COST-BENEFIT ASSESSMENT OF ON-GRID PV SOLAR SYSTEMS FOR A TWO STOREYED BUILDING

A PROJECT AND THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

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June 2021

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Certification

This is to certify that this project and thesis entitled "**Cost-benefit assessment of on-grid PV solar systems for a two storeyed building** " is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 27 June 2021.

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List of Abbreviations

IEA	International Energy Agency
GHGs	Green House Gases
CFCs	Chlorofluorocarbons
BP	British Petroleum
BPDP	Bangladesh Power Development Board
GWh	Gigawatt hours
MW	Megawatt
PV	Photovoltaic
SREDA	Sustainable and Renewable Energy Development Authority
HFO	Heavy Fuel Oil
COE	Cost of Energy
GDP	Gross Domestic Product
FIT	Feed in Tariff
NPC	Net Present Cost
IRR	Internal Return Rate
RE	Renewable Energy.
NASA	National Aeronautics and Space Administration
DC	Direct Current
AC	Alternating Current

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A	Ampere
V	Voltage
NPC	Net Present cost
IRR	Internal Return Rate

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ACKNOWLEDGEMENT

First of all, we give thanks to Allah. Then we would like to take this opportunity to express our appreciation and gratitude to our project and thesis supervisor **ENGR. Md. Sohel Rana ,Lecturer** of Department of EEE for being dedicated in supporting, motivating and guiding us through this project. This project can't be done without his useful advice and helps. Also thank you very much for giving us opportunity to choose this project. We also want to convey our thankfulness to **Dr. Engr. Md. Shahid Ullah**, **Professor and Chairperson** of the **Department of EEE** for his help, support and constant encouragement. Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us in making this project a success. Also thanks for lending us some tools and equipment. To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this University.

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ABSTRACT

For the development of a country, electrical energy is essential. For Bangladesh electricity generation cost is increasing rapidly as a result a solution is important to reduce the generation cost. At present, the scenario of power generation all over the world are mainly dependent on fossil fuel that is not climate-friendly and produces greenhouse gas that is responsible for global warming. Solar PV energy can be a solution. This solar PV model is designed by using a software tool named HOMER Pro. To design this study solar radiation, area, solar panel, and inverter price operation and management cost are considered. Total initial costs are $52639. We find a simple payback period of 8.7 years and an discount payback period is 12.16 years. An energy production cost is 0.0239 $/kwh that's is lesser than the electricity purchase price. 1270 tCO2 is gas emission is reduced every year. It is not only economically benefited but also environmentally benefited This study find that solar PV is financially feasible.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Bangladesh is a slightly developed country in south Asia . Total population of Bangladesh is almost 163.05 million [1] with an electricity access rate of about 94%[2]. The demand for energy is increasing day by day in Bangladesh. In 2009 electricity generation capacity was 4296 MW. Within 10 years It becomes 12539 MW[2]. The power demand in Bangladesh will about 34000 MW within 2030 .The install capacity including on grid solar is about 20813 MW[3]. There is a huge difference between the demand and installed capacity because of variation of energy demand and power production cost difference from various source . In Bangladesh 55.26% power generated by natural gas . It was more than 84% ten years ago . The reservation of fossil fuels is reducing day by day. Also the fossil fuels based power station is very harmful for environment. So, Bangladesh needs alternative way for producing electricity.

The World energy demand increasing rate is quite high. Now the day's electricity demand for China and India Increased at a remarkable rate. According to IEA 850 million people do not have access to electricity worldwide [4]. To meet increasing electricity demand world is move towards renewable energy . In this case, renewable sources like wind energy and solar energy are the main energy sources that are being used. The uninterrupted use of fossil fuels has reduced the amount of fossil fuel deposits and has greatly affected the environment, reducing the biosphere and adding to global warming. Among renewable energy, solar energy is more reliable for Bangladesh.

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1.2 World renewable energy status

World total renewable energy production capacity was 2356065 MW and production was 6586124GWh in 2018. Most of the renewable energy is generated in Asia. China(Fig1.1) produces 1811174GWh Power in 2018. More than 30% of the world's total renewable energy generation is generated in China. Renewable energy generation in India is 235722 GWh in 2018[5].

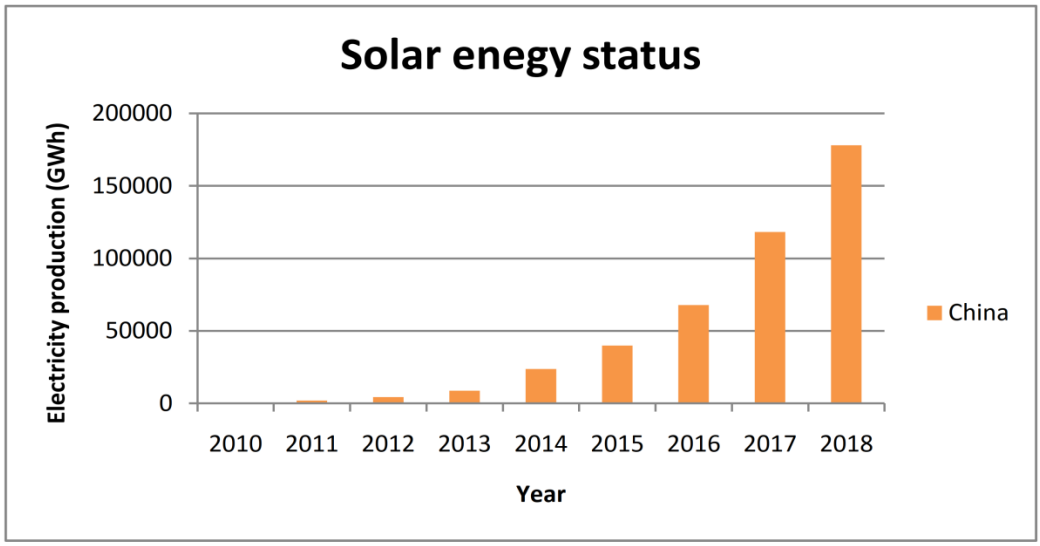

Fig.1. 1: Solar PV generation in China

Within renewable Hydro , PV , Wind , Tidal , Geothermal is most popular . IN 2010, USA produce 440677GWh electricity. In 2018 it increases 743177GWh[5].Worldwide solar production capability was 33 813GWh in 2010. In 2018 it becomes 562033GWh. That's Indicates that PV production increases quite a lot last 10 years. In solar energy production contribution of china is remarkable. In 2011 china produce 1999GWh solar energy. Now it is 178071GWh. India follows the same tends like china in 2010 India produces only 65GWh solar energy in. In 2018 it's 31067GWh[5] .India reaches in top ten in solar generation ranking . World

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renewable production is increasing in a remarkable rate . Specially PV become more popular for decreasing production cost and increasing efficiency.

