Feasibility Analysis of Urban Solar System and A Proposition of Renovated Design in Context of Bangladesh

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Authors:

Saadman karim (12321011)

S.M. Rahin Islam (12121076)

Md. Shariful Islam Sumon (12121133)

Rida Al Kazim (12321020)

Supervisor:

Avijit Das

Lecturer

Dept. of EEE, BRAC University

BRAC University Dhaka, Bangladesh

BRAC University

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Declaration of Authorship

We hereby declare that this thesis paper is based on the results found by our research work and other researchers are mentioned by reference. This thesis has not been submitted before for any degree.

Saadman Karim

S.M. Rahin Islam

Md. Shariful Islam Sumon

Rida Al Kazim

Date

Certificate of Approval

This undergraduate thesis report entitled "Feasibility Analysis of Urban Solar System and A Proposition of Renovated Design in Context of Bangladesh", submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the Bachelor of Science, has been evaluated by the panel of examiners with a mark of ________________ .

Board of Examiners:

____

Avijit Das

Lecturer, Dept. of EEE, BRAC University

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Finally, we take this opportunity to express the profound gratitude from our deep heart to our beloved parents for their love and continuous support both spiritually and materially.

Abstract

Daily headlines make everyone aware of the dangerous long-term effects of power generation from the fossil fuels. It is widely believed that continuing to depend on fossil fuels to generate electricity can cause serious environmental problems. Moreover, fossil fuels are finite in amount and cost a lot of money as well. Hence, renewable energy is a potential solution to meet up electricity demand for the developing countries like Bangladesh. Among all the renewable technologies, solar photo voltaic (PV) is the most potential, favorable and promising one which converts solar energy into electrical energy, including or excluding battery backup.

Although solar technology has nearly been successful in rural areas where most of the technologies are adopted based on Solar Home System (SHS), it has not yet been effective in urban areas after the imposed rule of meeting 3% of light fan load of a building. We have investigated the installed solar rooftop of 25 houses in Mirpur, Dhaka where the solar system of most of the houses were found inactive. Among them only 13 systems are active. In this thesis the overall analysis of urban solar prospect has been done in three layers based on this investigation. A comparable discussion on cost efficiency of different solar panels has been given depending on amounts of loads being run. Efficient batteries are modeled by HOMER in context of Bangladesh to improvise PV systems. A cost analysis has been performed by software HOMER for different types of watt peak ranges. Apart from these, a renovated design of solar system has been proposed to make urban rooftop solar installation effective and successful.

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Abbreviations

DPDC	**D**haka Power **D**istribution **C**ompany
SHS	**S**olar **H**ome **S**ystem
IDCOL	**I**nfrastructure **D**evelopment **C**ompany **L**imited
PDB	**P**ower **D**evelopment **B**oard
BREB	**B**angladesh **R**ural **E**lectrification **B**oard
REP	**R**enewable **E**nergy **P**olicy
LGED	**L**ocal **G**overnment **E**ngineering **D**epartment
HOMER	**H**ybrid **O**ptimization **M**odel for **E**lectric **R**enewable
PO	**P**artner **O**rganization
CC	**C**harge **C**ontroller
GOB	**G**overnment of **B**angladesh
OCV	**O**pen **C**ircuit **V**oltage
SCC	**S**hort **C**ircuit **C**urrent
MPP	**M**aximum **P**ower **P**oint

‘Dedicated to our beloved parents’

Chapter 1

Introduction

What is Energy? The simplest answer of this question is- Energy causes things to happen around us. Look out the window. During the day, the sun gives out light and heat energy. At night, street lamps use electrical energy to light our way. When a car is driven by, it is being powered by gasoline, a type of stored energy. The food we eat contains energy. We use that energy to work and play. So *"Energy Is the Ability to Do Work"*. Energy can be found in a number of different forms. It can be chemical energy, electrical energy, heat (thermal energy), light (radiant energy), mechanical energy, and nuclear energy. Energy is considered as one of the most important strategic inputs for development and industrial growth. In context of developing countries like Bangladesh, energy crisis is considered as a great problem in the path of future infrastructure development. It is also regarded as one of the widely discussed and concerned issues that is causing a lot of controversy as presently used conventional fossil fuels are the greatest pollutants and largest contributors of greenhouse gases. Whether you believe there are hundreds of years or just a few decades left of this resource, the fact remains that it is a finite resource. At some point, fossil fuels are going to either be gone or they are going to become too expensive to realistically use. It is a very common matter that the presently used conventional fossil fuels are not unlimited in quaintly. Rapid use of fossil fuels and enhanced environmental pollution as a result we now have no other choices but using renewable power sources for electric power generation. Renewable energy technologies are clean sources of energy that have a much less environmental impact than conventional energy technologies. In developing country like Bangladesh, it is therefore necessary to investigate the prospect of renewable energy sources especially solar energy that do not pollute environment, keep it clean and safe for our next generation.

Using Renewable Energy Technology for solving energy crisis in Bangladesh has received increasing attention in recent times. Many Researchers have devoted themselves for finding an economic solution to fight against the depletion of natural resources, responsible for electricity production in Bangladesh through different renewable energy sources like Solar Photo-Voltaic energy, Wind Energy, Biomass etc.

One of the great challenges facing society today is the supply of low-cost, environmentally friendly energy sources that can meet the growing demands of an expanding population. Photovoltaic power has the potential to meet these needs, since the amount of radiation striking the earth's surface is 1.76x10^5 terawatts (TW) and current world usage is estimated at 15 TW [2]. With respect to other renewable and nonrenewable energy resources, however, the cost of photovoltaic modules continues to be high, and cost per Watt remains the driving force behind much of photovoltaic research. Concurrently, nanophotonics has emerged as a widespread area of research, with focus on both fundamentals of light control at the nanoscale and applications to devices. Sub wavelength nanostructures enable the manipulation and molding of light in nanoscale dimensions. By controlling and designing the complex dielectric function and nanoscale geometry, the coupling of light into specific active materials can be controlled, and macro scale properties such as reflection, transmission, and absorption can be tuned. Applying the methods of nanophotonics to solar cells allows for the possibility of shrinking the absorbing layers while maintaining high levels of absorption, which enables higher efficiency, low cost, stable photovoltaic devices.

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 Exa Joule (1EJ=1018 J) or approximately 15TW (1.504*1013 W) [2]. Almost 80%-90% of this energy came from fossil fuel. From the sun earth receives 3,850,000 EJ of energy. Which is equivalent to 174 Peta Watts (1 PW=1015 W) [2]. 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 greenhouse effect, other environmental impact, cost, risk and availability solar energy has the greatest potential among all the energy sources.

We know that geographically Bangladesh is in semi-tropical region of the north eastern part in South Asia, we get the direct sun light for the whole year which is very favorable for solar photo-voltaic based electricity production. Understanding the future prospect and many opportunities of solar technology, Government of Bangladesh along with other concerned organizations are trying to solve the problem of energy scarcity through promoting and popularizing solar home systems (SHS) in both the urban and rural areas of the country. It is high time to think in a pragmatic way over the matter so that burden on the conventional fossil fuel is reduced to great extent and grid pressure is reduced for reliable and safe generation of electricity. Developed and developing countries around the world are aware of solar energy advantages and they are trying to use it every possible way, because in one sense it is a free energy which people can convert easily without hamper the environment.

Solar System is the most efficient one due to its easy installation process. It basically consists of solar panel, lead acid battery, charge controller and inverter [1]. Being the most feasible one to install, urban solar home system has now become a necessity for solving the energy crisis and decreasing the pressure on national Grid. However, feasibility analysis is a must for urban solar home system due to easy access to Grid for this area. Different theoretical [1] analysis has already been done for finding out the best economic solution; on the other hand different software packages [2] are also available for solar resource evaluation. To develop an efficient SHS most considered things are- the hourly energy demand, resource availability and energy production needs have to be considered. Therefore, the renewable energy-based system optimization tool developed by the US National Renewable Energy Laboratory (NREL) is mainly used for designing urban solar home system with perspective to different geographic locations [3],[4],[5]. In addition, the feasibility analysis is required against the Grid Energy. [5] Moreover, lack of efficient equipment like inverter and charge controller hampers the proposed Grid Connected System due to mostly frequency deviation from the Grid frequency. And the system efficiency fully depends on the efficiency of the system components. To use high quality batteries or highly efficient inverter for designing a solar home system with context to Bangladesh, which are not available in Bangladesh, is one of the major facts for solving energy crisis.

We focused on the already established solar photo-voltaic systems especially in the urban areas, what their condition actually is, how they are serving the city consumers. Based on the data that we found in our survey as a part of our thesis work, an economic architecture and renovated design is proposed in this thesis. This attractive attribute consists of modification of Renewable Energy Policy of Bangladesh to encourage the city dwellers for towards a green energy solution of the present energy crisis in Bangladesh and to prevent the upcoming depletion of present reserve of natural resources for a better future of urban areas.

Chapter 2

Energy: Scarce Resource and Barricade to the Development of Bangladesh

2.1 Present Scenario of Power Generation in Bangladesh

Since the settlement of the power generation, distribution and transmission system structure in Bangladesh after the division in the year of 1947 and after the time of independence in 1971, a certain deficit between the supply and demand of electricity existed and the situation is still continuing [6]. Different government, semi-government, autonomous organizations including statutory bodies are in charge for the operation and monitoring of the all the three major parts of the power systems of Bangladesh generation, distribution and transmission but it's a matter of sorrow that the deficit between supply and demand still exist.

Several generating units including some quick rental power plants from which government buys electricity at a higher rate, generate the necessary amount electricity needed for the country. Most of the power plants in the generation system in the country are run by the conventional energy sources like natural gas, coal and other type of fuels. Energy situation in present days Bangladesh is extremely critical. A lion share of the generating units of Bangladesh is natural gas driven. In order to cope up with the ongoing electricity demand resulting from the drastic increase of population and momentary growth of industrialization, gas reserve has fallen in to an alarming level. And it is very much expected that remaining reserve may last for another 7-8 years unless any alternative reserve is discovered and used as early as possible.

Government of Bangladesh has taken a systematic approach towards renewable energy development. In line with the Government approach Bangladesh Power Development Board formed the "***Ddirectorate of Renewable Energy and Research & Development***" in 2010. Since the very beginning of establishment the directorate is dedicated to keep a sign for the enhancement of Renewable Energy use in power sector. There is a good scope for solar, wind, biomass, micro-hydro power generation in Bangladesh. BPDB has taken systematic steps for developing Renewable Energy projects as well as implement and promote Energy Efficiency Measures for the last few years to achieve the target of the Renewable Energy Policy 2008. The directorate is established for feasibility study, planning, evaluation, examination, monitoring of such projects and to perform necessary research based works in relative fields. Present manpower of the directorate consists of the director, two deputy director, five assistant engineers and six staffs.

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 [7]. 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 [7]. 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 [7].

According to BPDB, its operation started with Installed Generation capacity of only 200 MW. Installed Generation capacity (April' 2016) has increased to **12,365 MW** [7].As part of reform and restructuring a number of Generation and Distribution companies have been created. The subsidiaries of BPDB are:

- Ashuganj Power Station Company Ltd. **(APSCL)**

- Electricity Generation Company of Bangladesh **(EGCB)**

- North West Power Generation Company Ltd. **(NWPGCL)**

- West Zone Power Distribution Company Ltd. **(WZPDCL)**

The BPDB is responsible for major portion of generation and distribution of electricity mainly in urban areas except Dhaka and West Zone of the country. The Board is under the Power Division of the Ministry of power, Energy and Mineral Resources, Government of Bangladesh. BPDB has taken a massive capacity expansion plan to add about 11600 MW Generation capacity in next 5 years to achieve 24000 MW Capacity according to PSMP-2010 by 2021 with the aim to provide quality and reliable electricity to all the people of Country for desired economic and social development. The power system has been expanded to keep pace with the fast growing demand.

According to the statistical data of BPDB, responsible for the major portion of generation and distribution of the country, the present peak demand of the country is around 11,405MW and the generation is around 9,036 MW or less [7]. So as matter of fact the power shortage causes frequent power cut and excessive load shedding. At present, not all the people of the country have the access to electricity. Many remote rural areas are still not connected to the national grid. There are more than 87,000 villages in the country. Because of the low demand, dispersion of the localities, cost of production-transmission, especially the distribution of the electricity would be prohibitively expensive for these regions. 62% of the total population has access to electricity and the latest per capital power consumption is only 321 kWh [7].

Table 2.1: Total energy generation by public and private sectors according to BPDB (percentages)

Public Sector	**Installed Generation Capacity (MW)**
BPDB	4320
APSCL	904
EGCP	622

NWPGCL	440
RPCL	77
BPDB-RPCL JV	149
Subtotal	6512 (53%)
Private Sector	
IPPs	2875
SIPPs (BPDB)	99
SIPPs (REB)	251
15 YR. Rental	167
3/5 YR. Rental	1861
Power Import	600
Subtotal	5853 (47%)
Total	12365

Now if we focus to the usage of energy resource, we will see that about 72% of the nation's energy comes from traditional fuels such as fuel wood, animal biomass and crop residuals while commercial energy including hydro power supplies rest of the 28% [7]. All commercial fuels are imported except natural gas. Coal can be the potential source of generating electricity and also it is available in big amount in the country. But coal based electricity production is not economically feasible because of its deep position although a small percentage of the total generation is being produced by coal.

The latent potential of non-exhausted sources of energy in the form of solar, wind, biomass, biogas, wind power can be harnessed to ensure energy security, environmental sustainability. Understanding the inevitability of the renewable energy sources in various available forms, efficient use of it has been adopted as a policy by the government. The government has plans to generate 2,000MW power from solar-based facilities by 2021[7]. It was disclosed today (15th February) in a contract signing ceremony between Bangladesh Power Development Board and MKGE Consortium Ltd. Additional Secretary (admin) of Power Development Board (PDB) Mazharul Haque and Managing Director of HKGE consortium Ki Yang Li signed the agreement on behalf of their respective organization. According to agreement PDB will buy electricity at $0.17 per unit from MKGE Consortium's upcoming 32 megawatt (MW) of solar power plant [7]. The Build Own and Operate (BOO) basis solar power plant will be set up at Dharmapashaupazila in Sunamganj by next 18 month. The duration of the agreement is 20 year. Presently less than 200 MW of solar-based electricity is produced in the country [7].

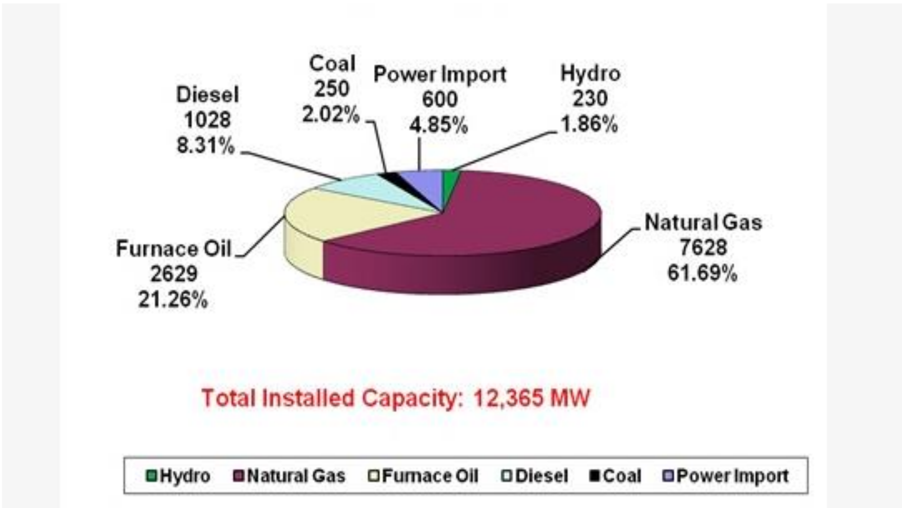


Figure 2.1: Total power generation scenario in Bangladesh (percentages)

2.2 Using Renewable Energy as an alternative Source

Bangladesh is a large and heavily densely populated country in South Asia, bordering Burma, India, Nepal and Bhutan. Bangladesh has an estimated 2016 population of 168.9 million. For poverty alleviation, rapid and sustainable economic growth, technological development energy more explicitly electricity is the most fundamental pre-requisite. The country has been facing severe power shortage for last few decades and it a matter of sorrow in next decades all our natural resources will finish and we fall in a deep ocean of shortage of resources, so now the time has come to think less about the natural resources and more about the renewable energy sources.

Our country is blessed with number of potential and renewable sources. Energy sources which are regenerated after a certain period of time cycle are generally known as renewable sources of energy. Commonly used renewable energy sources are Solar, Wind, Hydro, Biomass, and Biogas. In Bangladesh, solar energy, biomass, bio gas is being used since the time immemorial. Especially areas which are out of grid connection and gas coverage, use of bio gas for cooking, harnessing wind power and solar energy for drying of different grains and clothes is known to all. However for lack of proper technological advancement, policy enforcement and implementation, we are still lagging behind in promotion and mass use of renewable sources compared to other developed and developing countries in the world. Renewable energy is clean, sound and environment friendly. A brief over view of all the available renewable energy sources that are found in this country territory is provided in the section.

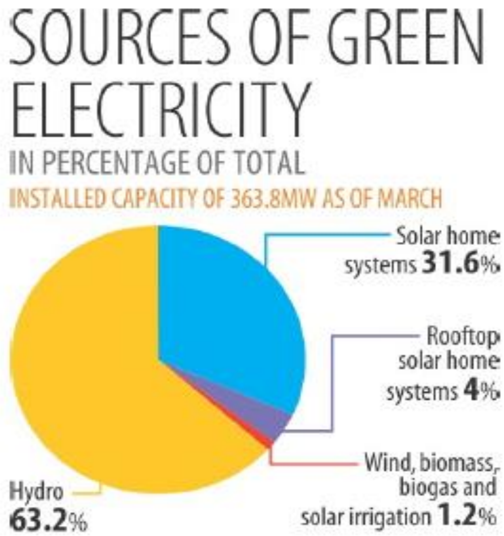


Figure 2.2: Renewable Energy Sources in Bangladesh according to Bangladesh Economic Review

2.2.1 Hydro energy

Hydropower is another kind of alternative energy that requires both water current and height to generate functional power. The system of this achievable energy is considered as conservation and absorption energy in the outline of automatic stream energy. Micro-hydro power is capable to produce up to 5–300 kW of electricity [7]. This is one of the simplest technologies, which transfers hydropower to mechanical power energy. The developing country like Bangladesh is very much suitable for Micro-Hydro technology and the cheapest technology as well. Many canals and branches of the rivers in Karnafuli, Shangu, and Matamuhuri are supposed to be good prospects for installing micro-hydro power along with the Chittagong Hill Tracts. Recently, the first micro-hydro power unit at Bamerchara, Chittagong, has been established by the Sustainable Rural Energy (SRE) under LGED [7]. However, only about 4 KW of electricity can be produced because of insufficient water current. In 1981, Bangladesh Water Development Board (BWDB) and Bangladesh Power Development Board (BPDB) in the year of 1981 explored potential sites, which are suitable for micro-hydro power generations [7]. Sustainable Rural Energy (SRE) has also

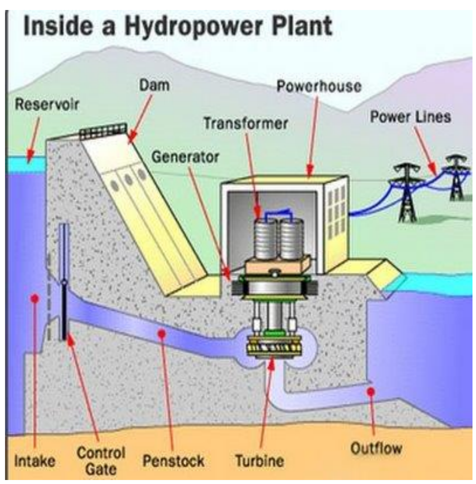


Figure 2.3: Inside of a hydropower plant

discovered some possible locations for micro-hydro sites in Chittagong areas in 2004.It is clear that there is immense option of generating electricity from the micro-hydro energy. However, unfortunately, Bangladesh has been unable to generate power energy from the hydro energy.

The total hydropower potential of Bangladesh in the three locations (Kaptai, Sangu and Matamuhuri) is about Gwh/year (755MW) of which 1000GWh/year (230MW) has been harnessed at Kaptai through 5 operational units of hydro power plants. For obtaining the advantage of hydro power, proper attention should be imparted for its further development. BPDB has submitted a proposal to the government to install a 25KW power plant at the Teesta barrage [7]. Further analysis can open a new door of success in this regard. The Bangladesh Water Development Board (BWDB) and Power Development Board (PDB) carried out a joint study for the future prospects of micro-hydro power potentials in the country. If by dint of proper planning, we can make the best use of hydro power electricity then the whole nation can be benefited to a great extent from the view point of energy security and energy reserve.

