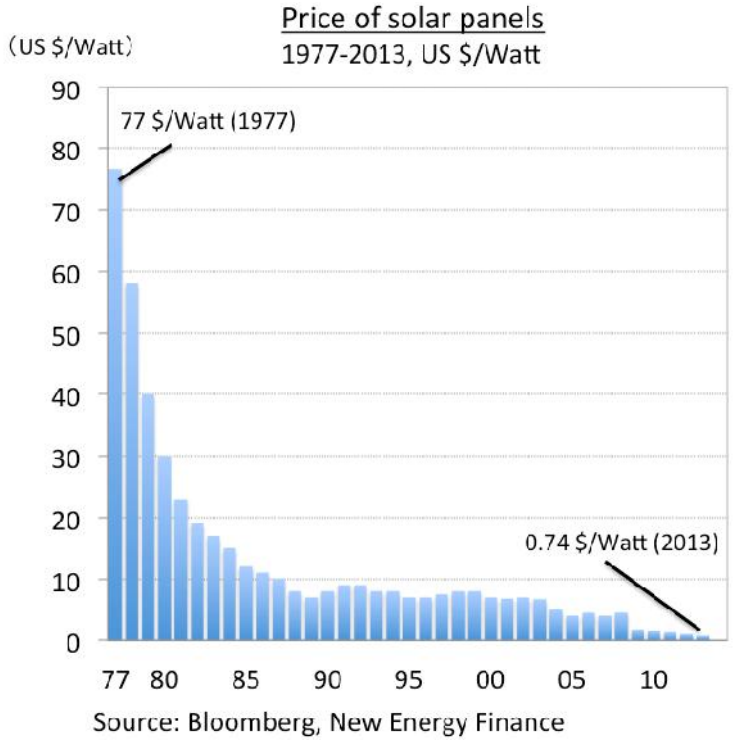


Chart 1: Projection of the SHS Market in Bangladesh

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.


The number of installed Solar home systems
2002-2013, thousand households
(Thousand)
3500
3000
2500
2000
1500
1000
500
0
Bangladesh
Japan
02
05
08
11
Source: IDCOL and Japan photovoltaic energy association


Price of solar panels
1977-2013, US $/Watt
(US $/Watt)
90
80
70
60
50
40
30
20
10
0
77 $/Watt (1977)
0.74 $/Watt (2013)
77
80
85
90
95
00
05
10
Source: Bloomberg, New Energy Finance

Is the roof suitable for installation of solar PV:

A rooftop solar PV installation comprises of PV panels assembled in arrays, mounting frames to support the panels and secure them to the roof, wiring, inverters, and other components depending on the type of installation. The roof site must be able to accommodate all of these components, which requires examining the following aspects:

Accessibility. The roof must be accessible to carry out installation and maintenance. It must be possible to lift the solar system components onto the roof and for personnel to physically access the site to install and maintain the system.

Roof configuration. A roof plan can help quantify the roof area available for the PV power plant. The plan should indicate the location (including longitude and latitude), height, and slope of the roof itself, as well as any additional structures present on the roof. Identify any possible conflicts in usage of the roof, such as a helipad or communication antennae, and contact relevant bodies to ascertain if any special permission is required to use and/or alter usage of the roof space.

Roof materials and structure. For existing buildings, first find out when the roof would need replacement. If a roof is nearing the end of its life span, it is more cost-effective to install the rooftop PV system once the new roof is in place. It is also easier to integrate a system into the design of a new roof.

Next, engage a structural engineer to determine if the roof can be penetrated to secure the mounting frames. Often, flat roofs have a membrane that will lose its waterproofing properties if penetrated—in this case, the system may require a ballasted mounting system (with concrete weights).

The engineer should also be able to determine if the roof can bear the additional weight of a PV system. As a general rule of thumb, a crystalline PV system will place about 15–20 kilograms per square meter (kg/m^2) (3–4 pounds per square foot) of dead load on the roof (California Energy Commission 2001), but this varies depending on the panels and mounting system used, the spacing

between panels, and the wind load.

Generally, a flat, concrete terrace roof will normally have the strength to accommodate the additional weight of the panels and supporting structures. Inclined roofs of storage sheds and residential buildings may be made of metal sheet, tiles, or similar materials, in which case it would be necessary to examine whether the trusses can support additional weight.