1.3 PV energy status Bangladesh

Bangladesh is a tropical country. Average daily solar radiation of Bangladesh is 4–6.5 kWh m^{-2} .In April radiation level is maximum and in December it is minimum..It is initiated that 94% of the land area in Bangladesh has such radiation[6]. Battery charging being substituted by SHS [7] .The success of solar Photovoltaic (PV) is recognized for rural household and small business areas. PV energy condition is remarkable in a rural area in Bangladesh. In the off-grid installation, the status of Bangladesh is high. Different government and non-governmental organizations working on the solar home system.

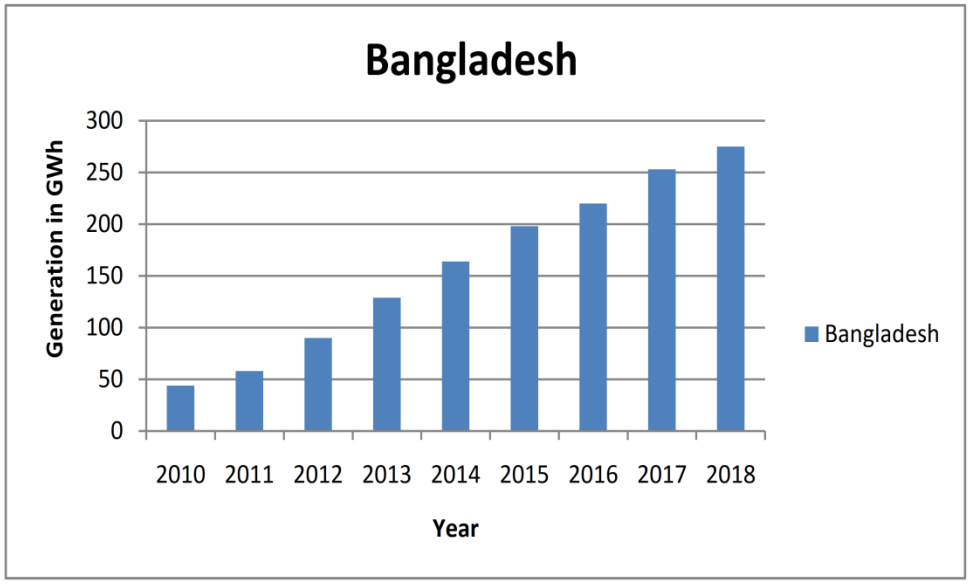

Fig 1.2: Solar PV Generation in Bangladesh

About 80% of the total PV is off-grid in type. only 20% of the PV installation is on-grid type. Most of them are installed in recent years [8].In the solar home system, the energy production cost is high because of the use of the battery. So now government concerned about on gird net metering system. In the net metering system consumer

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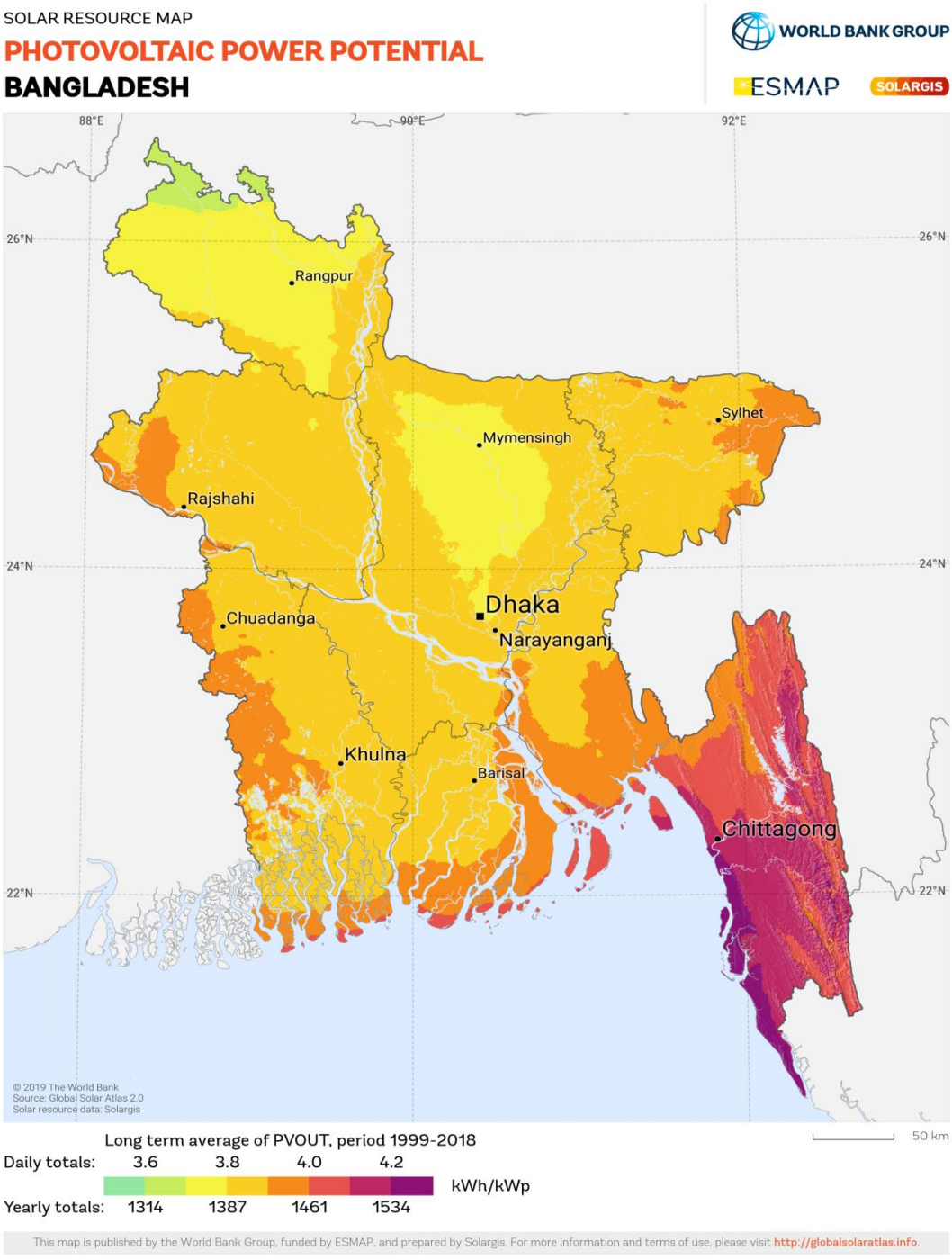

Fig.1. 3: Solar PV power Potential Bangladesh

can salepower to the grid and purchase power from the grid. For net metering rate of sale and purchase price is the same. In Bangladesh, solar radiation is more in

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Dinajpur and less in Barisal. Coastal area is less feasible for PV installation. PV generation depends on temperature and solar radiation both . Temperature decreases the PV production. More than 600MW solar PV project is in under construction under IPP sector [9]. More than 70MW PV project is commissioned in last three years. Trend of On-grid PV system is visible. Implementation of PV power generation will ensure future energy demand.