Table 2.2: Potential small hydro sites identified by BPDB and BWDB in Bangladesh

District	**River/ Chara /Stream**	**Potential of electrical energy (kW)**
Chittagong	Foy'slake	4
Chittagong	ChotoKumira	15
Chittagong	HinguliChara	12
ChittagonghillTrack	Sealock	81
Chittagong	Lungichara	10
Chittagong	Budiachara	10
Sylhet	NikhariChara	26
Sylhet	MadhabChara1500ft.fromfall	78
Sylhet	RangapaniGung	616
Jamalpur	Bhugai-Kongsaat2milesU/SofNalitabariP.S	69 kW for10 months 48kW for 2months
Jamalpur	MarisiatDukabadnearJhinaigatiThanaHeadquarter	35kW for 10months 20kW for 2months

Dinajpur	DahukatBurabari	24
Dinajpur	ChawaiatU/SofChawaiL.L.P	32
Dinajpur	TalamatU/SofTalamL.L.P	24
Dinajpur	PathrajatFulbari	32
Dinajpur	TangonatD/SofNargunL.L.P	48
Dinajpur	PunarbhabaatSingraban	11
Rangpur	BuriKhoraChikliatNizbari	32
Rangpur	FulkumaratRaiganjBazar	48

2.2.2 Wind Energy

The technology of wind energy is to exchange the airflow into motorized force, which is ultimately transformed into electricity. Bangladesh occupies huge highlands and islands in the Bay of Bengal and 724 km long coastlines, which may bring enormous potentials for power generation from wind energy, especially in the monsoon seasons as strong south and southwesterly monsoon air usually flows from the Indian Ocean over the Bay of Bengal and enters over the coastal regions. These winds propel from March to September where its monthly average speed is 3–6 m/s [10]. It is observed that the wind rapidity accelerates once it enters the V-shaped coastlines of the country. In recent the improvement of wind rotor aerodynamics made it easy to extract power even from lower wind speed of 2.5 m/s. According to research studies by BUET, BCAS, LGED and meteorological department, winds are obtainable in Bangladesh generally during the monsoon and sometimes couple of months before or after the monsoon. Bangladesh Centre for Advanced Studies initiated one-year data, which focused on 50 m height's turbines in the coastal regions which differ by the wind force that varies between 4.1 and 5.8 m/s whereas the energy density is about 100–250 w/per m2.Power generation from coastal wind can be transferred to different areas throughout the country through the high voltage transmitted connections [7]. There are lots of the economic aspects as operation and maintenance cost is very little throughout the full lifespan of wind turbines. Therefore, the deficiency of energy power might be compensated with the help of wind power plants along the coastal regions. As the wind force alongside the Bay of Bengal is relatively higher, the wind turbines such as from Kuakata, Sandwip and St. Martin islands can be considered as the prospective areas for wind energy power. It is apparent that many people on these islands are fishermen and unable to get access to the electricity from the national grid. Therefore, wind energy in the coastal areas can be an efficient solution of power energy and electricity generation as there is a sound advantage to set up wind turbines and develop wind energy in the coastal regions. To verify the potentiality of renewable sources for power generation, small-scale wind turbines can be set up in the regions like St. Martins Island, Patenga, Bhola, Barguna, Dinajpur, Thakurgaon and Panchagar.

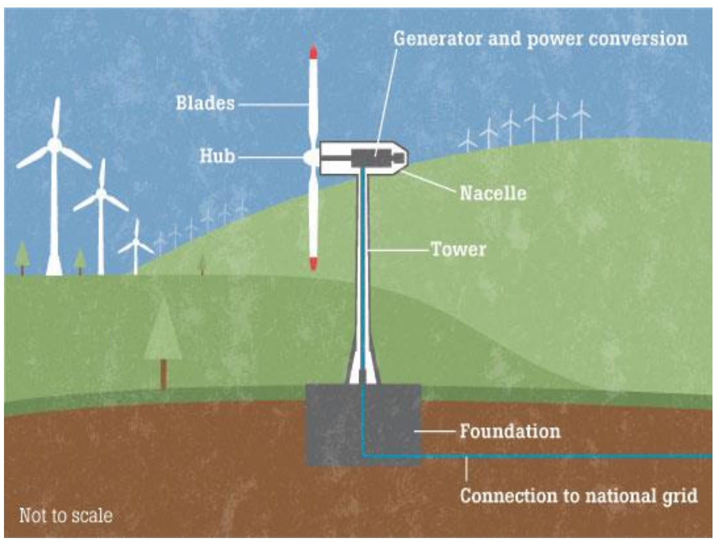


Figure 2.4: Wind mill topology in Bangladesh

However, some wind energy power sources from different institutions are available in Bangladesh, but their contribution to the national grid is negligible. Therefore, government intervention is greatly required in this regard.

Table 2.3: Wind conditions at different places in Bangladesh.

Site	**Reference height (m)**	**Annual average wind speed (m/s)**
Teknaf	5	2.16

Cox's bazaar	10	2.42
Patenga airport	5	2.45
Kutubdia Island	6	2.09
Sandip Island	5	2.16
Hatia Island	6	2.08
Bhola Island	7	2.44
Khepupara	10	2.36

Table 2.4: Wind turbine installations in Bangladesh by different organizations

Organizations	**Type of application**	**Installed capacity (Watt)**	**Location**	**Present status**
Grameen Shakti	3 Hybrid	4500	Grameen offices in the coastal region	Functioning
	Hybrid	7500	Cyclone shelter in the coastal region	Functioning
BRAC	Stand-alone	900	Coastal region	Functioning
	Hybrid	4320	Coastal region	Functioning
Bangladesh Army	Stand-alone	400	Chittagong hill Tracts	Functioning
IFDR	Stand-alone	1100	Teknaf	Functioning
	Stand-alone	600	Meghnaghat	Functioning
LGED	Hybrid	400	Kuakata	Functioning
	Total	19720		

2.2.3 Biogas

Biomass can be considered to be the largest energy source in Bangladesh. About 70% energy consumption of its total production is being supplied by the elemental energy for cookery and warming of pastoral household [7]. Biomass consists of varieties of natural and organic substances from fuel wood to aquatic foliage. There are many existing technologies available for biomass energy translation into electrical and heat energy. There are two types of extensive technologies available, which are the direct ignition and gasification. The straight ignition process occupies the corrosion of biomass with surplus air, creating warm chimney gases that result in generating steam, which is finally, applied for power generation. In contrast, gasification rivets biomass conversion producing a low and low medium calorific gas and then obtained gas is utilized in combined-cycle power to fuel generating plants. It is recognized from the literatures that up to 40% electrical translation efficiencies are achievable as about 30 MW in a short period. Typically, bio-gas refers to the gas produced by the biological breakdown of the different organic matter in the absence of oxygen. Country like Bangladesh, where the major portion of economy relies largely on the agro-based production, there exists a huge potential for utilizing biogas technology. Raw materials for biogas production are easily and cheaply available everywhere. Different NGOs along with government are working together for power production from biogas recently. Among them, Grameen Shakti can be mention in this field. They have settled 13,500 biogas plants across the country. Besides this, a government owned Infrastructure Company named IDCOL along with other organizations installed 18,713 biogas plants since May, 2011 [10]. Cost is the most dominant factor limiting the wide application of biogas based energy production. Proper planning, technology and economic assistance is needed to make this technology a more fruitful and popular mean of getting electricity among the people. Various feed stocks such as organic domestic waste, manufacturing waste, fertilizer, sludge, and others have been demonstrated and pertained commercially by the anaerobic digestion of biomass. Bio-gas comprises of 40–70% of CH_4, 30–60% of CO_2 and 15% other gases [10], which are generated from creature compost and poultry fertilizer in specific bio-digesters. Therefore, produced gas is burnable as well as usable for the generation of electricity. Bangladesh is a country where its main agricultural production is rice and average production is about 35,000,000 MT per year. If 20% of the produced rice (i.e. 7000,000 MT) could be turned useful for biomass, then the biomass power generation from rice husk can be more imperative [7]. In addition, Bangladesh is an agro-based country which produces a variety of waste products that can be turned into biogas energy which is economically profitable and may support to overcome the national power crisis. Moreover, a total of 436 tons recyclable industrial waste is managed every day in Bangladesh. Furthermore, per day 3054 tons wastes is projected to obtain by 2015 and collective dumping capacity is expected to 9 million tons by the end of 2015 [10]. The technology option to convert waste to energy might be an alternative option to support power at the national level. Though some of the rural people are using a small scale of electricity derived from their livestock's wastes for daily household work, government should focus on the issues and it should be commercialized connecting to the national grid where still no electricity is available in the rural areas. However, there are some biogases and biomass energy power sources from different institutions available in Bangladesh, but their input to the national level is insignificant. Therefore, government intervention is also greatly required in this regard as the rural power source is a concern.

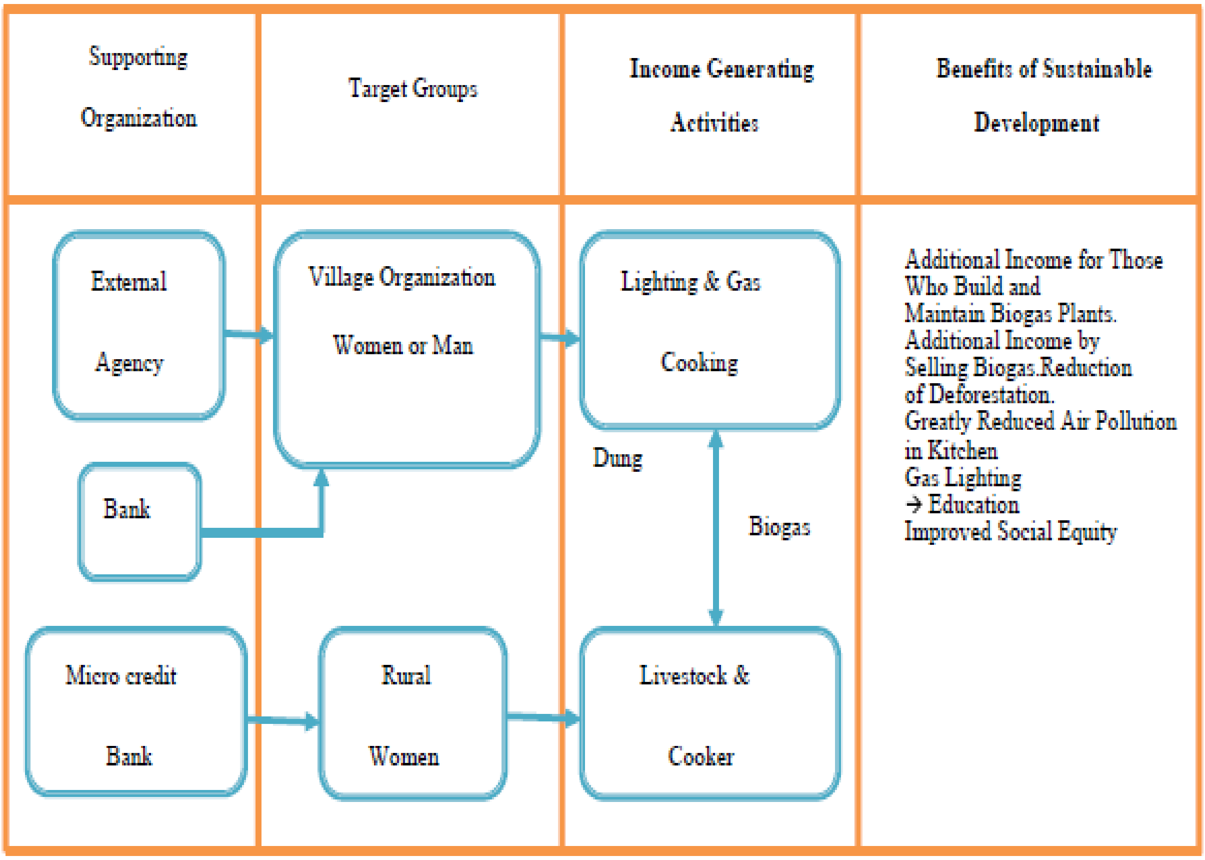


Figure 2.5: Biogas consumption in Bangladesh under NDBMP

2.2.4 Solar Energy

Of the different forms of renewable energies in Bangladesh, solar energy is the most popular and the effective one and compared to any other form of renewable sources solar energy has brighter prospect from application point of view. The energy received by the earth surface form the sun in the form of radiation is known as solar energy. Solar radiation is strongly dependent on the atmospheric condition, time of year, the angle of incidence of sun rays on the earth surface and other related geographical aspects. Bangladesh could possibly meet its unprecedented energy demand as well as increasing energy security through their progression by acknowledging the potential of solar-energy resources. Therefore, as an alternative of present energy crisis scenario, solar energy such as solar photovoltaic (PV) can resolve a portion of power demand with accompanying deficiency and problems. Bangladesh is positioned between 24º0'0″ N latitude and 90°0'0″ E longitude, which is an ideal position for preserving solar power. The unit price of PV, manufacturing and installation cost have been decreasing over the years, and that is the advantage for investment as an economic scale for a developing country like Bangladesh. Recent literatures on solar photovoltaic (PV) suggest that the daily average variation of solar discharge fluctuates following the pattern of dry and wet seasons in Bangladesh from 4 to 6.5 kWh in a square meter [11]. The highest level of radiation is accessible from March to April whereas the least from December to January and the average sunlight hours vary between 6.69/7.6 h, 6.16 h and 4.81 h respectively in winter, summer and monsoon seasons. The projected value of solar radiation is the highest in the month of March–May, where 1 (one) square meter area occupies the potential of producing 4–5 kWh/m2/day. The maximum sunlight hours recorded in Khulna differ from 2.86 to 9.04 h whereas in Barisal it varies from 2.65 to 8.75 h [11]. Therefore, Bangladesh has a great prospect to use solar energy not only as a direct production system but also as the accessible infrastructure together with combined cycle power station. There are some NGO's such as IDCOL, Grameen Shakti, Rahimafrooz and Energypac which are promoting the solar technology for power generation. Infrastructure Development Company limited (IDCOL) followed by RSF, BRAC and Srizony Bangladesh has contributed the maximum effort by installing 1,320,965 solar home systems (SHSs) with a capacity of 36.5 MW until January 2012 [7]. The number of installation of solar plant in Bangladesh is impressive considering the growing development as such by (a) Dhaka 346,161 (b) Chittagong 257,578 (c) Barisal (d) Rajshahi 185,267 (e) Khulna 146,388 and Sylhet140, 386 units but installed capacity is very little compared to the national power demand. Currently, the cost of PV technology is a vital question to afford for a least developing country like Bangladesh, even though geographical position is ideal for preserving solar power and the technology of PV is extremely capable to switch daylight into electricity. We comprehend from the literature that Bangladesh can be very prospective for generating solar energy in the near future for its geographical location. Even solar thermal power plant can be introduced to the northern provinces of Bangladesh where the solar intensity is very high. Therefore, as the issue is concerned for the long-run policy issues, appropriate integration of action plans, national budget, subsidy issues and national energy planning would be understood to eliminate the policy gaps. Apart from all these issues, the mass use of solar energy has not yet got popular acceptance as a commercial energy throughout the country for lack of technological advancement, absence of proper policy and implementation of the present policy. But still, government is willing to make it popular among the common people and proposed a renewable energy policy (rough Renewable Energy Policy, 2014) where more emphasis has given in to the solar energy. Moreover government and many other relevant organizations are trying to strive the address the problem of energy crisis through promoting solar home systems (SHS) in both the off grid rural areas and on-grid urban areas of the country.

IDCOL has financially supported different NGOs in the installation of solar home systems (SHS) and a total of 1,320,965 SHSs with a capacity of about more than 36.5 MW have been installed up to February,2012. Besides, BPDB has implemented an excellent solar PV based electrification project in the Chittagong hill tracts region. A 10 KW AC solar PV system has been installed in one selected market in each of the three sub-districts of Rangamati district. Other than these, governments proposition of installing 3% of the light and fan load driven by solar PV system for getting utility connection is also having an impact in the urban areas though the outcome of the proposition is not that much positive.

In our thesis, we actually worked on the problems of installed solar systems in the urban area and proposed some effective, renovated, economically feasible design so that consumers can get the positive effect from these new systems other than suffering.

Besides using in the household electrification, solar PV based technology can be used in the solar based recharging stations for the electric vehicles, in the roof top of the filling stations where the roof top is at in most of the cases and PV systems can be installed to track maximum power by adjust the inclination angle of the module. Only proper planning, mass awareness, using technological prospects in line with the country’s economic ability can make the best use of solar

Figure 2.6: Solar AC System (Off Grid) installed at Mawna, Gazipur

energy based photovoltaic systems across the country and can therefore lessen the grid pressure to a great extent which will also decrease the dependence on conventional fossil fuel.

Figure 2.7: Solar Arrays of 10 kWP Centralized AC Market Electrification System at BarkalUpazila under Rangamati District

2.3 Solar: The best form of energy

The measure of development in any society of today is synonymous with the level of energy consumption. Energy is therefore recognized as a critical input parameter for national economic development. Modern day energy demands are still met largely from fossil fuels such as coal, oil and natural gas. In 1980, the global primary energy demand was only 7228 million ton of oil equivalent but this had increased to 11,429 by 2005. Further increases can be expected, mostly in connection with increasing industrialization and demand in less developed countries, aggravated by gross inefficiencies in all countries. Fossil fuels provide energy in a cheap and concentrated form, and as a result they dominate the energy supply. In total energy demand, the share of fossil energy is around 80%, while the remaining 20% are supplied by nuclear and renewable energy. In 2005, a total of 26.6 billion tons of CO2 emissions were generated world-wide of which more than 41% was from power generation based on fossil fuels. The CO2 emissions from power generation are projected to increase 46% by 2030. In 1980, total global electricity generation was 8027 TWh, which had increased to 17,363 TWh by 2005. The installed capacity of power generation was 1945 GW in 1980 and had increased to 3878 GW by 2005 of which almost 69% was from conventional fuels. The main problem is that in the next 20 years the expected demand for electricity would require the installation of the same power generation capacity that was installed over the entire 20th century. This translates to the stunning number of one 1000-MW power station installed every 3.5 days over the next 20 years the location of Bangladesh is an ideal location for solar energy utilization. Here daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. There is a good prospect of harnessing solar power in Bangladesh. Solar energy is derived from the sun through the form of solar radiation. Power generation with solar energy depends on Photovoltaic and heat engines. In our case as we are finding a solution for urban power shortage problem. Here in urban area wind, ocean, hydropower etc. are not possible to be used as a form of renewable energy to generate power. And among the rest we are going to work with Solar, as it is already being popular in our country. Solar energy, among all other renewable energy sources is the most diversified form of renewable energy. Sun's heat energy can be used for various purposes which make it versatile. Through technological advancement, we have the capability to tap solar energy and produce energy and then store it. Therefore solar energy seems to be the true alternative energy source we can turn to. Some of it is in the form of infrared and ultraviolet light, but most of it is in the form of visible light. Some of this energy falls on the Earth, where it warms our planet surface, drives ocean currents, window, used by plants to make food etc. Life and Earth depends totally on the sun. Compared to any other renewable sources, solar has brighter prospect form application point of view. To a good approximation, the earth acts as a perfect emitter of radiation (black body). At the outer limit of atmosphere the total solar irradiation when the Earths mean distance from the sun is known as the solar constant. Solar radiation intensity is strongly dependent on the atmospheric conditions, time of the year, and the angle of incidence for the sun's rays on the surface of the earth. Solar radiation received at Earth's surface is quite different from extra-terrestrial radiation is important for utilization point of view. In general, the power from a radiant source falling on a unit area is called irradiance. On the contrary, Wind is basically created with the temperature changes. We also know that the wind blows from a high pressure area to a low pressure area. These changes in the temperature and pressure occur due to the difference in the amounts of heat energy received by different areas from the sun depending on the Earth's rotation. This energy in the form of wind can be converted into electrical or chemical energy, stored in the batteries. One wind mill can produce enough energy to power a house. However the electrical energy that is produced from the turbines is not enough compared to the energy produced from the fossil fuels. The disadvantage is that it is costly and not completely renewable; therefore a better way needs to be discovered to produce energy completely clean and eco-friendly. As the wind does not blow at a constant speed and there is no certainty about the wind direction and therefore the output is not efficient as it should be. Also, the wind mills subjected to a severe damage when struck by heavy rains and lightning storms can be subjected to heavy damage. Solar energy has some advantages over the other sources. Some of them are stated below:

1. Solar energy is non-polluting, clean, reliable and renewable source of electricity.

2. Solar cells make no noise at all and there are no moving parts in solar cells which make them long lasting and require very little maintenance. Solar energy provides cost effective solutions to energy problems where there is no electricity at all.

3. Solar cells generally do not require any maintenance and run for long time. More solar panels can be added from time to time when needed. Although, solar panels have initial cost but there are no recurring costs. Initial cost that is incurred once can be recovered in the long run and it doesn't create any offensive smell.