In the event that the roof is unable to support the load of a crystalline PV system, lighter thin-film modules could be an option. Finally, if the roofing installation and manufacturing warranties are still valid, determine if installation of a rooftop solar system could void the warranty.

Shading. Nearby buildings or trees can shade a roof during certain periods of the day, which will lower the power output of the solar PV system. Although shading changes throughout a year, observing the roof at various times during a day gives a fair idea of the typical number of sunlight hours.

Aesthetics. Check that the solar PV modules would not negatively affect the aesthetics of the building. From street level, solar modules will be more visible on a sloped roof than on a flat roof. If they will be seen, find out if there are any local building restrictions preventing a visible rooftop solar PV installation. With growing support for the use of renewable energy, guidelines are being modified, where necessary, to allow rooftop solar installations.

Roof leasing. If planning to lease the roof space to the owner of the rooftop PV system, consult a legal advisor who would be able to confirm whether that type of arrangement is permissible.

Electrical load. Obtain the current and expected electrical load of the building or facility. Should the load be comparable to or less than the electricity generated through solar PV, plan a smaller system or plan to use the excess energy—either store the energy in batteries, send it to another building within the facility, or feed it into the grid.

These aspects can easily be incorporated into the design of a new building. However, the investigation will take more effort for solar installations on a preexisting roof. Box 2 describes

ADB's site assessment, in the context of the site being on the roof of an older building.

RPV Market Potential:

Market can be estimated as bellow:

.Total house hold in bd

107 % having flat, concrete roofs

Area per average roof

.Total institutional rooftops in bd

% having flat, concrete roofs

Area per average roof

.Total rooftop area suitable for PV

.Size of one PV panel

The Calculation are based on Census 2011.

CHAPTER - 5

ESTIMATION AND CALCULATION

How much installed capacity could fit on the roof?

An estimate of the potential installed capacity of the rooftop solar PV system, C_R, in kilowatt-peak (kWp), may be made using the following equation:

where:

$$C_R = \left(\frac{C_M}{1{,}000}\right) \times \left(\frac{\text{RCR} \times A_R}{A_M}\right)$$

- A_R is the total roof area available for installation of solar modules in m^2,
- C_M is the individual module rated capacity in Wp,
- A_M is the area of one module in m^2, and
- *RCR* is the roof cover ratio, which is the fraction of roof area that the modules will cover.[7]

The roof area (A_R) should be the total area minus the footprint of any obstacles on the roof, such as helipads, water tanks, utility rooms, communication towers, and air conditioning systems.

For module rated capacity (C_M), we suggest obtaining up-to-date module specification sheets, since solar technology is continuously evolving. These module specification sheets are available for commercial solar modules from manufacturers and distributors.

A typical value for the roof cover ratio *(RCR)* is 0.3(for residential) and 0.6(for institutional), which would allow for 70% of the roof to be free for spacing between modules and away from obstructions.

Calculation: Here ,I consider

C_M is 180 Wp
RCR is 0.3(30% for Residential)
RCR is 0.6(30% for Residential)
A_M is 0.97 m^2

$$C_R = \left(\frac{C_M}{1{,}000}\right) \times \left(\frac{\text{RCR} \times A_R}{A_M}\right)$$

C_R is 0.046 A_R (for Residential)*

C_R is 0.092 A_R (for Institutional)*

Installed Capacity for Residential Area :

Division	Total House	House containing roof	Roof Area(m2)	Suitable roof area for solar(m2)	Installed Capacity (kwp)
Khulna	3708900	396852.3	53575060.5	16072518.15	739335.8349
Rajshahi	4455100	476695.7	64353919.5	19306175.85	888084.0891
Rangpur	3795900	406161.3	54831775.5	16449532.65	756678.5019
Sylhat	1762700	188608.9	25462201.5	7638660.45	351378.3807
Barishal	1822700	195028.9	26328901.5	7898670.45	363338.8407
Chittagong	5522900	590950.3	79778290.5	23933487.15	1100940.409
Dhaka	10516000	1125212	151903620	45571086	2096269.956

Installed Capacity for Institutional Area:

Division	Total House	House containing roof	Roof Area(m2)	Suitable roof area for solar(m2)	Installed Capacity (kwp)
Khulna	10400	4160	561600	336960	31000.32
Rajshahi	10800	4320	583200	349920	32192.64
Rangpur	7900	3160	426600	255960	23548.32
Sylhat	7900	3160	426600	255960	23548.32
Barishal	6500	2600	351000	210600	19375.2
Chittagong	30600	12240	1652400	991440	91212.48
Dhaka	50400	20160	2721600	1632960	150232.32

Total installed capacity in Bangladesh:

Installed Capacity for Residential Area	6296026.012KWp
Installed Capacity for Institutional Area	371109.6KWp
Total installed capacity in Bangladesh	6667135.612KWp or 6.66GWp

Limitations:

This is the Installed Capacity not the output power. So Output may vary.

- Solar radiation is not in consideration. Solar radiation is not same in all over the country.
- All houses are not in south facing.
- All the roofs are not in suitable condition to install RPV.
- There may shades in some roofs.

Total Installed capacity in Bangladesh considering limitations:

If we consider the limitations and reduce15 % of total installed capacity then the total installed capacity would be **5.66** GWp.

CHAPTER - 6

FUTURE WORK AND CONCLUSION

Here I Estimate the total installed capacity for all over the country in Bangladesh without considering various factors that I discussed in our limitations. If anyone can maintain the following procedure then total installed capacity can be calculated perfectly.

Site Assessment:

- Is the roof suitable for installation of solar PV?
- Is the solar resource high enough?
- How much installed capacity could fit on the roof?
- How much energy could that system deliver?

Legal and Regulatory Frameworks:

- Are there statements of government support for renewable energy and/or solar energy?
- Who are the stakeholders involved in renewable energy development?
- How are laws and regulations enforced?
- What entities are legally able to develop a renewable energy project?
- What are the electrical and grid codes by which the project must abide?
- What are the building codes and local zoning laws by which the project must abide?
- What kind of incentives are available?

Financing Options:

A system can either be purchased and financed directly or through a third party (via solar leasing or power purchase agreement).

Both options require estimating the net investment cost as a first step. This can be achieved using readily available information, such as indicative quotes or values for similar projects. If a market for PV systems has not been established in the country, it may be necessary to obtain proxy costs from markets in other countries.

The net investment cost is the cost of the system minus any cost offsets. The cost of the system includes the components and labor for design and installation, operation and maintenance, interest on loans, plus the cost of any required permits. Cost offsets would include tax credits, incentives or rebates, annual electricity savings, and any revenue from leasing the roof.

Site Characterization and Assessment:

- roof latitude, longitude, elevation, and orientation;
- floor plan of roof deck, with dimensions and total area;
- access to roof for installation and maintenance;
- competing uses of the roof, and proximity restrictions of the solar array from these uses;
- roof plan showing area usable for the solar installation, total calculated usable area, and slope;
- roofing materials, possible mounting connection points, and restrictions to mounting, to aid with selection of mounting method (mounting systems are further discussed later);
- shading analysis, by structures on the roof and nearby structures (detailed later);
- any restrictions for aesthetic purposes;
- specifications of the strength of the mounting system required to:
- comply with building or electrical codes for solar panels, and
- meet wind speed (jet blast) rating requirements for helipads, if present; and
- structural plans for the building and load capacity of the roof.

Shading Analysis:

It is vital to understand the shading on the rooftop, particularly in urban areas where surrounding buildings and structures can cast shadows on the roof. Even a small portion of shading on a PV array can significantly reduce output because of how the panels and array are electrically configured.

Ideally, all portions of the roof should be unshaded for at least 6 hours a day, preferably between 9 a.m. and 3 p.m. The shading analysis has to be carried out for all sunshine hours throughout the year to account for the seasonal variation of the sun path. This helps in the selection of the best location to mount the solar modules and gives a more accurate estimation of the annual output of the PV system.

Shading analysis methods range from simple manual methods to more complex three-dimensional (3D) rendering. This handbook explains both methods.

So finally we can say that with considering the limitations reducing 15% of total estimated installed capacity We can get 5.66 GWp If we pay attention in the following topics:

- Feed in tariff will be introduced so that people feel interest to install RPV.
- Quality power will be ensured.
- RPV will be familiarized.
- Maintenance will be in proper way.

CHAPTER - 7
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