1.4 Problem Statement

Electricity is the most expedient form of energy and a key factor for economic enlargement in any country. It cannot be replaced by other forms of energy. The energy status is confronted since the major power stations are run on natural gas, whose assets are now on the verge of diminution. Power generation by PV with Battery is more costly. So the calculation of cost we see that it's very harmful to consumers. Cause they waste a high amount of money on a low amount of power.

So it is important to calculate solar PV generation cost in on gird system. This study tries to solve the following questions.

- Is the system Techno-economically viable for Investment ?
- COE per unit generation.
- Find out the net preset cost for PV energy.

1.5 Objectives

In the solar roof top system if we implement properly we can get easily benefited. So at first we set a target and then we complete it step by step. If we complete our goal then we minimize the pressure of power on the national grid using the renewable energy. The broad Objectives of this report are mainly understood Installation benefit of the rooftop solar system. Give the information on the grid, off-grid solar system to the consumer. Give advice to the consumer for keeping the clean solar panel. Net

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metering system. With all the efforts of this entire time, it was the main goal to produce such informative report paper that will be useful to all . Moreover some of the specific purpose of this exploratory research are-

- To determine the per unit generation cost .
- To determine the difference between per unit generation cost and pushing cost.
- To study solar PV On-gird system of Bangladesh.
- To quantify a number of greenhouse gas emission from different systems of model.

1.6 Future scopes

Most of the energy is consumed in the industrial and commercial sectors that's are in City or town. In Bangladesh, those who use more electricity have to pay more electricity bills per unit. The net metering system can be a better solution to reduce their electricity bill. It is applicable for households, Mosque, school, and University buildings. This system not only saves electricity purchasing cost but also helpful for economical benefit. One can income from this system by selling electricity.

Besides that without solar energy other energy resources in limited in Bangladesh. So it will be a preparation for energy production through solar PV. Energy production cost by diesel generator is so high. So the on-grid system can easily replace diesel generator in the future.

1.7 Overview

This chapter discusses the energy status of Bangladesh and the world. The world is moving towards renewable, Bangladesh in the same way. Bangladesh has one resource to meet future energy demand. That is solar energy. Off-grid solar installed in Bangladesh with a remarkable amount .Different organization is working on it .

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But Off-grid has less benefit and it is not comfortable. So a recent trend is about on-grid solar energy. The cost of on-grid energy is less. So it is economically feasible. It is applicable for who has more than or equal 440-volt electricity connection. Now it is not available for the small user. Thesis Outline

This Project/thesis is organized as follows:

1.Introduction

2.Literature review

3.Method

4.Result and discussion

5.Sensitivity and Emission

6.Conclusion

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Bangladesh is a third world country with negligible natural resources. The resource of fossil fuel will finish within a few years. so recent studies focused on renewable. Within the renewable source of wind and solar is now vital for the researcher. Most of the study is about off gird. A few of them are gird connected. This chapter starts with the exhibition of wind and solar power technology and described various factors that are related to the renewable energy power conversion system. At present most of the renewable energy comes from wind energy and solar energy. We discuss the COE, NPV, IRR of different studies both on-grid and off-grid. Then we focused on the on-grid condition and future prospects of it.

2.2 Energy

Fig.2. 1:Energy

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The simple definition of energy is called the ability to do work. The various definition of energy. It's like a constant amount because the energy can't be created or destroyed. It simply changes his form from one form to another form. Energy has various from in the world. There are different forms of energy like electrical energy, potential energy, heat energy, thermal energy, kinetic energy, water energy, etc. In another classification, energy can be classified into two types of renewable energy and non-renewable energy. Coal, oil, and natural gas are non-renewable energy. We will focus on renewable energy.

2.3 Renewable energy

In the present world situation the renewable energy is more popular for his various good side. The renewable energy is good for our environment. So now it's really need to increase the use of fossil fuel base energy system. If the energy consume is lower than the energy generation then it's called renewable energy Now the renewable energy is most important in the whole world. Cause of that if the nonrenewable resources to be finished then the world energy system face a horrible situation. That's the thought it's time to convert the whole energy system to make renewable.

Fig.2. 2:Renewable energy

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2.4 Hydroelectric Energy.

Hydroelectric energy generate use to water flow. Here first create a dam to reserve the water. When the full fill the reserve then the water flow the direct in the water turbine. When the water is reserve it's called potential energy but when the water is flow then the potential energy is convert to the kinetic energy and when the water flow through the turbine then the kinetic energy of water is converted into the mechanical energy. At the final stage the mechanical energy is converted to the electrical energy using the alternator.