4. Solar panels are easy to install and require much less wires, cords or power sources. Unlike wind and geothermal power stations which require them to be tied with drilling machines, solar panels does not require them and can be installed on the rooftops which means no new space is needed and each home or business user can generate their own electricity.

Chapter 3

Potential Solar Home System (SHS) in Bangladesh

Solar home system are being used in the country over 4.5 million household level installation of 175 MW capacity (18th April 2016)[12]. The solar home system is both developed and implemented by BREB, LGED, IDCOL, GS, BSREA, BRAC, BGEF and much other organization. The potential of solar energy is so high within the country. The dissemination of solar home system (SHS) is being widely promoted by IDCOL, GS and BRAC through the practice of micro-financing and direct sales. Beside homes all the govt. and private offices are also encourages using renewable solar system to minimize the usage of electricity power from the grid.

3.1 Initiatives Taken by Bangladesh Government

To Progress the generation of electricity in Bangladesh through using renewable energy the government has undertaken some long term projects. Knowing the importance of solar photovoltaic (PV) systems, Bangladesh government has started their projects immediately to achieve the goal of electricity generation in Bangladesh. Some of the recent initiatives taken by the govt. and other organizations are as follows:

1. According to the renewable energy policy in December 18, 2008 the target has been set up, to generate 5% of the total electricity from renewable sources by 2015 and 15% of the total of electricity by 2020.
2. Adding 1,740 MW of solar power and 1,370 MW of wind energy capacity by 2021.
3. Installing 8, 00,000 SHS with the joint collaboration of government and non-government organizations (NGOs) so far in the rural and part of the number is in urban areas contributing 40.5 MW out of 47 MW coming from different renewable resources.
4. All types of VAT and taxes have been waived from solar panels to lessen the cost burden from the users and also from the importers.

5. Electricity from solar mini-grids is expensive for rural people when the grids are installed under private entrepreneurship. Therefore, Government has taken up different grid-tied solar park projects with a total capacity of 793 MW. They will be implemented by Government-owned utility companies or through private entrepreneurship. These programs are at different stages of implementation.
6. The Government of Bangladesh signed a $78.4 million additional financing from THE WORLD BANK to further scale-up support for the successful solar home systems (SHS) program of Bangladesh. The SHS program is currently installing over 70,000 solar home systems every month, making it the fastest growing SHS program in the world.
7. Infrastructure Development Company Limited (IDCOL) signed a Financing Agreement with Baraka Renewable Energy Ltd. (BREL) for a 168 KW solar mini-grid to be located at NoonerTek Island in Sonargaon of Narayanganj district. Total cost of the project is BDT 7.14 core of which IDCOL will provide 30% as soft loan and 50% as grant. IDCOL has received fund for financing such projects from the World Bank, DFID, JICA, KFW, ADB and USAID.
8. IDCOL, a government owned Non-Bank Financial Institution has a vision to finance 1550 solar irrigation pumps, 50 solar mini grids, 130 biogas based power plants by 2017[13]. It also aims to finance 6 million SHSs by the end of 2016.

3.2 Manuscript of Renewable Energy policy-2015

In the pursue of much sustainable solution for inspiring the solar home system in Bangladesh, The Government has tone down the Renewable Energy policy. Core points regarding the solar home system implementation from Manuscript of Renewable Energy policy-2015 is given below:
1. At present more than 80% (June, 2016) [21] of total population got access to Electricity. We have per capita of 378 KWh generation per year. The amount is not so much than the developed and developing countries of the world. Here in Bangladesh the urban habitant have more electric facilities than the rural. The large number of rural area is still getting no electricity. So, they have no access to modern standard of life. Moreover, the opportunity of using modern and standard fuel is becoming limited by the poor people.

2. The government has declared 500MW solar program for increasing the commercial use of solar energy. Which consist of solar mini grid, solar park, solar irrigation and roof top solar installation. It also include the solar electrification of remote places beyond reach of the grid such as educational institution, religious institution, union information center and health care centers.

3. The core objective of this policy is to bring the people under standard living of life, minimize the fuel pollution and reduce the cost of electricity by using power produced by the renewable energy sources to ensure 5% by 2015 and10% by 2030 renewable energy of total electricity production.

4. Beside SREDA other institutes are also contributing in Power division. Under Power division a directorate has been formed to help power division regarding consumption of fuel. DPDB and BREB also got such kind of directorate. The expansion of renewable is the main concern of these two organization. Various research activities are being arranged by many institutes like BUET, BRAC, DHAKA University, MIST, IUT and many others.

5. Grid connected electricity production, where produced electricity is sold toutilities or large buyer through national grid. Wind, solar, hydro, biomasspowers are all included to it.

6. Off grid, captive and standalone electricity production, in which residence, various government, semi-government and autonomous organization's offices are included and local as well as mini grid distribution management system where through solar PV or hybrid system or central solar PV system, electricity is allocated to large village or market. Electricity production methods through biomass or biogas such as live stocks, human wastes, small hydropower etc. are included.

7. The following categories of projects will be welcomed for private sectors:

- Independent Grid connected power project (IPP).
- Captive power project :
    a. Captive power project for own use
    b. Captive power project for selling extra power to utilities after own use
- The project of renewable energy in off grid regions (mini\ micro\ nano grid).

All the project of IPP will be taken to the grid connected region. Based on govt. /non govt. shareholding project will be taken in grid connected area. For Renewable fuel based electricity production following incentives is taken:

- To expand renewable energy within 2015 and 2030, target regarding renewable energy production fixed by the government will be fulfilled by government/SREDA. Bangladesh Power Development Board (BPDB) will purchase electricity from renewable fuel as unique electricity purchasing company. But power distribution utility will purchase electricity from 1 MW capacity power plant from entrepreneur directly.

- To deliver electricity in national grid produced from renewable fuel, metering point will be built by the entrepreneur organizations from own expense. If they need to use grid transmission line they will build grid transmission line and distributive utility next to metering point of their own expense. For this the entrepreneur organization will pay necessary whiling charge and payment due to system loss fixed by the commission.
- Incentives will be given to inspire solar rooftop installment in residences. Easy and low interest lending opportunity will be conducted by the IDCOL and other banking institutions for the solar rooftop installation.
- Tariff for the entrepreneur company of production will be fixed upon bargaining based on Feed in Tariff (FIT) applied by BERC. Benchmark price will be fixed based on various open tender price until FIT is applied by the BERC. Based on this benchmark price and considering the size, type and other peripheral expenses of the project the price of electricity will be fixed upon bargaining for the entrepreneur organizations of production. For cost-plus based tariff fixing the following issues will be considered:
    a. Capital cost
    b. Evacuation cost
    c. Tenure cost
    d. Interest on Loan
    e. Return on Equity
    f. Life of Plant, Machinery and Agreement Period
    g. Depreciation
    h. Debt-Equity Ratio

i. & M cost
j. Interest on Working Capital
k. Inflation Rate

3.3 Rural Electrification by Solar in Bangladesh

Approximately 75% of the total population lives in the rural area and only 42% of them have direct access to the grid electricity connection [14]. It is not possible to connect them to the existing grid connection neither economically nor technically because it is already overloaded with the existing connection. So, rural electrification must have to rely on renewable energy source considering economically and also as most available option. Considering all other resources and necessity, solar home system is the most available and affordable option for all. Most of the solar home system projects are extremely successful. As a result new projects are funding immediately to start their projects regarding the SHS programs .Presently a large number of rural and remote households are eagerly joining the Solar Home System (SHS) program. And also a large number of private entrepreneurs, IDCOL[14], BREB[15] and many others government and non-government organization are working very hard in Solar Home System(SHS) program to accomplish the goal of basic needs of electricity in our country.

3.3.1 The Associations working on Rural Solar Electrification

1. Bangladesh Rural Electrification Board (BREB)
2. Infrastructure Development Company Limited (IDCOL)
3. Local Government Engineering Department (LGED)
4. BRAC Solar
5. Grameen Shakti (GS)
6. Bangladesh Solar & Renewable Energy Association (BSREA)
7. Bright Green Energy Foundation(BGEF)
8. InGen Technology Ltd
9. Greenfinity Energy Limited

3.3.1.1 IDCOL: The most Significant one in SHS for Rural Areas

The Features of IDCOL (Infrastructure Development Company Limited) is as follows:

1. Government-Owned Financial Institution
2. Lead the promotion of private sector
3. Financing in infrastructure and Renewable Energy Sector

The main purpose of IDCOL SHS program is to meet the necessary electricity for the rural areas of Bangladesh so that the vision of Government's SHS program ensures the access of electricity to all the people of Bangladesh by 2021. More than 4 million SHSs have already been installed under the program in the off-grid rural areas of Bangladesh till April 2016[16].As a result, almost 18 million beneficiaries are getting solar electricity which is around 11% of the total population of Bangladesh. IDCOL has a target to finance 6 million SHS by 2017, with an estimated generation capacity of 220 MW of electricity [16].So far IDCOL have approved 18 Solar Mini-Grid Projects, among which 7 are operational while the rest are under construction. The mini-grid project has successfully created access to low- emission electricity for almost 5000 rural households in Bangladesh. IDCOL further targets to install 50 solar mini-grid by 2018[16].

Summary of IDCOL SHS Program

a. At present a total number of 56 Partner Organizations (PO) of IDCOL install SHS systems at the consumer household.
b. The electronic expense request is made by PO to IDCOL for refinance and grants, as possible.
c. Physical verification of the installed SHSs and Technical Standards committee (TSC) sets forth technical standard for the SHS equipment and approve solar equipment conducted by IDCOL.
d. IDCOL claims the funds used for financing from the World Bank, ADB, or IDB, and the grant from, KfW, GPOBA and GIZ.
e. To make the country self-sufficient in SHS technology and ensure reliable supply of solar modules at affordable cost, IDCOL published RFP on 6 October 2009 for setting up solar PV module assembling/manufacturing facilities in Bangladesh. In

response IDCOL received 23 proposals and after extensive due diligence financed 2 PV assembling plants with a combined capacity of 10 MW.

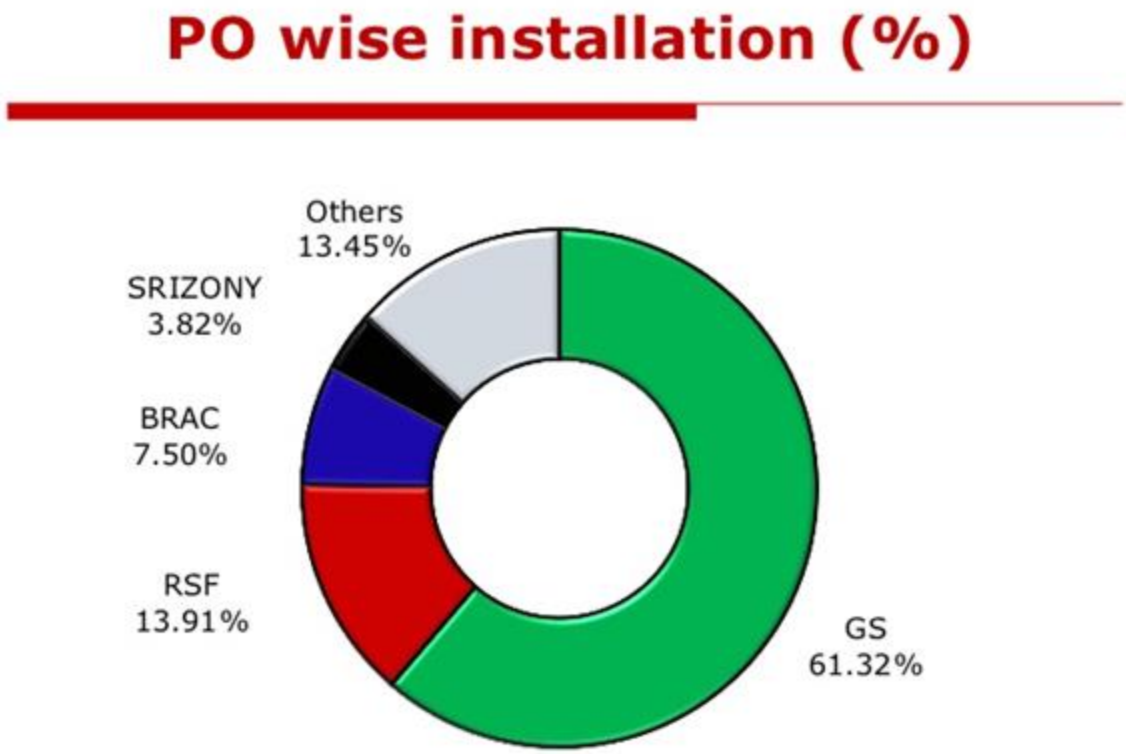


Figure 3.1: Po Wise Installation of solar home system.

IDCOL is the pioneer of the rural solar electrification by the cooperation of PO's. Gramen Shakti (GS) one of the leading PO's is playing the most important part among the others to make the solar home system affordable and acceptable to rural people. Figure 3.2 (a) and (b) shows the statistic of rural solar use and total sells of the PO's of IDCOL respectively.

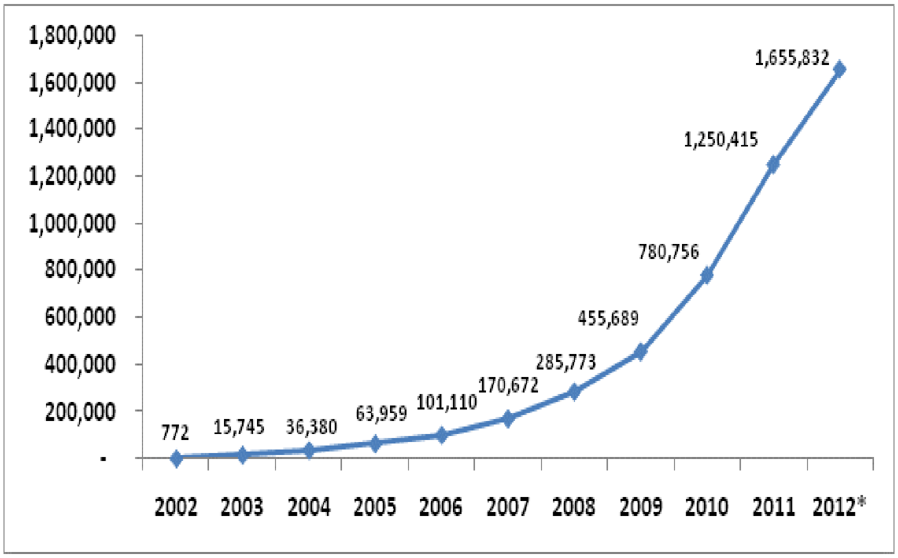


Figure 3.2: (a) Total SHS Installed in rural Area as of 2012 in Bangladesh.

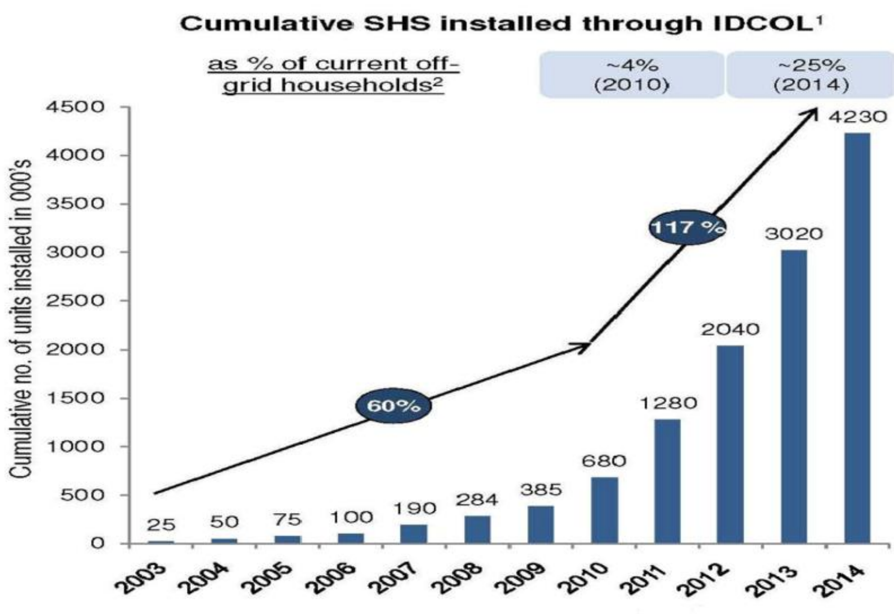


Figure 3.2: (b) Overall SHS Installed till 2014.

3.4 Urban Electrification by Solar in Bangladesh

In Order to accomplish the goals stated by the Government the ministry came up with the idea of installing solar panel for every new connection that demand more than 2KW electricity. According to the new renewable energy policy all the solar home system that will be installed in the new connection household must meet at least 2% of the total demand, for commercial 7% and for industrial 10%.

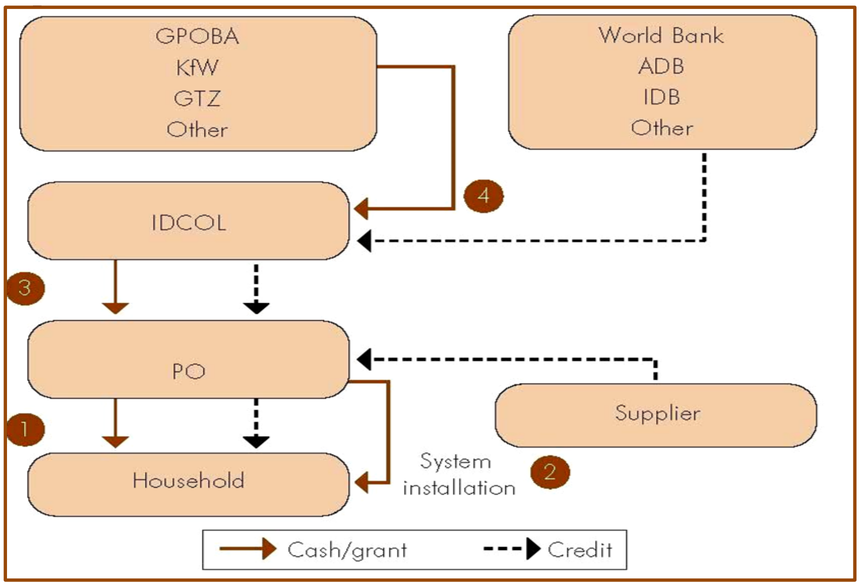


Figure 3.3: Schematics Diagram of IDCOL SHS Program.

After the successful implementation of solar home system projects in Bangladesh and many other countries like India, Japan, German etc., GOB introduced such rule for lowering the increasing pressure on the national grid and reduce the cost of produce the electricity for both urban and rural inhabitant.

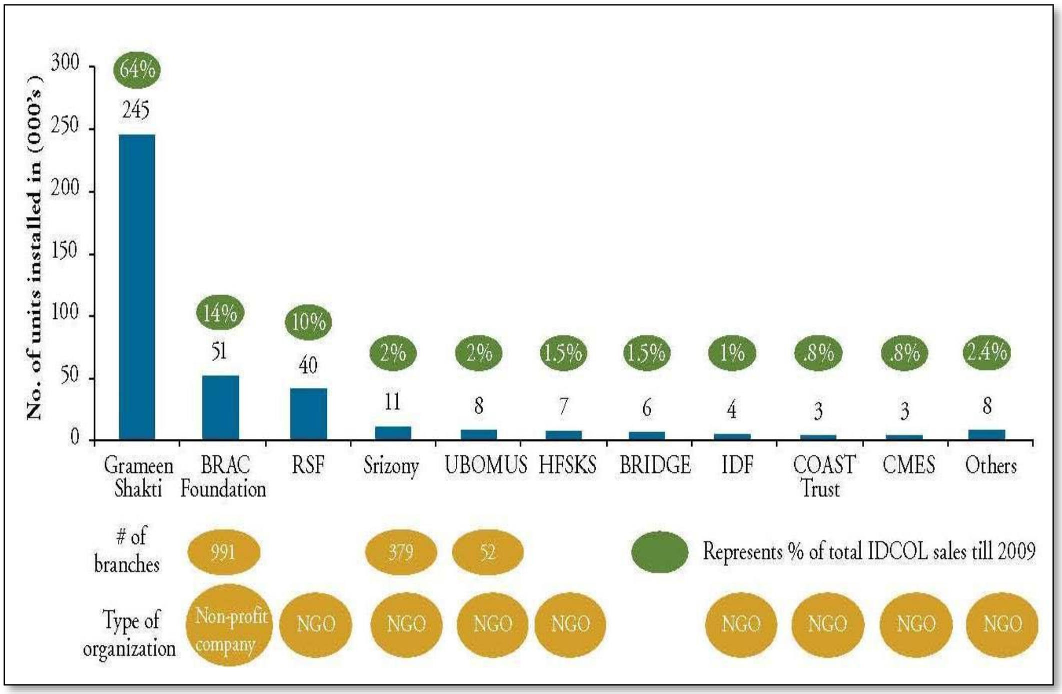


Figure 3.4: Cumulative sales pf specific POs of IDCOL

But the real scenario is not like it should have been. In most of the houses the loads mainly are the garage and staircase lights which are approximately around 300-500 watts. In most cases the panels used were oversized with respect to the battery and capacity (load).It can be easily conjectured that the house owners installed solar system only to get electricity connection. Besides, most of the houses own generators and power transformer engaging in massive competition of fossil fuel usage polluting the environment. The house owners are neither interested in solar power nor have any idea about their usefulness and long term benefits. They are victimized by a limited number of new and inexperienced providers of solar systems who are motivated by quick earning and easy profit. The present urban solar is facing different problems for some of the following reasons:

i. The Corruption in installation of solar panel is rising with the collaboration of Power distribution employees.
ii. As a result consumers hardly use the proper way to install the solar panel, they only do it for a show up and to get the new connection.

iii. Among the most consumers they complains about the unsatisfying battery performance and failure to supply the daily needs of their installation of the SHS.
iv. Instead of using high quality premium priced solar panels, most of the people are using cheap substandard brands and facing numerous troubles. Bangladesh is currently importing almost all the solar panels. Low cost substandard panels are inundating the market.
v. In this way the consumers losing their interest in solar PV system. Moreover, there is no available proper data in the market which make them more confusing.
vi. Maximum of the urban SHS solar controller showed false rating due to using fake controller.
vii. Most of the inverter used in urban area are only 75% efficient where more than 85% efficient inverter is available in the market.
viii. Sometimes the officials of power distribution companies are bribed into overlooking the irregularities by the consumers, while surveying some of the cases we found only solar but no inverter, battery or solar controller.