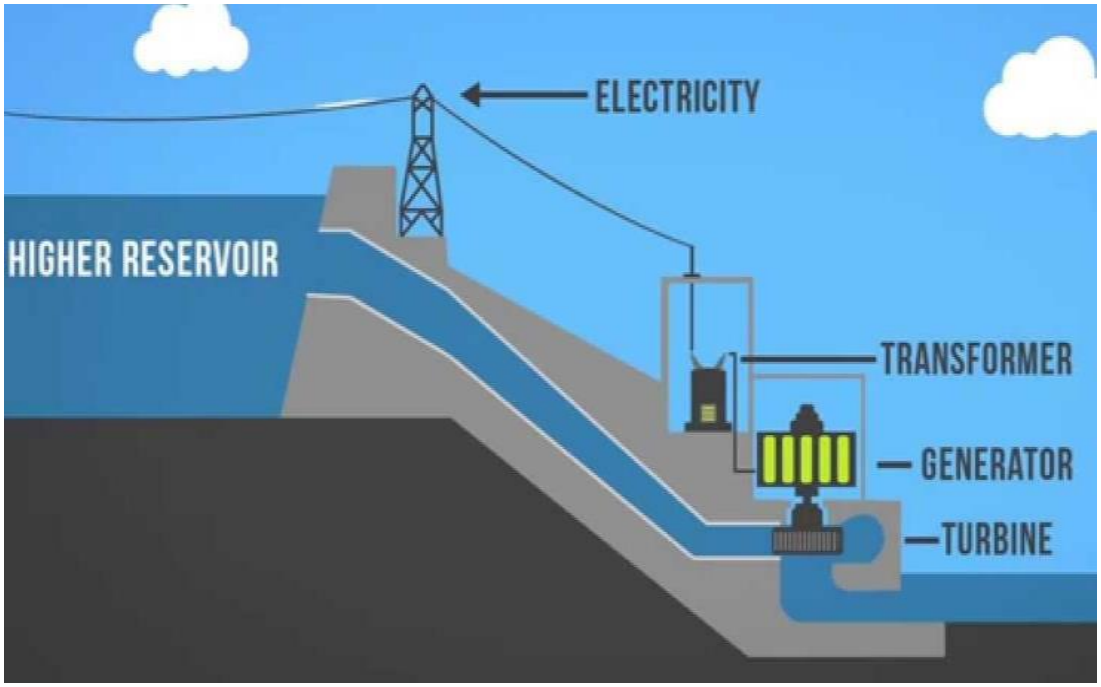

Fig.2. 3: Hydroelectric Power Plant

Being a plane country, Bangladesh is not in a favorable position for large-scale hydropower There are small probable of diminutive and micro-hydropower in CHT region and greater Sylhet region. The total hydropower probable of the country in three locations (Kaptai, Sangu and Matamuhuri) is 1500 GWh/year (755 MW) of which about 1000 GWh/year (230 MW) has been harnessed at Kaptai through 5 units of hydropower plants is shown fig 2.3 [10]. Future development of hydropower at

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Sangu and Matamuhuri should be measured with consideration to their harmful impacts on environment and on local population.

2.5 Wind energy

The first wind energy based power plant was installed in the UN in 1890 [11]. Then this technology became popular for power generation in the world. From 1973 using of many sources of renewable energy was increased in different countries in the world. A lot of research and illustration on wind turbine technology was simulated. There are a lot of advantages of using modern wind turbine. As the wind power technology has strong characteristics for utility scale power generation, a large wind firm implementation is becoming most popular at present [12]. The components of a present wind turbine are the tower, the yaw, the nacelle, the rotor, the generator and the gearbox. The most important part of the wind turbine is the tower holds that keeps the turbine blade. To turn the wind turbine rotor blades in the direction of wind speed a yaw system is used. Gearbox is another important part of wind turbine which is used for increasing the rotor speed on the electrical generator side. The gearless wind turbine has been used in various situation which is very easy to maintain.

2.6 Bio-gas

Agriculture based country Bangladesh has vast potential for utilizing biogas technology. Biogas is a fuel gas obtained from an aerobic (i.e. in the absence of oxygen) absorption of cattle dung, poultry droppings, human excreta, and agricultural residues. Bangladesh is in a favorable position in respect of accessibility of raw materials and the climatic conditions for biogas production. Cost is the most primary factor limiting the wide application of biogas .

2.7 Tidal Power

A mean head of at least five meters is regularly considered to be the minimum for viable tidal power generation. Therefore, there is very less potential viewpoint of tidal resource in Bangladesh. There may be scope of integrated tidal power plants in the coastal regions .

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Fig.2. 4:Tidal Power

2.8 Solar energy

Power developed by solar heat or PV system is called solar Power. In Bangladesh PV type of solar is commonly used . In this country solar radiation status is good. It's range is 4-5.5 KWh/m^2 [6] .Energy outcome of solar cell basically depends upon three variable . First of all solar radiation , second variable is Temperature and third variable is the time duration of solar radiation in a day . Beside that efficiency of solar panel, Inverter also responsible on Total power output from a PV system . Solar energy now used for pumping where no grid electricity connection is available .It now used in remote area of Bangladesh . Solar energy is more available and more useable form of renewable energy. Most of the research of renewable energy is about solar energy in present world .

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Fig.2. 5 :Solar Cell

2.9 Advantages of Renewable Energy

The renewable energy is the one of the best way to produce energy without any harmful effect of our environment. Its various good effect that's we benefited and the environments also benefited. So now it's time to changes to our mentality to increasing the using the fossil fuel base energy system. Now we discuss some advantages of renewable energy

- In the renewable energy resources is not limited resources its resources is unlimited.
- For the unlimited resources so we can easily get it. Cause its available everywhere that's why we continuously supply it all time when it need.
- Whenweconsumepowerwithinashortperiodtimeit'scanbepunished.Soit'saveryg ood advantages for us.
- In the most of the resources are available locally and fairly non-polluting.

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- Intheoneofthebestadvantagesisit'smaintaincostistoolittleandtherepaircostalso be little.
- After installation the renewable energy system supplies power in the long time period with a little amount of cost.

2.10 Disadvantages of Renewable Energy

There new able energy have more advantages then disadvantages. But it's also some disadvantages. The disadvantages is not the major issue if we compare its advantages.

- First cost or initial cost of the renewable energy is too high.
- This types of power plant can't be generate a high amount of power that's why its cant supply power continuously. That's why its limited supply.
- In the solar power when sunlight is not present or rainy day in that time it's can't be generate power.
- For hydro when occurs drought then the hydro can't generate power.

2.11 Study background

The sun is the largest source of energy it emits energy is 174 trillion KWh within one hour to the whole universe[13]. The radiation of solar energy to the earth by electromagnetic radiation Among them almost 33% of total energy is reflected back from the earth . Another 67% creates constant energy. Fig 2.4 is shown 828 MW solar power plant in Mexico. The largest solar power plant is situated in India . The name of the world largest power plant is Bhadla Solar Park and the capacity of the power plant is 2245 MW. The second largest solar power plant is located in China and it is known as Tengger Desert Solar parks. The capacity of this solar power plant is 1500 MW. The largest power plant of Bangladesh is located in Teknaf and its capacity is 28 MW .There has not been much study on on-grid photovoltaic power systems. Several studies about on-grid and off-grid system show that power production price is decreasing.

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Study of A. Allouhi, et al.(2019), shows the effect of three different solar PV panel .They are Polycrystalline, Monocrystalline, and amorphous .They analyze the COE and the Simple payback Period using PVSyst software . They vary the capacity of the system but electricity rate was same . They find minimum COF and shortest payback period by Polycrystalline technology[14] . In Thailand, used a constant PV system size with a constant power tariff to achieve a suitable FIT policy for the residential customer, and it was found that investing in a PV system on residential roofing under the current roofing scheme was economical. it is not feasible and reduces current. Market value can reach the expected investment return of 35%. While different researchers used a variable system size with variable power rates to obtain optimal PV system design with the best policy for different countries

Both used IRR as a parameter for the evaluation process. In addition, the capacity of a variable system with different load patterns was used to evaluate various Italian electricity pricing policies[15]. It is observed that the current tax program gets a shorter payment period. But in fact, it is not feasible that the payback period depends on the site latitude

Homer software was used to evaluate the effect of adding rooftop PV systems to the utility grid, and it was found that the use of PV systems could reduce power cuts, especially in summer, on the other hand, it It was observed that the efficiency of PV cells decreases as the temperature increases in the summer period. In context, it was concluded that consuming a small amount of electricity from the grid would increase the minimum electricity rate, while applying the minimum power from the grid is not guaranteed to achieve the minimum tariff, as a small amount of electricity can be Is to be consumed at high peak periods with high rates. In reference , it was shown that in 2016 only 0.1% of the Brazilian residence would be ready to use the PV system. This ratio would increase to 55% in 2026, while this study assumed that all economic factors are logical which need more studies to evaluate various opportunities for Brazilian customers. From the previous review, it has been shown that there is a lack of research from the point of view of pricing planning apart from the pricing

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2.12 Summery

This chapter focused on the past and present condition of PV system. Study before 10 years the PV production cost was BDT 15-25 KWh [16].Recent study about solar PV system indicate the price is now less than BDT 10 KWh[17]. The on-grid system without battery cost is less than BDT & KWh. The NPC, COE, IRR, is very important for financial analysis of On-grid power system. In this chapter, the source of renewable energy, it's a description, and the situation of solar energy and its production and financial part is discussed.

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CHAPTER 3

METHOD AND PARAMETER

3.1 Introduction:

In this thesis , on grid PV system is proposed for a two storey building . . Monthly average solar radiation and temperature data is collect from NASA surface meteorology. To design this study Homer Pro Software is used. By using the software, it can be also found out different types of cost such as cost of energy, net present cost, total annualizes cost, annual real interest rate, replacement cost, operation, maintenance etc. From the calculation, the best combination is determined the energy generation cost and financial benefit from PV energy export to grid. . The feasibility of the system also analyzed using this software. Here is also done the sensitivity for the designed solar PV system. At first need to design the model by using HOMER Pro and simulate this model to find and calculate all the data and also find out the feasibility of this model. All the design, Calculation, optimization, simulation and all kinds of necessary work are simulate by the HOMER Pro software.

3.2 Data Location

For select the data nearest location is considered .Solar radiation and temperature data is collect from NASA for latitude 23.7 and longitude 90.4 . Dhaka is very hot and humid climate zone . Solar energy production reducing with increasing temperature. But solar radiation of Dhaka is suitable for PV power generation . Average earth temperature is 14.2 °C.

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3.3 Solar radiation and Temperature

Table- 3.1: Monthly average daily radiation (KWh/square meter/day)

Month	Clearness Index	Daily Radiation (KWh/square meter/day)
January	0.559	4.034
February	0.537	4.43
March	0.526	5.001
April	0.491	5.146
May	0.466	5.108
June	0.361	4.003
July	0.320	3.511
August	0.361	3.829
September	0.387	3.793
October	0.500	4.292
November	0.559	4.149
December	0.585	4.016

Fig.3.1:Solar radiation and clearness index.

Solar radian data is collected from NASA. Radiation is maximum in April and minimum in September . After December solar radiation increase and after April it

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decreases . Solar temperature is also increase after march and it reduced after October . Rise of temperature has a negative impact in solar PV energy production .

3.4 Study Area

Rooftop area of a building is e selected for this analysis . Specific part of rooftop area of a two storeyed building is consider for this study . 300 square meter rooftop area is selected .Beside that additional area is also available according to demand .

Fig.3. 2: Rooftop area.

3.5 Grid connected solar PV power plant Model

In this thesis, the model is divided into main two parts . First parts is about PV power generation and export to grid. And another part is for maintain the load by PV power not from grid when PV energy is available. Actually this two process is work together in net metering system . In Fig3.3 Net metering system is shown .

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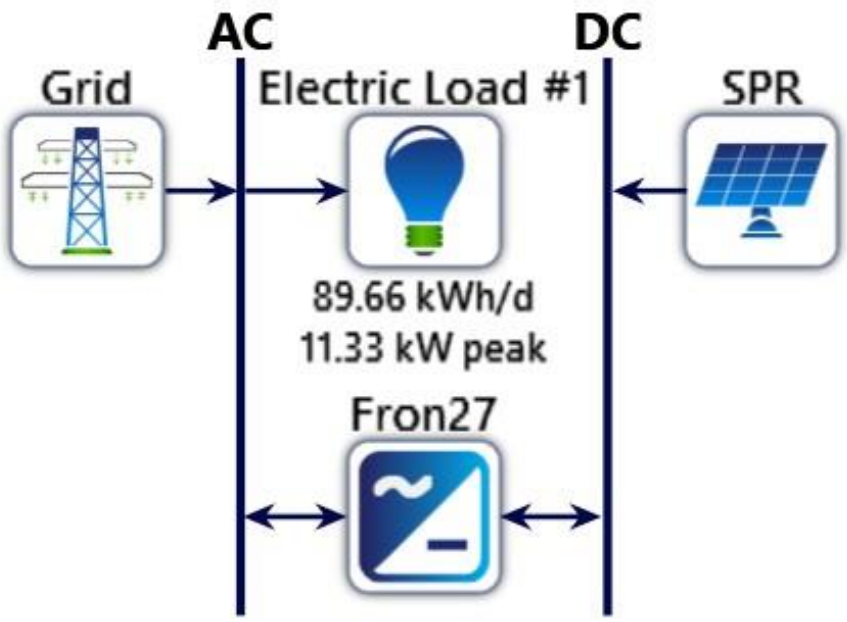

Fig.3. 3: Diagram of proposed model

3.6 Load Estimation for Proposed Region

Table 3.2. Load data of summer

Load	Quantity	Load (watt)	Total watt	Hours of operation per day	Watt hour per day
Fan	16	80	1280	20	25600
Light	24	25	600	8	4800
Laptop	20	45	900	12	10800
Desktop	12	120	1440	12	17280
Cellphone-charging	30	25	750	3	2250
Refrigerator	1	100	100	12	1200
Motor	1	1000	1000	3	3000
Water Heater	10	500	5000	0	0
Television	1	50	50	8	400
Outdoor lighting	2	20	40	12	480
Toilet lighting	4	5	20	1	20
Total watt hour per day					65830

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Table 3.3: Load data of winter.