Chapter 4

Survey of Mirpur Area

4.1 Necessity of the Survey

According to the Renewable Energy Policy as per Ministry directive to all the utilities, all new connections with demand above 2KW now require installation of solar panels. For domestic purposes, solar energy should meet at least 2 percent of the demand, for commercial 7 percent and for industrial 10 percent. But it is required to check out that how the installed systems are operating and if the users are being benefited by the installed solar system. A government survey recently pointed out that installation of solar panel on rooftop in urban areas would not add any additional power in the system rather it would create serious havoc in system management and cause huge financial loss to the consumers. The survey also pointed out that solar panel failed to catch public interest as the distributing agencies did not take any awareness program for the consumers as well as they faced serious obstacle to get service from the agencies. Considering the results from the survey, a detail survey was done on Mirpur Area, Dhaka to inspect the working status of the installed solar systems. Some of the houses were DPDC listed and others were not .Necessary possible data was measured from panel, battery. User feedback was also collected from every possible individual. The data collected was used to calculate the effective and ineffective systems. The efficiency calculation was carried out using the modified parameters of HOMER software.

4.2 List of the Inspected Houses

Table 4.1 shows the list of the 25 inspected houses. The serial no. corresponds to each home for the further tables.

Table 4.1: List of the Inspected Houses

Serial No.	House Address
01	Talukder Acumen Glory, Plot-247/1-ka, Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216.
02	188\8 Middle Paikpara Tajlan Road, Mirpur, Dhaka-1216
03	202/2, Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216.
04	Silicon Orchid, Road-3, House no-4, Block-E, Rupnagar, Mirpur-2, Dhaka-1216.
05	82/35, BaronTek, Balur Math, Dhaka-1206.
06	Shetu Bandhan, 82/15, BaronTek, Balur Math, Dhaka-1206.
07	Sohrab Mansion, 148/ka/1, Ahmed Nagar, Paikpara, Habuler Pukurpar, Mirpur-1, Dhaka-1216.
08	75/15, BaronTek, Balur Math, Dhaka-1206.
09	80/20, BaronTek, Balur Math, Dhaka-1206.
10	Galaxy Habul Tower, 184/3, Ahmed Nagar, Paikpara, Habuler Pukurpar, Mirpur-1, Dhaka-1216.
11	Shah Ali Nibash, 177/1, Ahmed Nagar, Paikpara, Mirpur-1, Dhaka-1216.
12	90/55, BaronTek, Balur Math, Dhaka-1206.
13	198/8, Ahmed Nagar, Paikpara, HabulerPukurpar, Mirpur-1, Dhaka-1216.
14	82/60, BaronTek, Balur Math, Dhaka-1206.
15	10/25, BaronTek, Balur Math, Dhaka-1206.
16	215/5, Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216.
17	201/8, Ahmed Nagar, Paikpara, Habuler Pukurpar, Mirpur-1, Dhaka-1216.
18	82/15, BaronTek, Balur Math, Dhaka-1206.
19	188/6 Middle Paikpara Tajlan Road, Mirpur, Dhaka-1216
20	84/16, BaronTek, Balur Math, Dhaka-1206.
21	88/18, BaronTek, Balur Math, Dhaka-1206.
22	Nil Poddo, 198/2 Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216

23	82/14, BaronTek, Balur Math, Dhaka-1206.
24	82/13, BaronTek, Balur Math, Dhaka-1206.
25	188/7 Middle Paikpara Tajlan Road, Mirpur, Dhaka-1216

Table 4.2 contains the installed solar panels of the inspected houses. The table only contains the number of panels with their individual power and the last column of the table contains the total amount of solar power installed.

Table 4.2: List of Installed Solar Panel in the Inspected Houses

Serial No.	Manufacturer	No. of panels	Max. Power	Total power
01	Sunny Power	8+(4)	200w+(50w)	1800w
02	Suntech	24	150w	3600w
03	Suntech	16	150w	2400w
04	Electro	30	150w	4500w
05	Sunlink	28	100w	2800w
06	Electro	18	100w	1800w
07	Genetic Solar	16	75w	1200w
08	Apex	18	85w	1530w
09	Sunlink	20	120w	2400w
10	Genetic Solar	20	100w	2000w
11	Apex	12+(6)	150w+(85w)	2310w
12	Electro	16	150w	2400w
13	Sunny Power	24	200w	4800w
14	Sunlink	20+(4)	100w+(150w)	2600w
15	Sunny power	16	150w	2400w
16	Sunlink	24	60w	1440w
17	Suntech	4	270w	1080w
18	Topsun Energy	8	75w	600w

19	Sindeo	12	125w	1500w
20	Interimpex	15	100w	1500w
21	Ben	5	100w	500w
22	Sindeu	2+1	75w+65w	860w
23	Resun Solar	2+(8)	50+(200)	1700w
24	Not Reachable			
25	Sunlink	28	50w	1400w

Table 4.3 shows the number of battery backup for each house with the series and parallel combination. Also the battery manufacturer list is also provided in the table.

Table 4.3: List of Installed Battery in the Inspected Houses

SL no.	Manufacture	No	Ah	Series	Parallel
01	Hamco	2	80	1	1
02	Volvo	4	80	2	2
03	Hamko	4	100	2	1
04	Electro	6	130	2	3
05	Hamco	4	80	2	1
06	Hamco	2	130	1	2
07	Hamco	4	100	2	2
08	Hamko	4	130	2	1
09	No Battery				
10	Rahim afrooz	4	130	2	1
11	Electro	4	130	2	1
12	Volvo	4	150	2	1
13	Volvo	4	130	2	1
14	Hamko	2	150	2	1

15	Hamco	2	130	2	1
16	Volvo	8	80	4	2
17	Unreachable	Unreachable	Unreachable	Unreachable	Unreachable
18	Volvo	4	100	Separate connection	Separate connection
19	Unreachable	Unreachable	Unreachable	Unreachable	Unreachable
20	No Battery	No Battery	No Battery	No Battery	No Battery
21	Hamko	1	150		
22	Navana	2	100	1	1
23	Voltex	2	130	2	1
24	Rahim afrooz	8	100	4	2
25	Volvo	4	80	2	2

Table 4.4 shows the installed Charge controller and Inverter with their rating. Both Current and Voltage Rating of the inverter is provided whereas the AC power output rating of the inverter is presented in the table.

Table 4.4:Installed Charge Controller and Inverter

SL no	CC Model	Current rating (CC)	Voltage rating(CC)	Inverter Model	Inverter Rating
01	Techmark	80A	12V	Powercom	400VA
02	Evershine	50-100A	48V	Supernova	400VA
03	Digital Charge Controller	150A	24V	Powercom	1000Va

04	Powercom	150A	12V	Powercom	1000VA
05	Sunpower	120A	24V	No Data	400VA
06	SN-1200 Supernova Engineering	80A	24V	Supernova	400VA
07	Sunpower	150A	24V	Powercom	400VA
08	Powercom	120A	12V	Powercom	1000VA
09	Techmark	80A	24V	Supernova	400VA
10	Evershine	100A	48V	Powercom	1000VA
11	Powercom	120A	12V	Powercom	400VA
12	Techmark	80A	48V	No Inverter	No inverter
13	Sunpower	150A	48V	No Data	400VA
14	Evershine	120A	24V	Supernova	1000VA
15	Techmark	80A	48V	No Data	No data
16	xentech	50A	48V	navana	No data
17	Tristar	No data	No data	Rahim afroz	No data
18	Universal	No data	No data	Star digital	2050VA
19	Not connected	No data	No data	Not connected	No data found
20	Sunpower	Unreachable	Unreachable	Powercom	No data found
21	Pe solar	No data	No data	Not available	No data found
22	Wellsee	15A	12V	Sine	300VA
23	Powercom	ND	ND	Off	No data found
24	Morning Star	ND	ND	Genus RA	No data found
25	Zaman electric	60A	24V	Zaman electric	No data found

Table 4.5 shows the data collected from the houses who have installed solar home system. Here

-Panel Voltage refers to voltage of the solar panel measured at CC terminal.

-Panel Current refers to incoming current from panel through CC.

-Battery Voltage refers to voltage of the battery measured at CC terminal.

-Battery Current refers to outgoing current to battery through CC.

-Inverter Voltage refers to AC output voltage of the inverter.

-NM, ND, NC stands for Not Measurable, No Data and No Connection respectively.

Table 4.5: Collected Data from the Houses

SL no.	Panel Voltage	Panel Current	Battery Voltage	Battery Current	Inverter Voltage
01	88.04V	0.9A	12.43V	0.23A	230V
02	40.7V	0.3A	Damage	Damage	0V
03	36.5V	1.23A	27.8	1.7A	229.2V
04	11.5V	0.40A	28.65V	2.8A	230V
05	40V	0.1A	25.2V	0.28A	0V
06	14.75V	0.87A	12.8V	0.2A	220V
07	26.6V	4A	54.8V	3A	229.2V
08	40.65V	0.9A	15.43V	1.6A	210V
09	12.8V	0.48A	27.8V	1.7A	189V
10	37.8V	1.58A	20.7V	2.73A	230V
11	40V	0.25A	21.7V	2.01A	230V
12	72.48V	1.28A	52.7V	3A	230V
13	39.8V	1.23A	58.3V	2.32A	230V
14	45.8V	3.5A	Damage	Damage	0V
15	37.5V	2.3A	Damage	Damage	230V
16	58.25V	.5A	Damage	Damage	0V
17	No data	No data	No data	No data	No data
18	14.75,18.25	3.8A	15.99,18.75	5.85,0.1	0

19	NC	NC	NC	NC	NC
20	ND	ND	ND	ND	ND
21	14.35V	1.25A	NM	0.22A	254V
22	12.41V	3.25A	12.30V	3.1A	NM
23	38.4	0.17	12.54V,13.79V	0	Off
24	19.32V	0.5A	NM	0.05A	NM
25	32.45V	12.85A	36.54V	15.68	230V

4.3 General Discussion of the Inspected Houses

Specific problems were found out regarding the inspected houses like on arrangement of battery and solar panels and circuit connection through the CC. The following section focuses on the details of the problems as well as relating them to our findings.

4.3.1 Arrangement of Solar Panels

To start it is important to analyze how the solar panels can be connected to increase the output power of the panel. Connecting several panels in parallel arises from the need to reach certain values of output current, without changing the voltage. In fact, by connecting more solar panels in series voltage is increased(keeping the same current while connecting them in parallel causes the current to rise(while maintaining the same voltage).In the market there are many different types of diodes. The best kind of diode for photovoltaic applications, is the Schottky diode. This type of diode has the characteristic of having a very low threshold voltage (of the order of 0.35 V 0.6 V against the common diodes), which ensures a very low power dissipation. We recommend, pay attention also to the choice of the length and the section of the electrical cable increases because of connected panels, also increases the current and therefore the dissipation of energy in it. For high currents requires a cable of suitable section.

4.3.1.1 Parallel connection of two solar panels of same power

If there are two solar panels of the same voltage and power, the connection is very easy. It will be sufficient to connect the positive terminal of one panel to the positive pole of the other, and connect the negative terminal of one panel to the negative terminal of the other. In series to each panel a blocking diode is inserted to protect the entire string from possible faults or short circuits that can occur on the individual panels of the string. It is also a good thing during the design, choosing solar panels that have at least three bypass diodes already present to prevent the most of the energy losses due to shading. This type of connection is very efficient if the following conditions are met:

1. Put the panels next to each other and oriented in the sun at the same angle
2. Check that the panels do not shade each other and are far from possible causes of shading
3. Choose an appropriate section of the electric connection cable according to the distance of the panels
4. Uses of junction boxes to connect neatly between the terminals of the panels

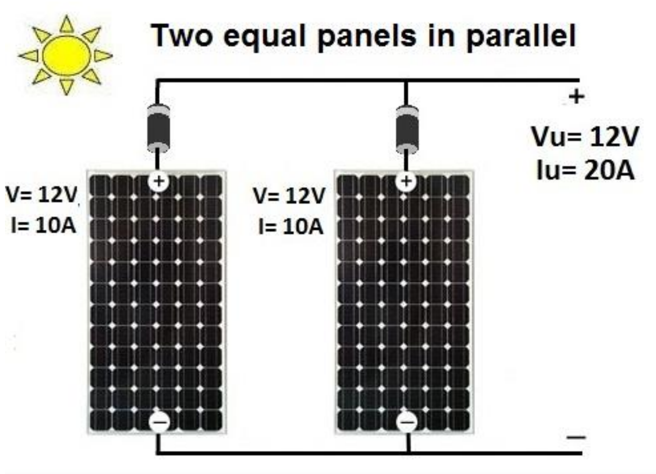


Figure 4.1: Parallel connection of two solar panels of same power

4.3.1.2 Parallel connection of two solar panels of different power

If there are two solar panels of the same voltage but with different power they can be easily connected in parallel. If instead the two photo-voltaic panels are with different both power and voltage, then it is not possible to connect in parallel, because the panel with lower voltage would act as a load, and would begin to absorb current, instead of producing with the related consequences. However, if there is a single panel of 12V and two panels each of 6V, then the two panels from 6V can be connected in series and then the series obtained can be connected in parallel to the panel 12V. This latter type of connection, however, is to the detriment of efficiency. So before making a parallel connection, it is a must to check the voltage of the photo-voltaic panels. Attention to current! You can connect multiple solar panels with this method, but you have to pay attention to current values. If your output value is greater than 70A, your panels and your system may be damaged and issues related to power management. To avoid this, it is used to connect the panels in series-parallel, so as to increase both voltage and current simultaneously. For example, if we were to connect in parallel by six panels 10A, we will output a current high enough, i.e.; 60A. To solve this problem and to optimize the energy efficiency of the entire system, it is advisable to connect two panels in series (resulting in a doubling of voltage) and then connected in parallel to the three pairs previously connected in series (so as to have doubled and tripled voltage current). In the figure below you can see the outline of this connection. This type of connection is frequently used for installations of considerable power.

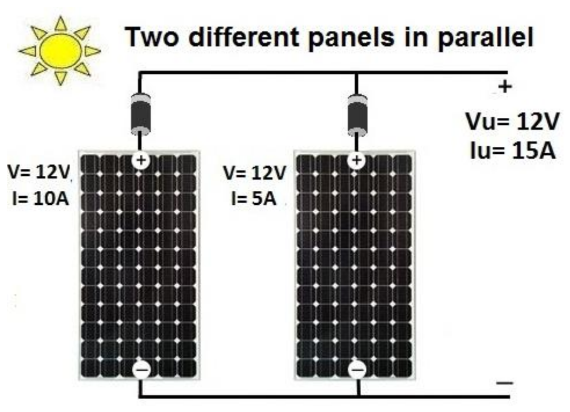


Figure 4.2: Parallel connection of two solar panels of different power

4.3.1.3 Series Parallel combination of solar panels

In an off grid photovoltaic system, the choice of the total power of the system and the tension of the battery bank must be carefully considered in the design phase. For those who want we have made available a free program to perform a correct design of a photovoltaic system, the calculation of the daily energy requirements, up to the size of the panels according to the area where it will be installed.

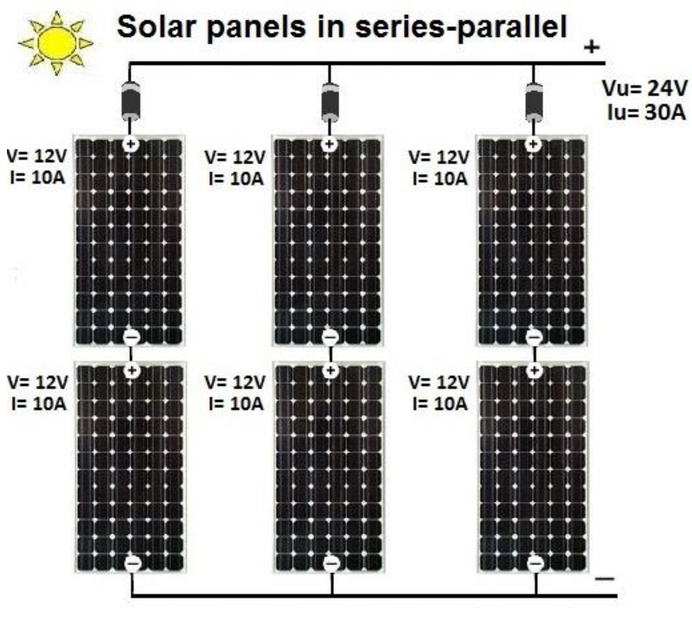


Figure 4.3: Series Parallel combination of solar panels

4.3.2 Arrangement of Battery

Naturally deep cycle Lead Acid Batteries are suitable for solar system operation due to its long time energy delivery. Deep cycle batteries have thicker plates and can survive a number of discharge cycles. Naturally the 12V Lead Acid batteries have internal resistance less than 100 ohm. It is suggested that C/10 ratio should be maintained for safe discharge and charging operation. For instance, a 100Ah battery should be charged at maximum 10A and should be discharged at maximum 10A. While making a series-parallel combination of battery two increase the voltage level (series connection) or the Ampere Hour (parallel Connection).Battery internal resistance is not elected by its ampere hour capacity. So while making parallel combination it is to be kept in mind that the batteries should have same Ampere Hour rating. Otherwise, the battery having less capacity will be charged faster than the other one and will be damaged first.

4.3.2.1 Parallel connection between batteries (Use parallel wiring to increase current)

This diagram shows a simple parallel circuit to increase current or power. Assume that we are using 12 volt batteries. The power of all 3 batteries add to give us the effect of a battery 3 times as powerful but the voltage stays the same at 12 volts. Parallel wiring increases current but the voltage does not change.

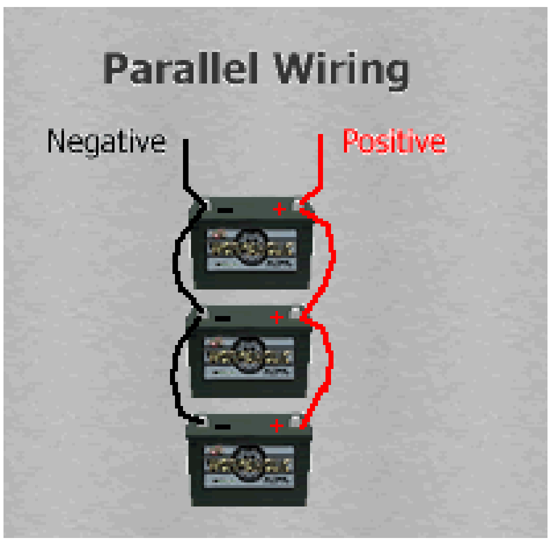


Figure 4.4: Parallel connection between batteries

4.3.2.2 Series connection between batteries (Use series wiring to increase voltage)

This diagram shows a simple series circuit to increase the battery voltage level. Assume that we are using really big 4 volt industrial batteries. The voltage of all 3 batteries adds to give us the effect of a battery 3 times the voltage or in this case a very large 12 volt battery. In this circuit the current is the same as the current in just 1 of the batteries. But since the 4 volt industrial batteries are very large, we have in effect created a huge 12 volt battery.

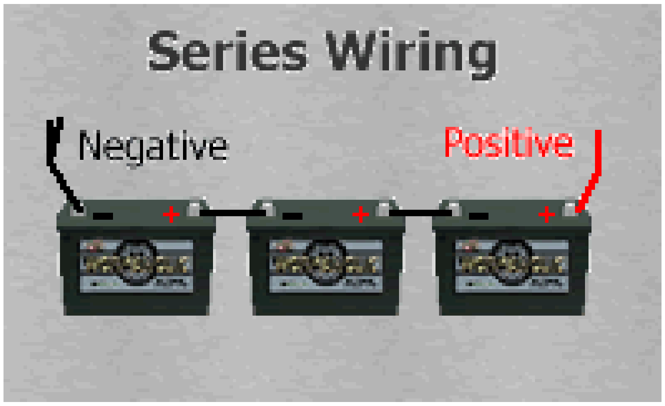


Figure 4.5: Series connection between batteries

4.3.2.3 Use Series and Parallel combination wiring in connection

This diagram shows a combination series and parallel circuit to increase both the battery current and voltage level at the same time. Assume this time we are using 12 volt batteries. The left to right series connection add the two 12 volt batteries to make 24 volts. And, since we did this 3 times and then connected each group of 2 (now 24 volts) in parallel we end up with one very large 24 volt battery. It has twice the voltage of a single 12 volt battery and 3 times the current or power because all 3 groups are wired in parallel.

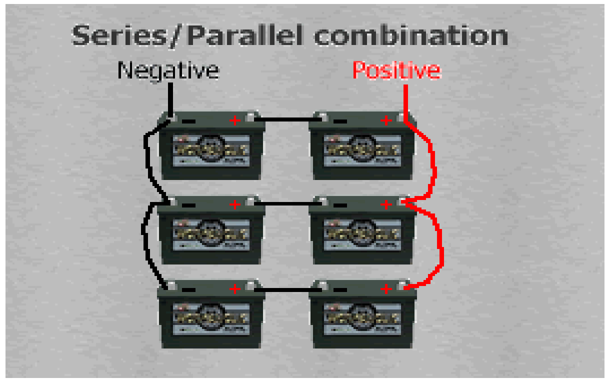


Figure 4.6: Use series & parallel wiring in combination

4.3.2.4 The sky's the limit

So, using series wiring, you can build up the voltage to the level you need and using parallel wiring you can increase the current or power. For example, you could setup a 24 volt battery bank by connecting two 12 batteries together in series or create a 48 volt battery bank by connecting four 12 volt batteries in series. Then just repeat these until you get the power you want and put all those now 24 or 48 volt groups in parallel. Batteries for solar power systems are available in 2, 4, 6, and 12 volts, so any combination of voltage and power is possible. Try this yourself using the Battery Bank Designer with 4 easy point & click choices.

4.3.3 Circuit Connection

The most efficient connection for an AC load connected SHS is charging the battery from the solar panel through a Charge Controller. Charge Controller controls the charging of the battery up to a specific level so that the battery is not over charged. It was found that at most of the houses inverter directly takes power from battery. The company responsible for installation of the solar system installs an inverter already manufactured by not considering the amount of load the inverter had to handle. So in most of the cases inverters were over-sized causing a high price. Moreover, a commercial inverter for IPS purpose does not suit the purpose of the inverter for a solar home system. The IPS which is being used as inverter has the Lower Voltage Disconnect point to a relatively voltage level than the specified level by IDCOL for solar home system. As the charge controller does not have authorization over the safe discharge of battery, some of the batteries were found out at dying state.

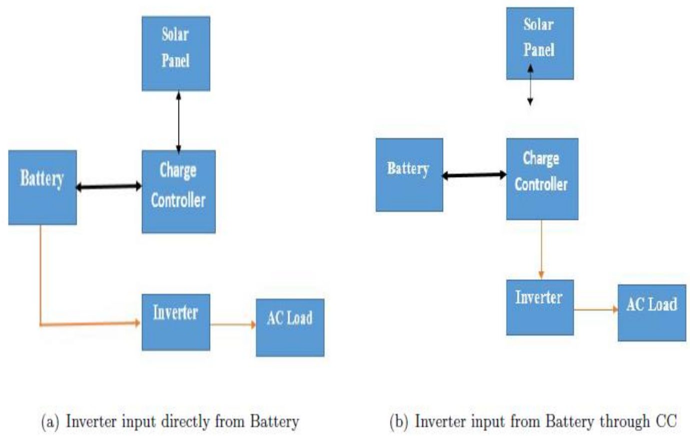


Figure 4.7: Connection among SHS Components

Only 13 of the 25 houses have active solar home system which is only 52% of the total number of samples. Only 1 of the 6 samples had almost flawless system while the other ones had some design problems. Most of the inverters were found out oversized than the load to them. An inverter produces it's no load voltage whether load is being served it or not. But most of the inverters were found off during our inspection. From the observation of the systems it is found that the charge controller and the inverter are not dedicated for that specific house. The installer company used an already available CC with an inverter. Due to this reason, most of the houses were manually operated by a person who had the responsibility of switching on and off the load which is not an efficient system and also responsible for battery damage. Efficient systems are also responsible for battery damage. Panels of two different open circuit voltages were found out in parallel combination in some houses. Batteries of different Ampere Hour were found to be both in parallel and series configuration which is detrimental to battery. To increase the input DC voltage to inverter different Ampere Hour battery was found in series configuration whereas different ampere hour battery was found in parallel configuration for increasing the total capacity duration which is detrimental to battery. To increase the input DC voltage to inverter different Ampere Hour battery was found in series configuration whereas different ampere hour battery was found in parallel configuration for increasing the total capacity.

Chapter 5

Different Types of Solar Panels And Efficiency

5.1 Solar Panels

A solar cell is nothing but a electrical device that directly converts the light energy to electrical energy through the process of photovoltaic effect. Basically the component of this solar cell is silicon. There are three common types of panel available on the market and they are:

1. Monocrystalline Panels
2. Polycrystalline Panels
3. Thin Film Panels (Amorphous Silicon)

The efficiency of a solar panel affects the whole solar home system, so it is very important to buy a proper solar panel for a proper solar home system. For example: if a customer has a low budget the panel should be a low cost one on the other hand if there is a huge budget or the system is for a grid, it should be a high efficiency solar panel regardless of cost.

In our survey we found that all of the cases clients used only Monocrystalline and Polycrystalline Panels. In some of the cases, we found that clients used Monocrystalline solar panels for huge size of solar panels array as a high efficient conversion of energy. We also found that people used Polycrystalline Panels because of its low cost, regardless of efficiency calculation for a huge size of solar panels array. In most of the overall efficient solar home system we found that only Monocrystalline solar panels are used for high end performance.

5.2 Monocrystalline Panels

The dark black color solar panels are known as Monocrystalline solar panels. Monocrystalline panels get their name from the fact that the silicon wafer used to make them is cut from a single crystal or 'boule' of silicon. Silicon is grown in a laboratory to achieve a high degree of purity and is then sliced very thinly to make wafers. The best efficiency is 21.5% until now released by the Sun Power a leading solar manufacturer company. [18]

5.2.1 Advantages:

1. Have the highest efficiency of all solar panels available in the market.
2. Space-efficient**.**
3. Longer lifetime, usually come with a 25yr warranty.
4. Performs better than any other solar panel in low light condition.

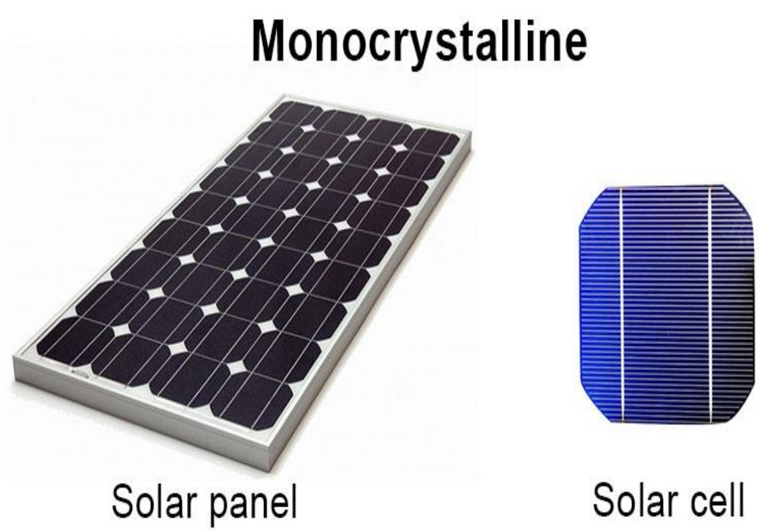


Figure 5.1: Monocrystalline solar panel

5.2.2 Drawbacks:

1. Most Expensive.
2. A significant amount of silicon ends up as waste.
3. Performance suffers under high temperature.

5.3 Polycrystalline Panels:

The light or dark blue color solar panels are known as Polycrystalline Panels. It is also known as poly silicon (p-Si) and multi-crystalline silicon (mc-Si). These cells are cut from an ingot of melted and re-crystallized silicon. Raw silicon is melted and poured into a square mold, which is cooled and cut into perfectly square wafers [18]. The efficiency of polycrystalline solar panels is usually 13-17%.

5.3.1 Advantages:

1. Low cost.
2. Waste of silicon is much lower than Monocrystalline for the manufacture.
3. Performance gets higher in the higher temperature.
4. Excellent life span, usually come with a 25yr warranty.

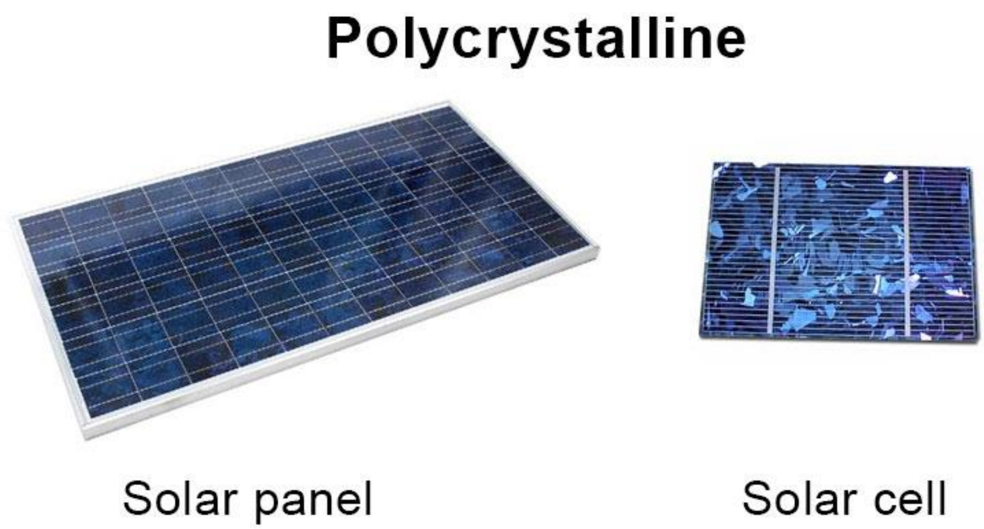


Figure 5.2: Polycrystalline solar panel

5.3.2 Drawbacks:

1. Slightly less efficient than Monocrystalline.
2. Need more space than Monocrystalline to produce the same amount of electricity.

5.4 Amorphous Thin Film:

Thin film, or amorphous, silicon cells are made up of silicon atoms in a thin layer rather than a crystal structure. Amorphous silicon can absorb light more readily than crystalline silicon, so the cells can be thinner. For this reason, amorphous silicon is also known as 'thin film' photovoltaic (PV) technology. The efficiency of Thin Film is very low, usually around 7-13%[18].

5.4.1 Advantages:

1. Mass-Production is very simple.

2. High temperatures and shading have less impact on the performance.
3. It could be flexible, which opens the doors of a new potential of solar panels.

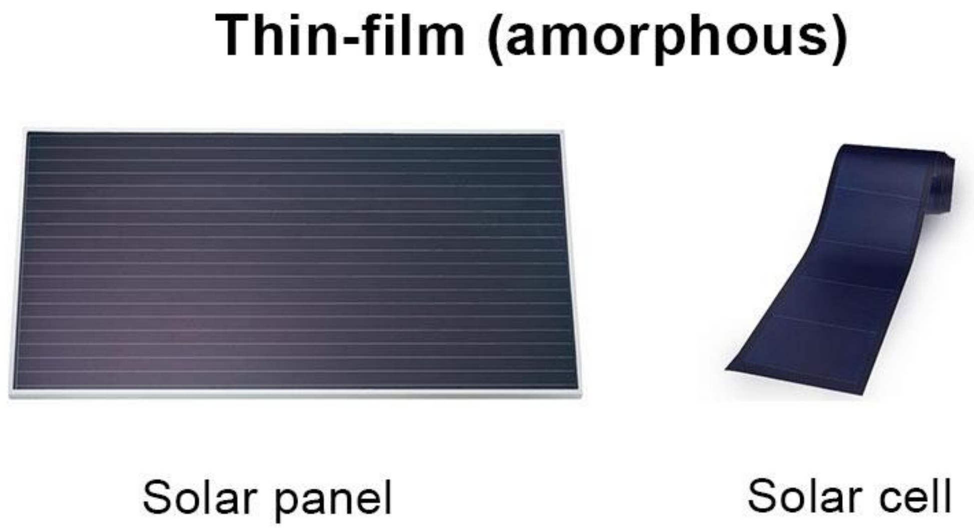


Figure 5.3: Amorphous Thin Film solar panel

5.4.2 Drawbacks:

1. Has the lowest conversion efficiency among the all other solar panels.
2. Need a huge space to produce the same amount of electricity as crystalline based panels.
3. Life span is much lower than the crystalline based panels.
4. Efficiency decrease in the cold weather.

5.5 Cost of Different Solar Panels:

The Cost of different solar cells are varies with place to place and because of shipping cost. Here is a chart of the prices in different country for different solar panels [19].

Solar Panel Brand	Peak Power Watts	Min Q*	Total Watts	Cost US$ per Solar Panel	Total Cost	Poly Mono Thinfilm	%= module efficiency	Price per Watt	UL** Listed?	Country of Manufact.
Hyundai	325	1	325	$276.25	$276.25	M	18.50%	$0.85	UL	
DMSolar	158	2	316	$134.00	$268.00	M	18.00%	$0.85	-	
Suniva OPT285-60-4-099	285	1	285	$320.00	$320.00	M	17.34%	$1.12	-	
Suniva OTP-335w	335	22	7370	$283.97	$6,247.34	M	17.18%	$0.85	-	
Suniva OPT335-72-4-100	335	22	7370	$300.00	$6,600.00	M	17.18%	$0.90	-	
Suniva OPT-280-60-4-100	280	25	7000	$225.97	$5,649.25	M	17.04%	$0.81	-	
Suniva OPT275-60-4-1B0	275	1	275	$255.00	$255.00	M	16.73%	$0.93	-	

Figure 5.4: Showing the price of Different solar panels with the different efficiency

From the above discussion we can say that for huge production of electricity it is better to use Monocrystalline solar panel for having higher efficiency of energy conversion. But if there is a budget issue or the production is much lower, it is convenient to use Polycrystalline solar panels.

Chapter 6

Modification of HOMER Software for Simulation Purpose with context to Bangladesh

6.1 HOMER

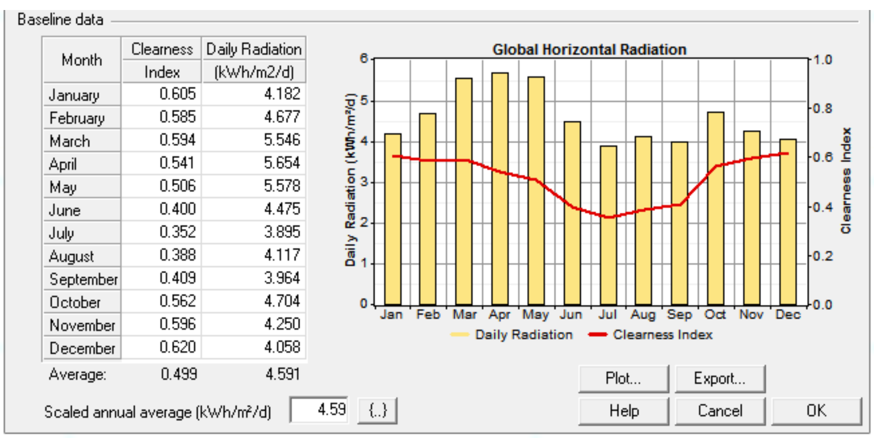
HOMER (Hybrid Optimization of Multiple Electric Renewable) is a micro-power optimization model that simplifies the task of evaluating designs of both off-grid and grid connected power systems for a variety of applications. Homer can model both single and multiple technology systems and compare multiple combinations of different technologies. But modeling a system may get difficult because of the large number of technology options and the variation in the technology costs and availability of energy resources. HOMER’s optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. This software was first developed in 1993 for internal DOE (Department of Energy) use to understand the trade-offs between different energy production configurations but a few years later NREL (National Renewable Energy Limited in the United States) made a free version for serving the growing community of system designers interested in Renewable Energy [17].

HOMER simulates different system configurations or combinations of components and generates results when provided the inputs. These inputs describe technology options, component costs and resource availability. HOMER provides the results as a list of feasible configurations sorted by net present cost in a wide variety of tables and graphs and help compare configurations and evaluate them on their economic and technical merit. Moreover, we can use the model to perform sensitivity analyses depending on the designing factors such as resource availability and economic conditions of different systems configurations. HOMER performs such analysis over a range of values provided.

As this thesis work has a purpose to design the Urban Solar System by using the local panels and batteries, it is necessary to make the simulation software HOMER compatible to the available panels and batteries in Bangladesh. So, to start over the simulation work, necessary battery models were made in HOMER. The battery models available in HOMER are of higher Ampere Hour rating with higher life time. Hence, the life time output from a battery is much more than available battery models in Bangladesh. To remodel a battery certain specifications are to be modified.

6.2 Solar Resource

Solar irradiance's the rate at which radiant energy is incident on a surface per unit area of surface. Solar irradiation data is required for simulation through HOMER. This data is collected from NREL's Climatologically Solar Radiation (CSR) or from NASA's Surface meteorology and Solar Energy (SSE) data set [17]. After providing the latitude and longitude of Bangladesh HOMER collects the data of Daily Radiation and Clearness Index automatically. It is advisable that the average radiation should have a constant trend and the annual radiation is above 4 kWh/m^2/d in order to have a reliable source of power coming from the photovoltaic panels.



Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.605	4.182
February	0.585	4.677
March	0.594	5.546
April	0.541	5.654
May	0.506	5.578
June	0.400	4.475
July	0.352	3.895
August	0.388	4.117
September	0.409	3.964
October	0.562	4.704
November	0.596	4.250
December	0.620	4.058
Average:	0.499	4.591

Figure 6.1: Solar Resource Input of HOMER

6.3 Modeling Battery in HOMER

1. **C and E rate:** Discharge current is often expressed as a C rate in order to normalize against battery capacity which is often very different between batteries. A C rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. A 1C rate means that the discharge current will discharge the entire battery in 1 hour. For a battery with a capacity of 100 Ah equates to a discharge current of 100 Amps. A 5C rate for this battery would be 500 Amps and a C/2 rate would be 50 Amps. Similarly, an E rate describes the discharge power. A 1E rate is the discharge power to discharge the entire battery in 1 hour [20].

2. **State of Charge (SOC) (%):** An expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time [20]. Minimum state of charge is almost always 30-50% for a deep-cycle battery. For simulation purpose state of charge is taken to be 40%.

3. **Cut-off Voltage:** The minimum allowable voltage. It is this voltage that generally defines the “empty” state of the battery [20].

4. **Nominal Capacity:** The nominal capacity, the total Amp-hours available when the battery is discharged at a certain discharge current (specified as a C-rate) from 100 percent state-of-charge to the cut-off voltage. Capacity is calculated by multiplying the discharge current (in Amps) by the discharge time (in hours) and decreases with increasing C rate [20]. For simulation purpose 80Ah, 90Ah, 100Ah, 130Ah are used in this thesis. These values are set respectively in HOMER for each battery.

5. **Nominal Voltage:** Nominal voltage for each model is taken to be 12V.

6. **Round Trip Efficiency:** Round Trip efficiency is considered to be 80% according to previous experience.
7. **Float Life:** As the manufacturers provide a 5 year warranty for their battery, the float life is taken to be 5 years.

8. **Maximum Charge Rate:** The maximum charge rate variable imposes a limitation the rate at which the system can charge the battery bank. That limit is directly proportional to the amount of "unfilled capacity" in the battery, where the unfilled capacity is defined as the battery's maximum capacity minus its current absolute state of charge. For example, a battery can be considered having maximum capacity is 350 Ah and whose maximum charge rate is 0.4 A/Ah. If at some point in time the battery's absolute state of charge is 310 Ah, then it has 40 Ah of unfilled capacity, so the highest charge current it could accept would be 40 Ah * 0.4 A/Ah= 16 A. If at some other point in time its state of charge was 335 Ah, then the highest charge current it could accept would be only 6 A. So the allowable charge current decreases with increasing state of charge. In modeling the batteries the maximum charge rate is kept to 0.4 A/Ah.