Load	Quantity	Load (watt)	Total watt	Hours of operation per day	Watt hour per day
Fan	16	80	1280	0	0
Light	24	25	600	12	7200
Laptop	20	45	900	12	10800
Desktop	12	120	1440	12	17280
Cellphone-charging	30	25	750	3	2250
Refrigerator	1	100	100	12	1200
Motor	1	1000	1000	3	3000
Water Heater	10	500	5000	0.5	2500
Television	1	50	50	8	400
Outdoor lighting	2	20	40	12	480
Toilet lighting	4	5	20	1	20
Total watt hour per day					45130

3.7 Selection of Component

To design the solar PV power system, we used HOMER Pro software. The components that we took for simulation are- PV array, Inverter , Grid ,and bidirectional meter. HOMER Pro software simulates the results of on-grid arrangements. To select the components, the quality and the availability of the components are given priority. Price is also an Important factor for this analysis. Every component that are taken to design this model will describe below.

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3.7.1 Solar PV

A solar panels how much electricity produce it's depend on three factors. This three factor is

- Panel's size
- Efficiency of solar cells
- Amount of sunlight that the solar gets.

While there are a number of factors that determine the electrical output of a solar power system, the number of solar cells and overall size of the solar panel array, are the major determinants in how much electricity can be generated from a solar system. The more solar cells and larger the solar panel array is, the more electricity can be generated. Photovoltaic (PV) is a method of changing light energy into direct current electricity using semi conducting materials that exhibit the photovoltaic effect, a phenomenon commonly studied in physics, photochemistry and electrochemistry. This system employs solar panels composed of a number of solar cells to supply usable power. Two common PV panel types are mono and polycrystalline panels. Loom solar panel 375 W is selected for this study , shown in Fig.3.4. [19]

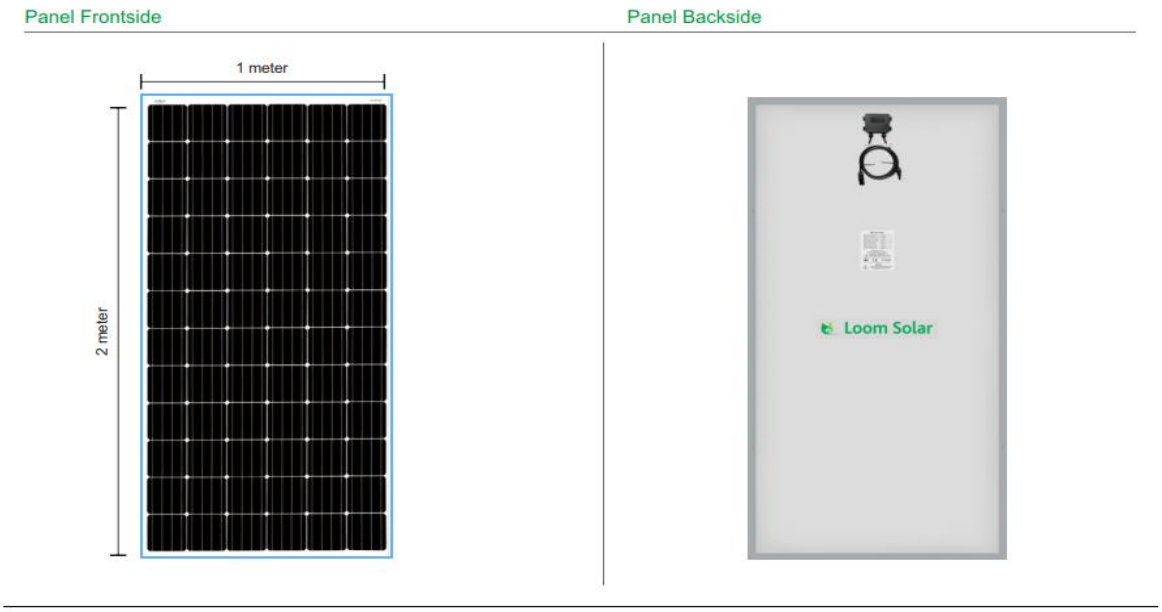

Fig.3. 4:Loom Sonar Panel

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Loom is mono crystalline solar Panel . It's output Voltage is 24V and Plant capacity is 75 KWh. Efficiency of solar PV is 22% , Lifetime is 25 years and capital cost is 800 USD/KW.

Table.3. 4: Installed PV panels parameter.

Parameter	Unit	Value
Pannel voltage	Volt	24
Total Capacity	(kWh)	620
Efficiency	Percent (%)	22.00%
Pannel Power	W	335
Capital cost	USD/kW	850
Replacement cost	USD/kW	850.00
Lifetime	Year	25

3.7.2 Inverter

This step is necessary, because solar panels cannot create AC power on their own and in the United States, most electrical devices run on DC power. In a DC system, the electrical current flows in one direction. By contrast, AC power is a bit more complex, moving in both directions, backwards and forwards. Solar PV systems would be worthless without solar inverters - as such, many consider solar inverters the "brains" of the entire system. The way they work is, once radiant sunlight is converted into electricity, solar inverters transform the electrical current from direct current (DC) power to alternating current (AC), so it can actually be used in various applications. Typically, solar inverters are about 98% efficient, so they only lose about 2% of the electricity during the conversion process.[20]

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Table.3. 5: Parameter installed inverter

Parameter	Unit	Value
Inverter efficiency	Percent (%)	98
Capital cost	USD/KW	150
Operation and maintenance cost	USD/Year	150
Life Time	Year	12

Inverter is an electronic device which converts the DC electricity to AC electricity which most appliances run on it. It is necessary to point out that the mentioned inverters which are used in stand-alone systems are very much different from those used in on-grid systems, because they must have the capability to ensure all the AC appliances requirements and also to have a sufficient efficiency. The inverters of PV systems usually come in two models, ON-GRID & OFF-GRID. In this study efficiency of inverter is 96.8% and Power rating is 20KW [21].

3.7.3 Mounting System

Solar mounting systems must be installed according to local building codes. However, generally speaking, rooftop PV arrays are generally mounted parallel to the surface of the roof with just a few inches of space between the system and roof. Arrays are mounted at angles that enable them to optimize sunlight capture - i.e. closest to a 90 degree angle with the sun.

3.7.4 Grid

This study is Grid connected PV system . For Grid connected system consumer can purchase or sell to the grid at the same time. In Grid Connected system Battery is not required . Transmission line cost also included in this study.

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3.7.5 Meter and Net Meter

Meter can measure power consumption but cannot measure power sell and consumption both . For this Bi Directional meter is used . It can measure electricity use and supply to grid. For Bangladesh Net Meter is supply by SREDA .[20]

Fig.3. 5:Fig meter

3.8 Mathematical Model

Before entering into the details of the PV model, it will be useful to review briefly some basic concepts of solar energy engineering. Many of the variables derived in this section will be used in several parts of the model. Mathematical model is base of all kinds of analysis .

3.8.1 Extraterrestrial radiation and clearness index

Solar radiation outside the earth's atmosphere is called extraterrestrial radiation. Daily extraterrestrial radiation on a horizontal surface, H0 , can be computed for day n from the following equation:

$$H_0=86400G_{sc}/\pi(1+0.033\cos(2\pi n/365))(\cos\Psi \sin\delta \sin\omega_s + \omega_s \sin\psi \sin\delta)\ldots\ldots\ldots 3.2$$

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where G_{sc} is the solar constant equal to 1,367 W/m2, and all other variables have the same meaning as before. Before reaching the surface of the earth, radiation from the sun is attenuated by the atmosphere and the clouds. The ratio of solar radiation at the surface of the earth to extraterrestrial radiation is called the clearness index. Thus the monthly average clearness index, K_T , is defined as:

$K_T = H/ H_0$ 3.3

where H is the monthly average daily solar radiation on a horizontal surface and H_0 is the monthly average extraterrestrial daily solar radiation on a horizontal surface. K_T values depend on the location and the time of year considered; they are usually between 0.3 (for very overcast climates) and 0.8 (for very sunny locations).

3.8.2 Mathematical model of solar PV energy

The output of solar PV mainly depends upon solar radiation, the efficiency of the solar panel, capacity of PV array , the effect of temperature, derating factor of the module[39].PV output of HOMER Pro is shown in eq.1 .

$P_{pv}=Y_{pv} * f_{pv} (G_T/G_{T,STC}) [1+\alpha p(T_C-T_{C,STC})]$ ……..(3.1)

P_{pv}= PV output power.

Y_{pv}= Rated Capacity of PV array under standard condition .

f_{pv}= Derating factor of solar PV.

G_T= Incident solar radiation on the PV array in the current time step [KW/m^2].

$G_{T,STC}$=Incident solar radiation at standard conditions .

αp = temperature coefficient of PV power [%/oc].

T_C= PV cell temperature in the current time step [oc].

$T_{C,STC}$=the PV cell temperature under standard test conditions[25°C][40].

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3.9 Cost model for optimization analysis

To calculate the cost for rooftop on-grid solar systems in the industry in Bangladesh are included different parameters like COE , NPC , Capital cost or fixed cost, Operational and management, or running cost .

3.9.1 Net Present cost

Net present cost is a vital issue to invest in any fanatical project . To calculate the NPC HOMER Pro software use following equation:

$NPC = C_{TAC}/CRF(I,R_{PLT})$……..(3.3)

Where ,

C_{TAC}= Total annualized cost.

I= Annual real interest rate .

CRF(.) =Capital recovery factor.

R_{PLT} = Project lifetime.

3.9.2 Cost of energy

To Find out the COE HOMER Pro software use following equation:

$COE = C_{TAC}/(E_{Prim}+E_{Def}+E_{GS})$.....(3.4)

Where

C_{TAC}= Total annualized cost.

E_{prim}=Total primary load /year.

E_{def}= Tortal deferrable load /year .

EGS = Amount of energy is sold to the grid /year [41]

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3.9.3 Operating cost

Operation cost is important parameter for cost analysis to determine operating cost following equation is used by homer :

$C_{OC}=C_{TAC}-C_{TACC}$……(3.5)

Where ,

C_{TAC}=Total annualized cost.

C_{TACC} =Total annualized capital cost .

3.10 Economic data

HOMER Cost Analysis Model includes costs related to development, engineering, power system and balance of systems and miscellaneous, for initial costs; and operation and maintenance, for annual costs[22]. In the economic analysis, specific micro-economic and macro-economic variables were considered . From the micro-economic point of view, the electricity market structure of Bangladesh was studied in order to determine if there were any structures to support solar PV developments. In addition, the demand and supply of renewable energy and how solar PV energy could play an important role in the diver section of the Bangladeshi Energy Matrix was analyzed. From the macro-economic point of view, four variables were addressed: the share of renewable energy production; and finally employment opportunities that solar PV projects may establish was also studied.

3.10.1 Discount Rate and Inflation Rate

To find the present value of an expected cash flow which is going to happen in the future is known as discount rate. In this thesis inflation rate have been taken 5 and discount rate have been taken 6 for economic analysis.

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3.10.2 System Fixed Capital Cost

Capital cost means initial cost of a project. It includes inverter, wind turbine, solar panel, preparation cost, labor cost, engineering design cost and other various costs.

3.10.3 The Project Lifetime

Project lifetime means for how many years the project will be operated. In this project the lifetime has been taken 25 years.

3.10.4 Selection of Component

To design the hybrid power system, we used HOMER software. The components that we took for simulation are- PV array, wind generator, converter and load. HOMER simulates the results of on-grid arrangements. To select the components, the quality and the availability of the components are given priority. Every component that are taken to design this model will describe below.

3.11 Scenario

In this propose PV installation for House , there are two scenarios carried out. That system initially reduced a large amount of initial cost and there has 25 years life. Despite less capital cost but there is no load shedding backup in the industry. They have used diesel base generation for back up. In the present electricity tariff in the local market is 0.100$ when using diesel engine it cost become high than the present tariff rate.

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CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, there is presented the results of the proposed grid connected solar PV power generation system for a two storey building. All outputs shown in graphically and tabular form. Also the economic comparison has been made on the basis of NPE, Energy production cost , total contribution solar PV on a grid system, total annualized cost and greenhouse gas emission for proposed model. The results of this calculations are given below.