9. **Maximum Charge Current:** The maximum charge current, imposes an upper limit on the allowable charge current, regardless of the state of charge. If our example battery were empty, the maximum charge rate variable would imply that it could accept a charge current of as high as 350 Ah * 0.4 A/Ah = 140 A. But a current that high might be very damaging to the battery. To maintain the C/10 ratio, the batteries modeled having a maximum charge current of one tenth of Ampere Hour rating plus with 1A margin for fast charging. For instance, for the maximum charge rates are set as 9A, 10A, 11A and 14A for 80Ah, 90Ah, 100Ah, 130Ah Battery. HOMER ensures that the charge current never exceeds the set value, no matter what the state of charge.

10. **Capacity Curve Modeling:** HOMER uses the capacity curve to calculate the kinetic battery model constants, the most important of which is the "maximum

capacity", which is essentially the y-intercept of the curve. From experience the c and k values, which relate to the shape of the curve, have surprisingly little effect on the simulation results. And they typically do not vary much from one battery to the next. The capacity curve data from the Vision 6FM55D (55Ah) battery is scaled to the size of the required battery. For example, for a battery having a maximum capacity of 130 Ah, multiplying each capacity value by 130/55 (since the Vision 6FM55D has a maximum capacity of 392 Ah) provides the capacity curve for the designed battery.

11. **Lifetime Throughput:** HOMER uses the lifetime curve to calculate the suggested value of the lifetime throughput. As reference the batteries from Electro Solar are used as reference. Homer then suggests a lifetime throughput value by using the lifetime curve and capacity curve. The suggested value is used for the lifetime throughput value. Considering the above parameters the battery details for four models of battery (80Ah, 90Ah, 100Ahand 130Ah) are calculated and are presented in Figure 5.2.

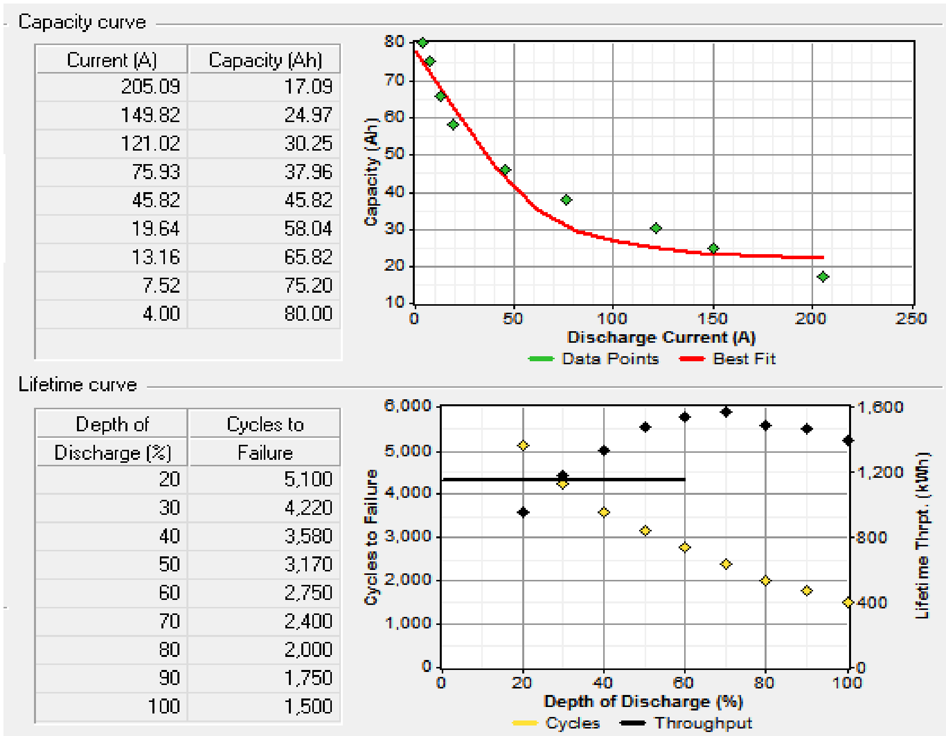
Table 6.1: Parameters to model battery

Parameters	Nominal Capacity (Ah)			
	80	90	100	130
Nominal Voltage	12 V	12 V	12 V	12 V
Roundtrip Efficiency	80%	80%	80%	80%
Minimum State of Charge	40%	40%	40%	40%
Float Life	5 yrs	5 yrs	5 yrs	5 yrs

Maximum Charge Rate	0.4 A/Ah	0.4 A/Ah	0.4 A/Ah	0.4 A/Ah
Maximum Current Rate	9 A	10 A	11 A	14 A
Lifetime Throughput	1,150 KWh	1,400 KWh	1,650 KWh	2,000 KWh
Suggested Value	1,296 KWh	1,680 KWh	1,694 KWh	2,175 KWh

Table 6.2: Calculated parameters by HOMER to model battery

Calculated Parameters	Nominal Capacity (Ah)			
	80	90	100	130
Maximum Capacity	77.7 Ah	101 Ah	102 Ah	130 Ah
Capacity ratio, c	0.242	0.275	0.317	0.258
Rate Constant, k	4.08 1/hr	1.37 1/hr	.306 1/hr	3.87 1/hr



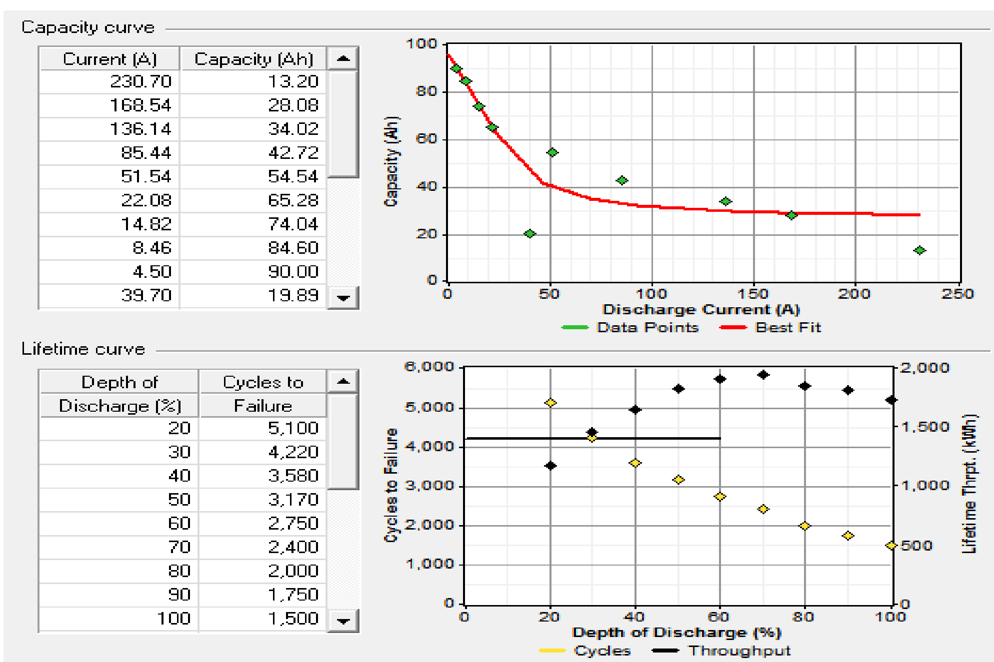
Capacity curve

Current (A)	Capacity (Ah)
205.09	17.09
149.82	24.97
121.02	30.25
75.93	37.96
45.82	45.82
19.64	58.04
13.16	65.82
7.52	75.20
4.00	80.00

Lifetime curve

Depth of Discharge (%)	Cycles to Failure
20	5,100
30	4,220
40	3,580
50	3,170
60	2,750
70	2,400
80	2,000
90	1,750
100	1,500

(a) Battery Details for 80Ah



Capacity curve

Current (A)	Capacity (Ah)
230.70	13.20
168.54	28.08
136.14	34.02
85.44	42.72
51.54	54.54
22.08	65.28
14.82	74.04
8.46	84.60
4.50	90.00
39.70	19.89

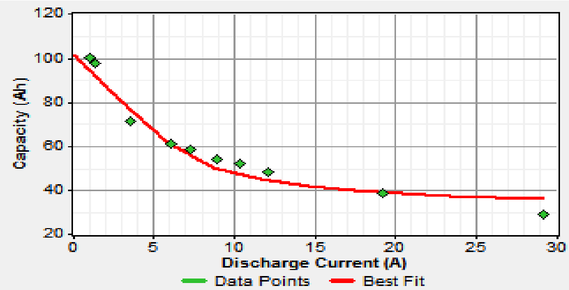
Lifetime curve

Depth of Discharge (%)	Cycles to Failure
20	5,100
30	4,220
40	3,580
50	3,170
60	2,750
70	2,400
80	2,000
90	1,750
100	1,500

(b) Battery Details for 90Ah

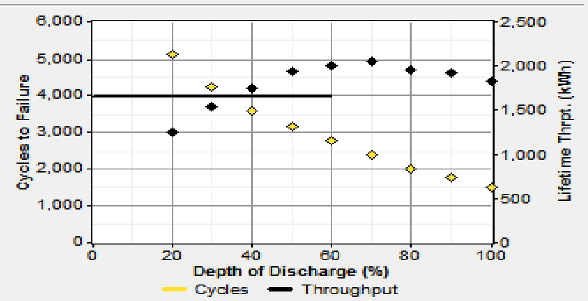
Capacity curve

Current (A)	Capacity (Ah)
1.00	100.00
1.32	97.44
3.55	71.05
6.11	61.10
7.26	58.26
8.95	53.68
10.37	51.89
12.11	48.32
19.21	38.37
29.16	29.16



Lifetime curve

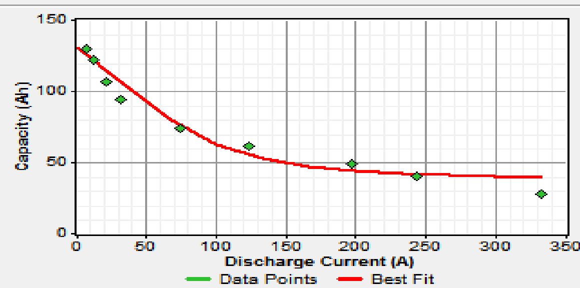
Depth of Discharge (%)	Cycles to Failure
20	5,100
30	4,220
40	3,580
50	3,170
60	2,750
70	2,400
80	2,000
90	1,750
100	1,500



(c) Battery Details for 100Ah

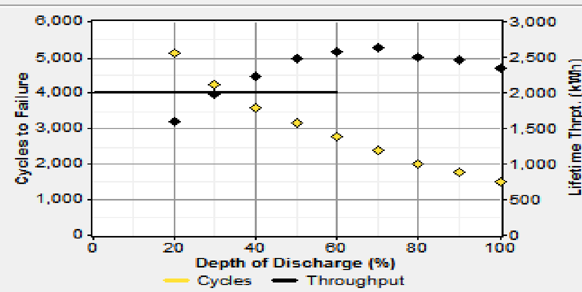
Capacity curve

Current (A)	Capacity (Ah)
332.76	27.73
243.08	40.52
196.35	49.09
123.19	61.60
74.34	74.34
31.39	94.16
21.36	106.79
12.20	122.01
6.49	130.00



Lifetime curve

Depth of Discharge (%)	Cycles to Failure
20	5,100
30	4,220
40	3,580
50	3,170
60	2,750
70	2,400
80	2,000
90	1,750
100	1,500



(d) Battery Details for 130Ah

Figure 6.2: Battery Details for the Modified Battery

6.4 Pricing of Solar Panels and Battery

For simulation purpose the prices of available solar panels and batteries are required. There are many battery manufacturers in Bangladesh as well as panel manufacturers. Market survey was done and approximately same value was found for same capacity battery and panel. The prices of battery and solar panel used for simulation purpose are presented in Table 5.3 and Table 5.4 respectively.

Table 6.3: Price of Available Battery Models

Capacity (Ah)	Unit Price (TK)	Unit price ($)
15	3000	39
23	4050	52
30	4500	58
45	6750	87
55	7500	97
80	10150	130
90	11310	145
100	12400	159
130	15500	199

Table 6.4: Price of Available Panels in Bangladesh

Capacity (Wp)	Unit Price (TK)	Unit Price ($)
20	1300	16
30	1950	25
40	2600	33

50	3250	41
65	4225	54
85	5525	71
100	6500	83
130	8450	108

Chapter 7

Analysis of Active System & Efficiency Calculation

From the collected data, only serial no 1,3,4,6,7,10 and 11 of table 4.1 had active solar home system. But most of the cases those systems were not efficient enough, although they have all the latest equipment. Moreover, some of the cases connection problem was found in the solar panel and the battery combination regarding the overall solar panel home system. Every active house was simulated in Homer software and efficiency was calculated through detail analysis of the system.

HOMER is used to measure the efficiency of the installed solar home system for the High Watt load in the active houses. The efficiency of the system is measured by following the steps described below:

1. From the installed panel and battery of the house and the present running load, the COE (Cost of Energy) is calculated.
2. In the HOMER software, simulation is run by varying the load but keeping the battery and solar panel exactly same to the installed system with a purpose of finding the maximum possible load which can be run by the installed panel and battery. The simulation thus produces a minimum COE with a maximum possible load which can be served.
3. The relative change of COE in % returns the percentage by which the present system is inefficient.
4. The final efficiency system is = (100 Relative Change of COE) %.

Here, Table 7.1 shows the considered specifications for the purpose of efficiency calculation by HOMER.

Table 7.1: Specifications used for Efficiency Calculation for Active Systems

Panel Lifetime	20 Years
Derating Factor	80.00%
Slop	23.12
Ground Reflectance	20.00%
Normal Operating Cell Temperature	25
Efficiency at Standard Condition	13.00%
Fixed Capital Cost	$100.00
Annual Interest Rate	6.00%
Inverter Efficiency	85.00%
Battery Lifetime	5 Years
Inverter Lifetime	10 Years
Inverter Price	$158 per KW
O & M Cost Battery	$10

Already explained battery and panel Pricing are used for calculating the efficiency of the system. Inverter parameters were not found for all the installed systems. In such cases the lowest required inverter capacity for meeting up the load is used which was being found by sensitivity analysis.

7.1 Talukder Acumen Glory

Serial No - 1

Address: Plot-247/1-ka,

Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216.

Date of Inspection: April 23, 2016, Time of Inspection: 12.00 pm

7.1.1 Load Specification

From the collected data we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 100 W.

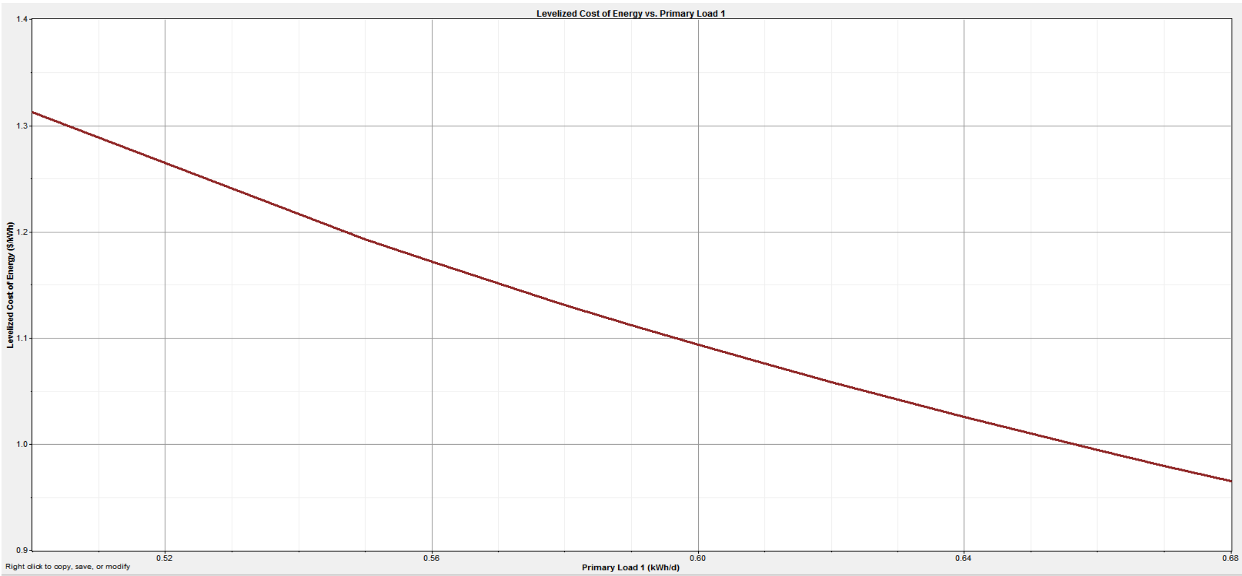
7.1.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 80Ah one. There were 2 batteries in the system. One string consists of 2 batteries connected in series. There were 8 panels of 200W and 4 panels of 50W resulting total panel size of 1800W. This house has an efficiency loss in wiring the panels because of parallel connection of two panels of two different voltage levels. The specifications of every panel are provided in Table 4.2. The problems due to parallel connection of mismatching panels are already discussed in Section 4.3.1.2. The inverter rating was found to be 1000VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.1.3 Efficiency Calculation

Pri. Load 1 (kWh/d)	PV (kW)	12V80A...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
0.620	1.8	2	1	$ 1,948	87	$ 3,061	1.058	1.00	5.0
0.550	1.8	2	1	$ 1,948	87	$ 3,061	1.193	1.00	5.0
0.560	1.8	2	1	$ 1,948	87	$ 3,061	1.172	1.00	5.0
0.570	1.8	2	1	$ 1,948	87	$ 3,061	1.151	1.00	5.0
0.580	1.8	2	1	$ 1,948	87	$ 3,061	1.131	1.00	5.0
0.590	1.8	2	1	$ 1,948	87	$ 3,061	1.112	1.00	5.0
0.600	1.8	2	1	$ 1,948	87	$ 3,061	1.094	1.00	5.0
0.610	1.8	2	1	$ 1,948	87	$ 3,061	1.076	1.00	5.0
0.630	1.8	2	1	$ 1,948	87	$ 3,061	1.042	1.00	5.0
0.640	1.8	2	1	$ 1,948	87	$ 3,061	1.025	1.00	5.0
0.650	1.8	2	1	$ 1,948	87	$ 3,061	1.010	1.00	5.0
0.660	1.8	2	1	$ 1,948	87	$ 3,061	0.994	1.00	5.0
0.670	1.8	2	1	$ 1,948	87	$ 3,061	0.980	1.00	5.0
0.680	1.8	2	1	$ 1,948	87	$ 3,061	0.965	1.00	5.0
0.690	---	---	---	---	---	---	---	---	---
0.700	---	---	---	---	---	---	---	---	---
0.500	1.8	2	1	$ 1,948	87	$ 3,061	1.312	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.1: Efficiency Analysis for Talukder Acumen Glory in HOMER

Figure 7.1 show that 500Wh load is daily used in this house with a COE of $1.304 per KWh. But simulation results show that maximum 680Wh load can be served by the installed solar home system with a CEO of $0.959 per KWh.

Here, Relative decreases of COE= $\frac{(1.304-0.959)\times 100}{0.959}$ = 35.97%

So, Efficiency for the system is (100-35.97) % = 64%

7.2 Dr. Tanjim Ahmed

Serial No - 3

Address: 202/2, Ahammad Nagar, Paikpara, Mirpur, Dhaka-1216.

Date of Inspection: April 23, 2016

Time of Inspection: 1.00 pm

7.2.1 Load Specification

From the discussion with the in-charge personal of the system, we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 160 W.

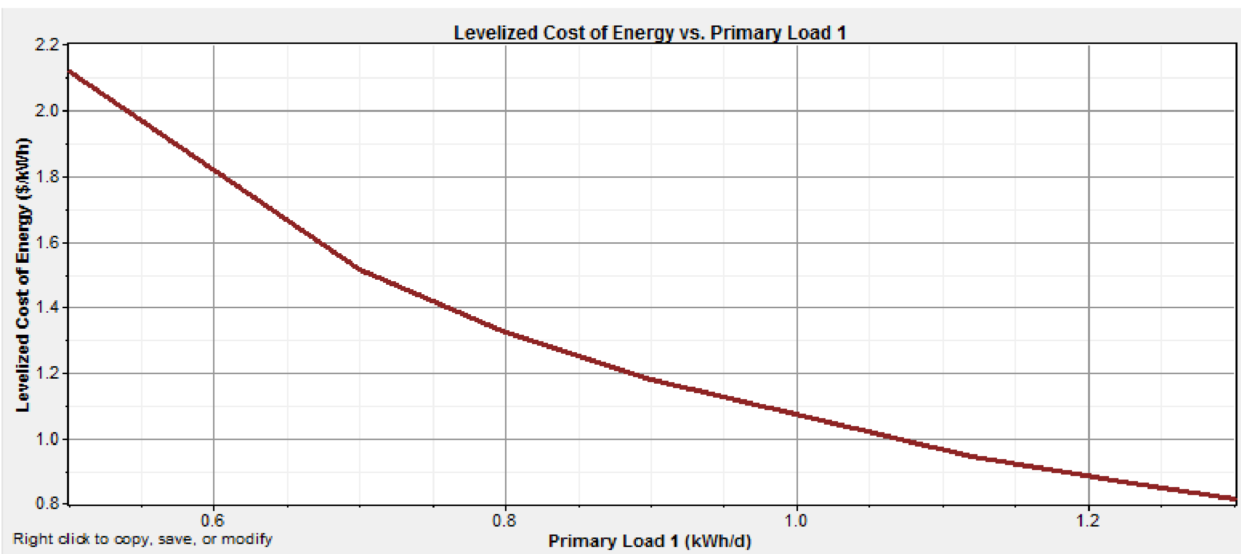
7.2.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 100Ah one. There were 4 batteries in the system. Two string ofparallel battery, each string containing two batteries. One string consists 2 batteries connected in series. There were 16 panels of 150W resulting total panel size of 2400W. The specifications of every panel are provided in Appendix B. The inverter rating was found to be 1000VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.2.3 Efficiency Calculation

Pri. Load 1 (kWh/d)	PV (kW)	12V100...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
0.900	2.4	4	1	$ 2,750	172	$ 4,943	1.177	1.00	5.0
0.700	2.4	4	1	$ 2,750	172	$ 4,943	1.513	1.00	5.0
0.500	2.4	4	1	$ 2,750	172	$ 4,943	2.119	1.00	5.0
0.800	2.4	4	1	$ 2,750	172	$ 4,943	1.324	1.00	5.0
0.900	2.4	4	1	$ 2,750	172	$ 4,943	1.177	1.00	5.0
1.120	2.4	4	1	$ 2,750	172	$ 4,943	0.946	1.00	5.0
1.230	2.4	4	1	$ 2,750	172	$ 4,943	0.861	1.00	5.0
1.300	2.4	4	1	$ 2,750	172	$ 4,943	0.815	1.00	5.0
1.400	---	---	---	---	---	---	---	---	---
1.120	2.4	4	1	$ 2,750	172	$ 4,943	0.946	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.2: Efficiency Analysis for Dr. Tanjim Ahmed in HOMER

Figure 7.2 show that 1120Wh load is daily used in this house with a COE of $0.946 per KWh. But simulation results show that maximum 1300Wh load can be served by the installed solar home system with a CEO of $0.815 per KWh.

Here, Relative decreases of COE= $\frac{(0.946-0.815)\times 100}{0.815}$ = 16.07%

So, Efficiency for the system is (100-16.07) % = 84%

7.3 Silicon Orchid

Serial No - 4

Address: Road-3, House no-4, Block-E, Rupnagar, Mirpur-2, Dhaka-1216.

Date of Inspection: 25th April, 2016

Time of Inspection: 2.00 pm

7.3.1 Load Specification

From the discussion with the in-charge personal of the system, we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 200 W.

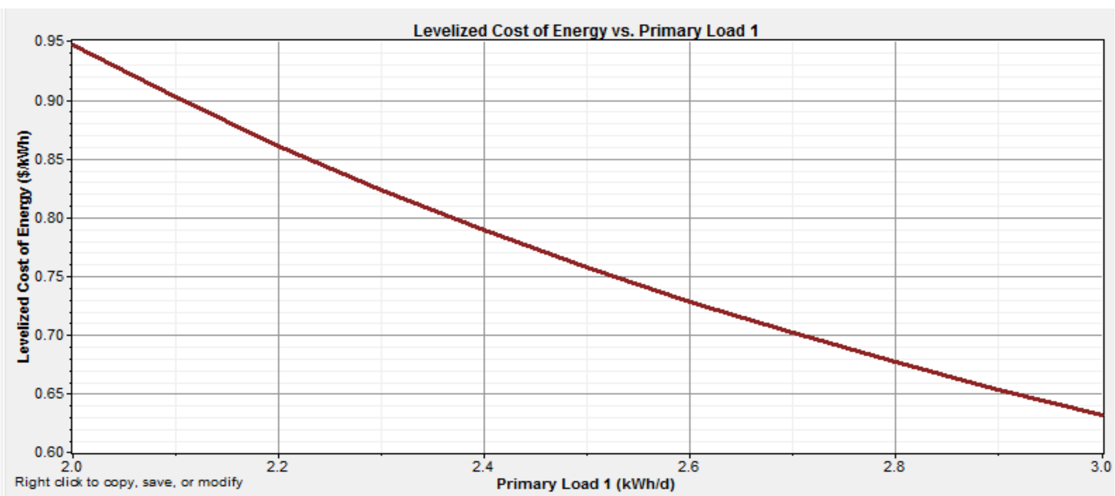
7.3.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 130Ah one. There were 6 batteries in the system. One string consist of 2 batteries connected in series and three strings of parallel connection. There were 30 panels of 150W resulting total panel size of 4500W. The specification of every panel is provided in Appendix B. The inverter rating was found to be 1000VA. These exact parameters are provided as input for the simulation purpose.

7.3.3 Efficiency Calculation

Pri. Load 1 (kWh/d)		PV (kW)	12V130...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
2.500		4.5	6	1	$ 5,020	299	$ 8,838	0.758	1.00	5.0
2.000		4.5	6	1	$ 5,020	299	$ 8,838	0.947	1.00	5.0
2.100		4.5	6	1	$ 5,020	299	$ 8,838	0.902	1.00	5.0
2.200		4.5	6	1	$ 5,020	299	$ 8,838	0.861	1.00	5.0
2.300		4.5	6	1	$ 5,020	299	$ 8,838	0.824	1.00	5.0
2.400		4.5	6	1	$ 5,020	299	$ 8,838	0.789	1.00	5.0
2.500		4.5	6	1	$ 5,020	299	$ 8,838	0.758	1.00	5.0
2.700		4.5	6	1	$ 5,020	299	$ 8,838	0.702	1.00	5.0
2.800		4.5	6	1	$ 5,020	299	$ 8,838	0.676	1.00	5.0
2.900		4.5	6	1	$ 5,020	299	$ 8,838	0.653	1.00	5.0
3.000		4.5	6	1	$ 5,020	299	$ 8,838	0.632	1.00	5.0
3.100		---	---	---	---	---	---	---	---	---
2.600		4.5	6	1	$ 5,020	299	$ 8,838	0.728	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.3: Efficiency Analysis for Silicon Orchid in HOMER

Figure 7.3 show that 2600Wh load is daily used in this house with a COE of $0.728 per KWh. But simulation results show that maximum 3000Wh load can be served by the installed solar home system with a CEO of $0.632 per KWh.

Here, Relative decreases of COE= $\frac{(0.728-0.632)\times 100}{0.632}$ = 15.18%

So, Efficiency for the system is (100-15.18) % = 84.8%

7.4 Shetu Bandhan

Serial No - 6

Address: 82/15, BaronTek, Balur Math, Dhaka-1206.

Date of Inspection: 27th April, 2016

Time of Inspection: 2.00 pm

7.4.1 Load Specification

From the discussion with the in-charge personal of the system, we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 140 W.

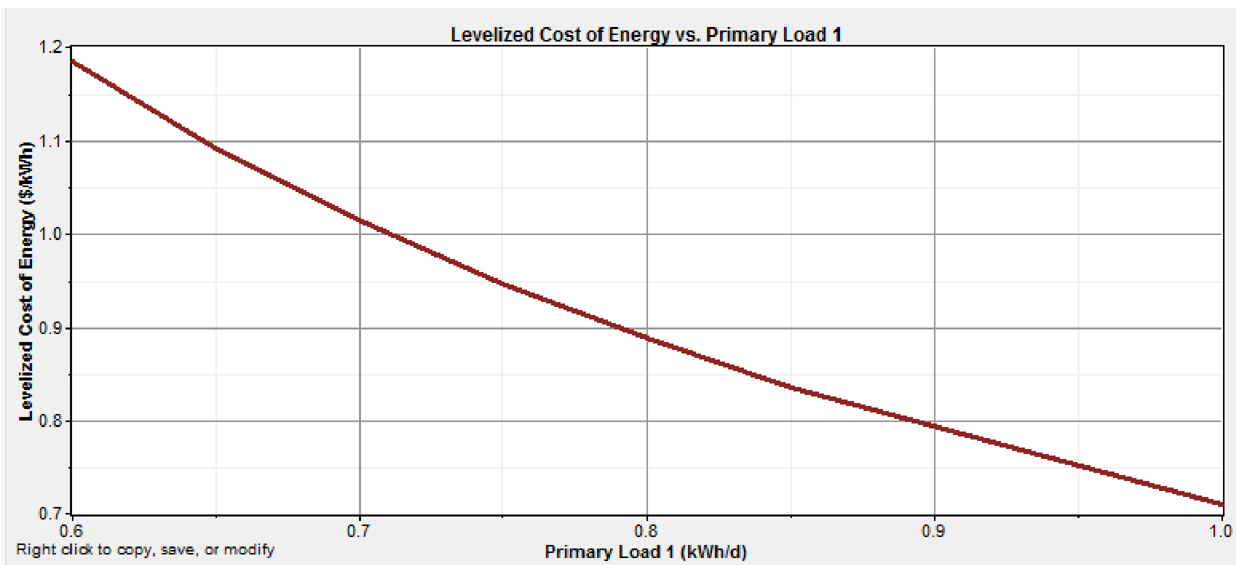
7.4.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 130Ah one. There were 2 batteries in the system. One string consist of 2 batteries connected in series. There were 18 panels of 100W resulting total panel size of 1800W. The inverter rating was found to be 400VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.4.3 Efficiency Calculation

Pri. Load 1 (kWh/d)	PV (kW)	12V130...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
0.800	1.8	2	0.4	$ 1,991	103	$ 3,314	0.888	1.00	5.0
0.600	1.8	2	0.4	$ 1,991	103	$ 3,314	1.184	1.00	5.0
0.650	1.8	2	0.4	$ 1,991	103	$ 3,314	1.093	1.00	5.0
0.700	1.8	2	0.4	$ 1,991	103	$ 3,314	1.015	1.00	5.0
0.750	1.8	2	0.4	$ 1,991	103	$ 3,314	0.947	1.00	5.0
1.000	1.8	2	0.4	$ 1,991	103	$ 3,314	0.710	1.00	5.0
1.100	---	---	---	---	---	---	---	---	---
0.850	1.8	2	0.4	$ 1,991	103	$ 3,314	0.836	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.4: Efficiency Analysis for Shetu Bandhan in HOMER

Figure 7.4 shows that 850Wh load is daily used in this house with a COE of $0.836 per KWh. But simulation results shows that maximum 1000Wh load can be served by the installed solar home system with a CEO of $0.710 per KWh

Here, Relative decreases of COE= $\frac{(0.836-0.710)\times 100}{0.710}$ = 17.75%

So, Efficiency for the system is (100-17.75) % =82.25%

7.5 Sohrab Mansion

Serial No - 7

Address: 148/ka/1, Ahmed Nagar, Paikpara,

HabulerPukurpar, Mirpur-1, Dhaka-1216.

Date of Inspection: 29th April, 2016

Time of Inspection: 12.00 pm

7.5.1 Load Specification

From the collected data we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 100 W.

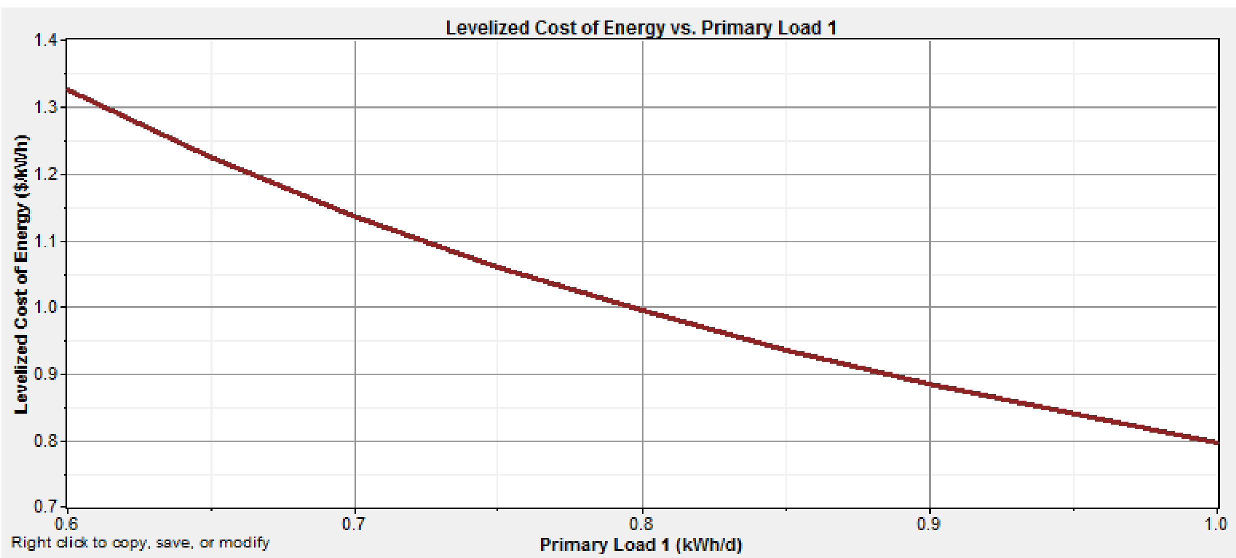
7.5.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 100Ah one. There were 4 batteries in the system. One string consist of 2 batteries connected in series and one strings of parallel connection. There were 16 panels of 75W resulting total panel size of 1200W. The inverter rating was found to be 400VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.5.3 Efficiency Calculation

Pri. Load 1 (kWh/d)	PV (kW)	12V100...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
0.800	1.2	4	0.4	$ 1,719	156	$ 3,712	0.994	1.00	5.0
0.600	1.2	4	0.4	$ 1,719	156	$ 3,712	1.326	1.00	5.0
0.650	1.2	4	0.4	$ 1,719	156	$ 3,712	1.224	1.00	5.0
0.700	1.2	4	0.4	$ 1,719	156	$ 3,712	1.137	1.00	5.0
0.850	1.2	4	0.4	$ 1,719	156	$ 3,712	0.936	1.00	5.0
0.900	1.2	4	0.4	$ 1,719	156	$ 3,712	0.884	1.00	5.0
1.000	1.2	4	0.4	$ 1,719	156	$ 3,712	0.796	1.00	5.0
1.100	---	---	---	---	---	---	---	---	---
0.750	1.2	4	0.4	$ 1,719	156	$ 3,712	1.061	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.5: Efficiency Analysis for Sohrab Mansion in HOMER

Figure 7.5 show that 750Wh load is daily used in this house with a COE of $1.061 per KWh. But simulation results show that maximum 1000Wh load can be served by the installed solar home system with a CEO of $0.796 per KWh.

Here, Relative decreases of COE= $\frac{(1.0615-0.796)\times 100}{0.796}$ = 33.29%

So, Efficiency for the system is (100-33.29) % =66.7%

7.6 Galaxy Habul Tower

Serial No - 10

Address: 184/3, Ahmed Nagar, Paikpara,

HabulerPukurpar, Mirpur-1, Dhaka-1216.

Date of Inspection: 29th April, 2016

Time of Inspection: 1.00 pm

7.6.1 Load Specification

From the collected data we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 160 W.

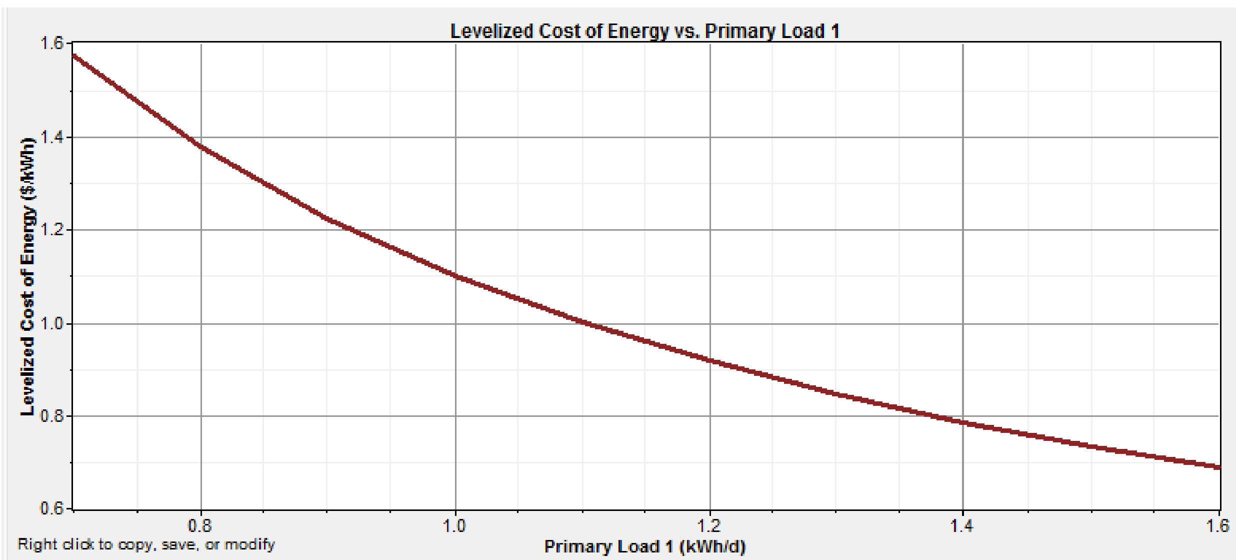
7.6.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 130Ah one. There were 4 batteries in the system. One string consist of 2 batteries connected in series and one strings of parallel connection. There were 20 panels of 100W resulting total panel size of 2000W. The inverter rating was found to be 1000VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.6.3 Efficiency Calculation

Pri. Load 1 (kWh/d)				PV (kW)	12V130...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
1.200				2	4	1	$ 2,654	194	$ 5,137	0.917	1.00	5.0
0.700				2	4	1	$ 2,654	194	$ 5,137	1.573	1.00	5.0
0.800				2	4	1	$ 2,654	194	$ 5,137	1.376	1.00	5.0
0.900				2	4	1	$ 2,654	194	$ 5,137	1.223	1.00	5.0
1.000				2	4	1	$ 2,654	194	$ 5,137	1.101	1.00	5.0
1.100				2	4	1	$ 2,654	194	$ 5,137	1.001	1.00	5.0
1.300				2	4	1	$ 2,654	194	$ 5,137	0.847	1.00	5.0
1.400				2	4	1	$ 2,654	194	$ 5,137	0.786	1.00	5.0
1.500				2	4	1	$ 2,654	194	$ 5,137	0.734	1.00	5.0
1.600				2	4	1	$ 2,654	194	$ 5,137	0.688	1.00	5.0
1.700				---	---	---	---	---	---	---	---	---
1.200				2	4	1	$ 2,654	194	$ 5,137	0.917	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.6: Efficiency Analysis for Galaxy Habul Tower in HOMER

Figure 7.6 show that 1200Wh load is daily used in this house with a COE of $0.917 per KWh. But simulation results show that maximum 1600Wh load can be served by the installed solar home system with a CEO of $0.688 per KWh.

Here, Relative decreases of COE= $\frac{(0.917-0.688)\times 100}{0.688}$ = 33.28%

So, Efficiency for the system is (100-33.28) % =66.7%

7.7 Shah Ali Nibash

Serial No - 11

Address: 177/1, Ahmed Nagar, Paikpara, Mirpur-1, Dhaka-1216.

Date of Inspection: 30th April, 2016

Time of Inspection: 1.00 pm

7.7.1 Load Specification

From the collected data we were able to know that some of the garage and stair case lights are PV-system driven and the load connected is approximately about 200 W.

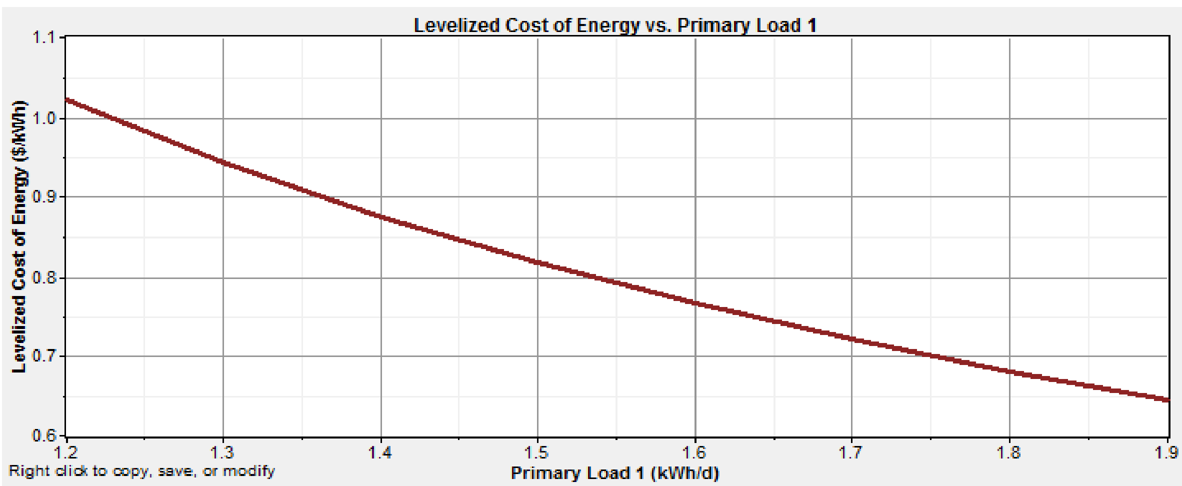
7.7.2 Battery, Panel & Inverter Specification

The Battery is a 12V, 130Ah one. There were 4 batteries in the system. One string consist of 2 batteries connected in series and one strings of parallel connection. There were 12 panels of 150W and 6 panel of 85W resulting total panel size of 2600W. The inverter rating was found to be 1000VA. So that specified inverter is used for system efficiency calculation. These exact parameters are provided as input for the simulation purpose.

7.7.3 Efficiency Calculation

Pri. Load 1 (kWh/d)	PV (kW)	12V130...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
1.200	2.6	4	1	$ 3,164	200	$ 5,717	1.021	1.00	5.0
1.500	2.6	4	1	$ 3,164	200	$ 5,717	0.817	1.00	5.0
1.600	2.6	4	1	$ 3,164	200	$ 5,717	0.766	1.00	5.0
1.700	2.6	4	1	$ 3,164	200	$ 5,717	0.721	1.00	5.0
1.200	2.6	4	1	$ 3,164	200	$ 5,717	1.021	1.00	5.0
1.300	2.6	4	1	$ 3,164	200	$ 5,717	0.943	1.00	5.0
1.400	2.6	4	1	$ 3,164	200	$ 5,717	0.875	1.00	5.0
1.500	2.6	4	1	$ 3,164	200	$ 5,717	0.817	1.00	5.0
1.700	2.6	4	1	$ 3,164	200	$ 5,717	0.721	1.00	5.0
1.800	2.6	4	1	$ 3,164	200	$ 5,717	0.681	1.00	5.0
1.900	2.6	4	1	$ 3,164	200	$ 5,717	0.645	1.00	5.0
2.000	---	---	---	---	---	---	---	---	---
1.600	2.6	4	1	$ 3,164	200	$ 5,717	0.766	1.00	5.0

(a) Sensitivity Analysis in Tabular Form



(b) Sensitivity Analysis in Graphical Form

Figure 7.7: Efficiency Analysis for Shah Ali Nibash in HOMER

Figure 7.7 show that 1600Wh load is daily used in this house with a COE of $0.766 per KWh. But simulation results show that maximum 1900Wh load can be served by the installed solar home system with a CEO of $0.645 per KWh.

Here, Relative decreases of COE= $\frac{(0.766-0.645)\times 100}{0.645}$ = 18.76%

So, Efficiency for the system is (100-18.76) % =81.24%

7.8 Improvisation of Installed Systems

For the charging of the battery a charger controller is used. Inverter takes its input from the battery and converts it from DC to AC. As it is a conversion it is obvious that there are some losses in the process. But if there is an inverter in the midway, conversion efficiency become lower while it could be more than 10% efficient without an inverter.

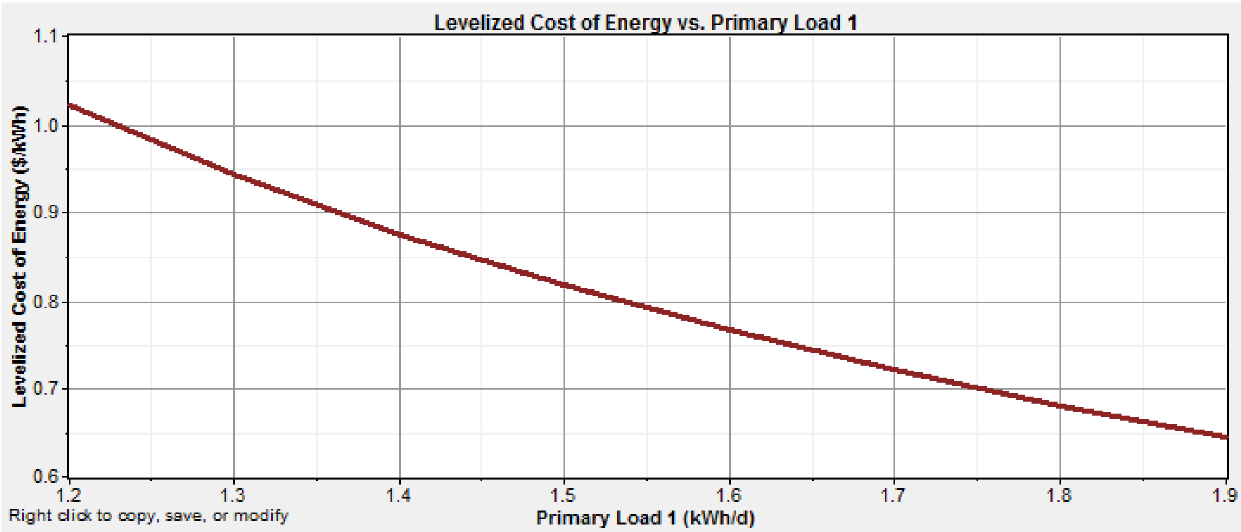
For the same system of 7.7 without inverter we can get 83.78 % Efficiency. Which is 2.5% more Efficient than the installed one.

Pri. Load 1 (kWh/d)	PV (kW)	12V130...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
1.200	2.6	4	1	$ 3,164	200	$ 5,717	1.021	1.00	5.0
1.500	2.6	4	1	$ 3,164	200	$ 5,717	0.817	1.00	5.0
1.600	2.6	4	1	$ 3,164	200	$ 5,717	0.766	1.00	5.0
1.700	2.6	4	1	$ 3,164	200	$ 5,717	0.721	1.00	5.0
1.200	2.6	4	1	$ 3,164	200	$ 5,717	1.021	1.00	5.0
1.300	2.6	4	1	$ 3,164	200	$ 5,717	0.943	1.00	5.0
1.400	2.6	4	1	$ 3,164	200	$ 5,717	0.875	1.00	5.0
1.500	2.6	4	1	$ 3,164	200	$ 5,717	0.817	1.00	5.0
1.700	2.6	4	1	$ 3,164	200	$ 5,717	0.721	1.00	5.0
1.800	2.6	4	1	$ 3,164	200	$ 5,717	0.681	1.00	5.0
1.900	2.6	4	1	$ 3,164	200	$ 5,717	0.645	1.00	5.0
2.000	---	---	---	---	---	---	---	---	---
1.600	2.6	4	1	$ 3,164	200	$ 5,717	0.766	1.00	5.0

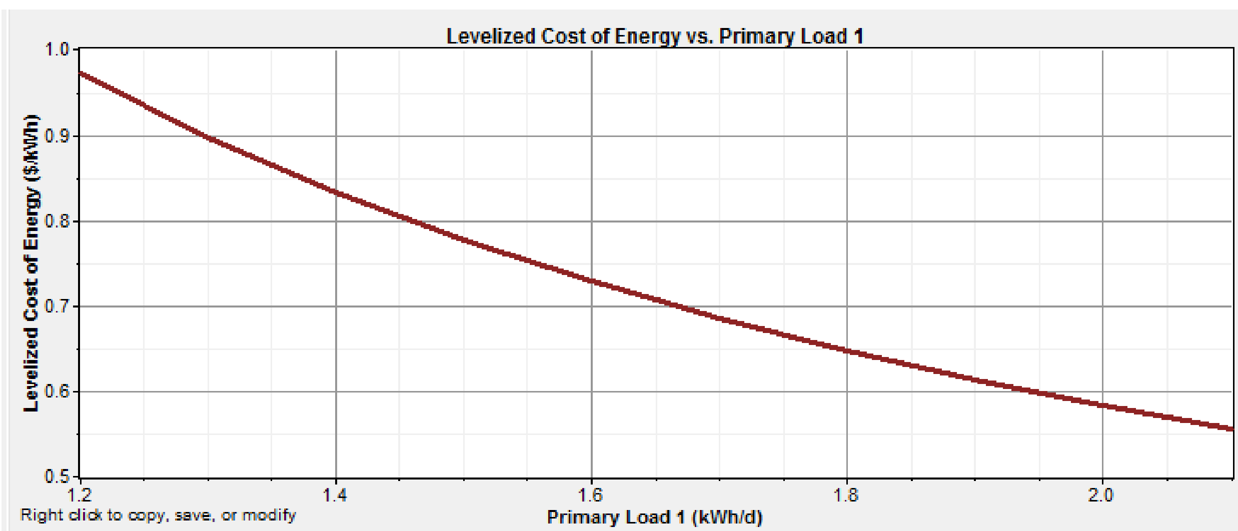
(a) Sensitivity Analysis in Tabular Form (With Inverter)

Pri. Load 1 (kWh/d)	PV (kW)	12V130...	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
1.650	2.6	4	$ 3,006	190	$ 5,440	0.707	1.00	5.0
1.200	2.6	4	$ 3,006	190	$ 5,440	0.972	1.00	5.0
1.300	2.6	4	$ 3,006	190	$ 5,440	0.897	1.00	5.0
1.400	2.6	4	$ 3,006	190	$ 5,440	0.833	1.00	5.0
1.500	2.6	4	$ 3,006	190	$ 5,440	0.777	1.00	5.0
1.700	2.6	4	$ 3,006	190	$ 5,440	0.686	1.00	5.0
1.800	2.6	4	$ 3,006	190	$ 5,440	0.648	1.00	5.0
1.900	2.6	4	$ 3,006	190	$ 5,440	0.614	1.00	5.0
2.000	2.6	4	$ 3,006	190	$ 5,440	0.583	1.00	5.0
2.100	2.6	4	$ 3,006	190	$ 5,440	0.555	1.00	5.0
2.200	---	---	---	---	---	---	---	---
1.600	2.6	4	$ 3,006	190	$ 5,440	0.729	1.00	5.0

(b) Sensitivity Analysis in Tabular Form (Without Inverter)



(c) Sensitivity Analysis in Graphical Form (with inverter)



(d) Sensitivity Analysis in Graphical Form (without inverter)

Figure 7.8: Efficiency Analysis for Shah Ali Nibash With and Without an Inverter in HOMER

From the Figure 6.8 we can see maximum AC load 1900Wh could be run with a COE of $0.645 while without inverter in DC load it can run 2100Wh load with COE of $0.555.

Here, Relative decreases of COE= $\frac{(0.645-0.555)\times 100}{0.555}$ = 16.21%

So, Efficiency for the system is (100-16.21) % =83.78%

Chapter 8

Proposition Regarding the Renovated Urban Solar System

8.1 Steps taken by the government/further steps

In Bangladesh the gap between supply and demand of electricity especially in summer is very high. Urban areas mainly use more electricity than rural areas. Urban Households can use solar energy as an alternative source not only to get rid of everyday load shedding miseries but also to reduce the power shortage. But the use of solar energy in urban area is yet not very popular. Solar energy is best known for lighting rural households of Bangladesh where electricity has not yet reached.

Bangladesh government has taken initiatives for efficient promotion of solar home systems and other renewable technologies. There are still many drawbacks for the whole renovated urban solar system. SHS, use of biogas and other renewable energies are more used in rural areas than urban areas where more local areas are not connected to national grid.

In urban areas effectiveness of solar system is a huge issue. In our survey of urban solar systems we have found that the major part of the installed solar system is not operational or not effective. City dwellers are not that much interested in the effectiveness of renewable energy sources. The main reasons behind this situation are high installment cost, technical problems during installing, specialized disadvantage and absence of strict policy enforcement by the government.

Government cannot diminish this crisis alone. We all have to work together. Other private organizations e.g. NGOs, distinctive solar manufacturer organizations, contributor offices approach readily and work as an inseparable unit.

The government needs to take logical, realistic steps other than the already taken initiatives. If government comes forward in favor of promoting the solar home systems in urban areas other organizations and institutions will regain courage to lessen the crisis.

Recently solar technology has become very popular in our neighboring country India. The amount of electricity generation by solar system has increased to a very large scale compared to

Bangladesh. The reason behind this sudden improvement is the initiatives taken by their government. Many autonomous and semi-autonomous organizations have introduced many fruitful policies in India. The administration and numerous self-governing and semi-independent associations there has presented numerous productive strategies. Our government can take similar kind of steps here so that people especially in the urban area can get more practical advantages and take advantages of our geographic location. Steps government can take are listed below:

1) Government can initiate a subsidy scheme to help individuals (both in rural and urban area) and organizations to buy solar technologies at reduced capital cost. Then people will be more interested in solar energy.

2) The plan can be implemented by establishing a solar system renewable energy development agency through a government bank (e.g. Shonali/Rupali/Agrani/Janota/Krishi Bank). The renewable energy development agency can be kept under the direct monitoring of government. The government will be checking, controlling the organization and will be modified depending on the economic situation of our country.

4) A few illustrations can be drawn to control the above mentioned plans, so that it is not misspent by any stretch of the imagination. These steps can be:

a. Selecting the right manufacturer for solar PVs from whom the user can buy the proper equipment. These manufacturers have to be approved by Ministry of Power, Energy and mineral resources.
b. These manufacturers will produce the best solar PV in Bangladesh.
c. Only the models approved by the respective governing ministry, would be eligible to be covered under the scheme.
d. Only individuals, group of individuals, non-government organizations (NGOs), farmers club and institutions like this will be eligible for this scheme.
e. For availing the scheme, individual or the organization needs to have an account with the respective commercial bank or local government bank.
f. The bank will have the right to review the sponsorship in case they observe that the sponsorship is misused.

In the rural areas, the impact of solar PV based electricity generation is extremely positive. Many underlying factors are responsible for this. One of the main reason is, many rural remote areas are still not connected to national grid system and people there need electricity connection even for limited number of time because they do not have any electricity at all. The government and SHSs (solar home system) have made it easy for them to get the components of solar PV. They have also helped rural people installing solar panels at a low cost. People of rural areas are not that much mindful of the PV based framework detail. They simply pay for the system installment for getting electricity in their houses and they are availing the opportunity. As a matter of fact, there is no rigorous need of imposing the policy of installing the solar home systems in rural areas because people in rural areas are in need of electricity. They will try to install solar PV even if the government does not force them. A simple request and some effective advertisement of the practical advantages of solar energy based system are effective to make the aware of the positive outcomes of green energy.

On the contrary, people of urban area are not getting the proper advantages of the installed solar systems on the roof tops. Low priced cheap components, low evaluated modest parts, lack of proper moderation and involvement in corruption of the personnel of related field, lack of awareness, high installation cost of the PV based systems, technological drawbacks, mechanical downsides and many other reasons are dominant in this case. People in the urban area are not getting anything beneficial over grid electricity. So requesting to implement the solar energy promotion policy is not an option in the urban areas. Rather, forcing the approach can bring some positive results if the arrangement execution is connected.

a. Battery backup is a must necessity if we want to design and install solar PV systems in the context of Bangladesh. In the event of a DC framework, there are no different alternatives than including battery reinforcement to store the solar energy. By using the AC systems, there exists an option of connecting the output of solar panel directly to the inverter input. But this option is also not feasible at all because if there is no battery backup then at night when there is no solar radiation, no input will fed the inverter and as a result there will be no electricity to drive the necessary connected load. This happens because of the absence of the storage element (battery) to store the necessary energy at nigh time to deliver energy. So, in perspective of Bangladesh, whether any company designs and installs any solar home systems, battery backup is a must option.

b. Inclusion of an optimizer in the newly installed solar home systems can be an possibility for efficient operation. An optimizer is a DC-DC converter that boosts the required level of DC voltage according to the user need and this device can be packed with the charge controller. The main advantage of including an optimizer is it reduces the copper loss to a great extent. The ostensible operating DC voltage in our country is 12 volts. If we want to use a DC load that is placed in a far remote area from the PV system, then the amount of current (for a load of around 200W- 600W) is high enough to incur a huge copper loss. Practically, in 12 volts DC systems no output is usually found after 25 feet of long wire. As a result, we have to thicken the wires to reduce the loss. But this will increase the copper cost which will discourage the urban people to install PV systems in their home. So to connect any remote DC load, a choice other than utilizing thick wire is to use an optimizer which boosts the DC voltage level to a significant level (usually 120 volts) at the PV system end. This results in a low estimation of current which thus diminishes the copper loss to a great amount. Particular loads are being outlined which can be utilized with the optimizer yield. In this way, clients can be motivated to introduce sun based PV systems alongside the incorporation of optimizer for getting sunlight based electricity at a lower cost.

c. Introducing Feed in Traffic (F.I.T) system in the scenario of Bangladesh is discussed in the latest version of the rough Renewable Energy Policy, 2014. Feed in Traffics a policy mechanism designed to accelerate investment in renewable energy technologies. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. Some plans also have been proposed for the policy of introducing F.I.T. Some points needed to be considered before we can start this policy. In our country, meter tempering is a very common issue in urban areas. The persons who take the meter readings from houses to houses are drowned in corruption. They are taking bribery from almost every house on the particular area. Other than this, components and meters used in our utility systems are very low graded. There is no rigorous quality checking provisions for these elements in the country. So reducing the corruption to almost zero level is a priority for encouraging the people in urban areas to take solar energy seriously and using the very best components, meters and other related elements along with establishing a quality monitoring system of these components are the fundamental pre-requisites for introducing and applying F.I.T in Bangladesh.

d. The old houses, where the AC wiring is already present, executing another DC wiring there would add an extra cost which is not achievable by any stretch of the imagination. So if we need to use the output of solar PV system effectively in the AC wiring based old houses, then we can run the motor for water pumping from the PV framework. Traditional AC motors are appraised at 300W-400 with adequate head and pressure ability to lift water. So an insightful utilization of PV system in this situation would be to drive the engine for around 4hours a day from the solar PV system where an inverter is fused for driving AC load. Other than AC systems, a full DC wiring can be executed in the new manufactured houses those are smaller in size. In these new houses, garage and stair case lights, DC fan and TV can be driven by solar PV system.

Chapter 9

Conclusion

Global demand for energy will be more than double by mid-century and more than triple by the century's end. Meeting this demand is society's foremost challenge. Renewable energy advancement in existing energy technologies can bridge the gap between today's production and tomorrow's needs. The enormous untapped potential of the solar energy is a friendly opportunity to meet our future energy needs. Considering the fact, we started our thesis project to analysis current urban solar home system efficiency.

We have inspected 25 solar home systems in Mirpur area in Dhaka. It is very unfortunate that most of the systems were inactive or not connected in proper way. Although urban people are more likely to know the efficient usage of solar energy, they still prefer fossil fuels for their power generation. In this manner, they are indirectly contributing to environmental hazards and wasting lots of money too. The main aim of our thesis is to analysis the existing solar systems' efficiency regarding the power supply and cost consuming. We have used HOMER software to calculate those facts of efficiency and have been able to propose an effective system to meet up our demand. We have remodeled the available batteries in Bangladesh by HOMER software to enhance the performance of solar system.

Moreover, we also have proposed some initiatives those should be taken by Bangladesh Govt. to increase the power generation from solar energy and solar energy user as well. Thus a developing country like Bangladesh can be self dependent in power generation, can keep the environment green and save money by using solar energy.

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Appendix A

Grameen Shakti

Grameen Shakti, an a_liated not for pro_t organization of the Grameen Bank, has been implementing PV program for rural applications for the last 3 years. The main activity under its PV program is the installation of Solar Home System (SHS) in Mymensingh, Tangail, Comilla, Khulna, Sathkhira , Rangpur and Bandarban districts. Grameen Shakti (GS) follows the so called hard approach in implementing the PV program. It sells PV systems in rural areas. GS also installs and maintains the systems. However, to make the system more easily accessible to rural households, GS sells PV systems even on credit . The credit is as follows:

I. Customers pay 15% as down payment
II. The remaining 85% is paid on a monthly installment basis within 3 years.

Grameen Shakti, the leading NGO in Bangladesh has installed 276,549 SHSs in 2013. In this year out of 10 packages with diffierent combination of lights and LCD/LED TV (load), 20 Wp system is the most popular Sales figures are: total installed SHSs 276,549, 20Wp 140,206 nos., 30Wp 55,064 nos. and 50Wp 55,064 nos.

The major experience of Grameen Shakti for rural electrification using PV systems are as follow:

I. There is no damage of battery
II. Customers are generally happy with technical performance of the systems
III. Some customers are using PV system for income generation
IV. Customers usually show interest for PV systems
V. The main hindrance behind the slow expansion of the PV program is the very high cost of the system