4.2 Financial parameters

Financial parameters are extremely important for expected revenue. Because profit-loss, risk everything depends on the financial parameters. Inflation rate , Discount rate and project life are general parameter .

Table.4. 1: Financial parameters

Nominal discount rate (%):	10.00
Expected inflation rate (%):	5.30
Project lifetime (years):	25.00

4.3 Cost summary

The cost summary of the hybrid power plant model without wind turbine are shown in figure 4.1. The cost summary is included component, capital cost, replacement cost, operation and maintenance cost, fuel cost and salvage value.

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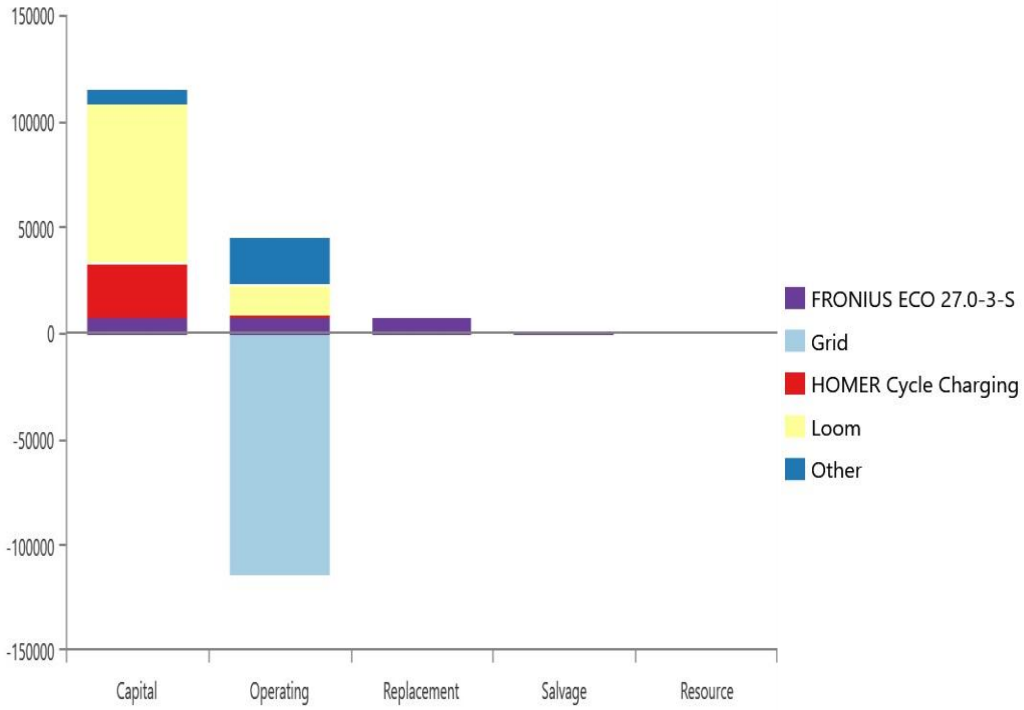

Fig.4. 1: On grid PV system cost.

Table 4. 2 and Table 3 shows Net present costs and Annualized Costs

Table 2: Net Present Costs

Name	**Capital**	**Operating**	**Replacement**	**Salvage**	**Total**
FRONIUS ECO	$7,650	$7,591	$8,138	-$1,284	$22,095
Grid	$0.00	-$113,596	$0.00	$0.00	-$113,596
HOMER Cycle Charging	$25,000	$1,488	$0.00	$0.00	$26,488
Loom	$75,000	$13,396	$0.00	$0.00	$88,396
Other	$6,930	$22,326	$0.00	$0.00	$29,256
	$114,580	-$68,794	$8,138	-$1,284	$52,639

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Table 4.3: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Total
FRONIUS ECO	$513.97	$510.00	$546.73	-$86.26	$1,484
Grid	$0.00	-$7,632	$0.00	$0.00	-$7,632
HOMER Cycle Charging	$1,680	$100.00	$0.00	$0.00	$1,780
Loom	$5,039	$900.00	$0.00	$0.00	$5,939
Other	$465.60	$1,500	$0.00	$0.00	$1,966
System	$7,698	-$4,622	$546.73	-$86.26	$3,537

4.4 Cash Flow

In figure 4.4, cash flow of proposed hybrid power plant are shown. Form this figure it's clear that initial cost is greater and after every 10 year there is a large amount of replacement cost of inverter. Operation and management cost is relatively low.

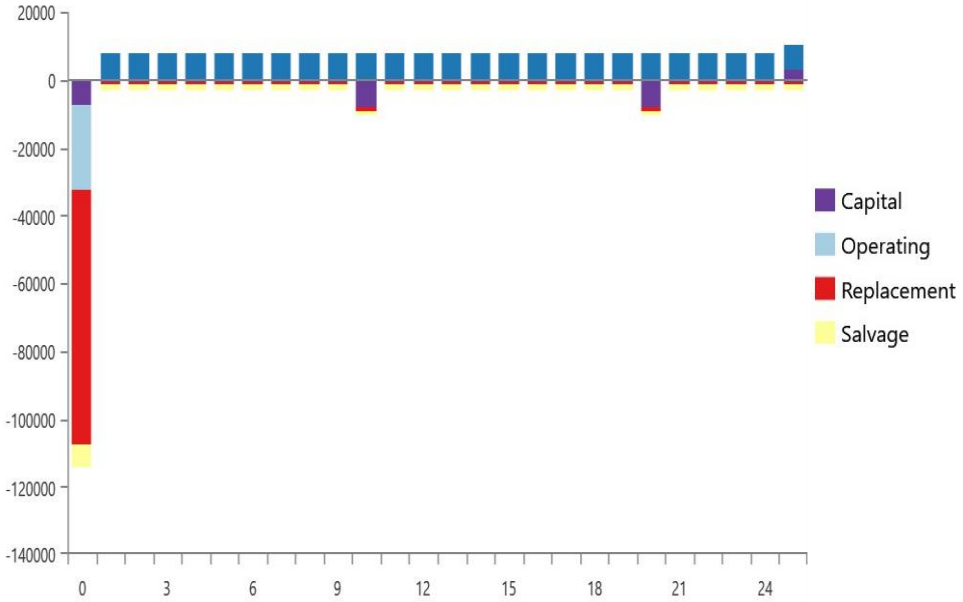

Fig.4. 2: Cash flow.

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4.5 Monthly Electric Production

Figure 4.3 shows the monthly production of electricity. Solar PV will produce

143064 KWh/yr. AC primary load is 22.1 % Grid sales 77.9%.

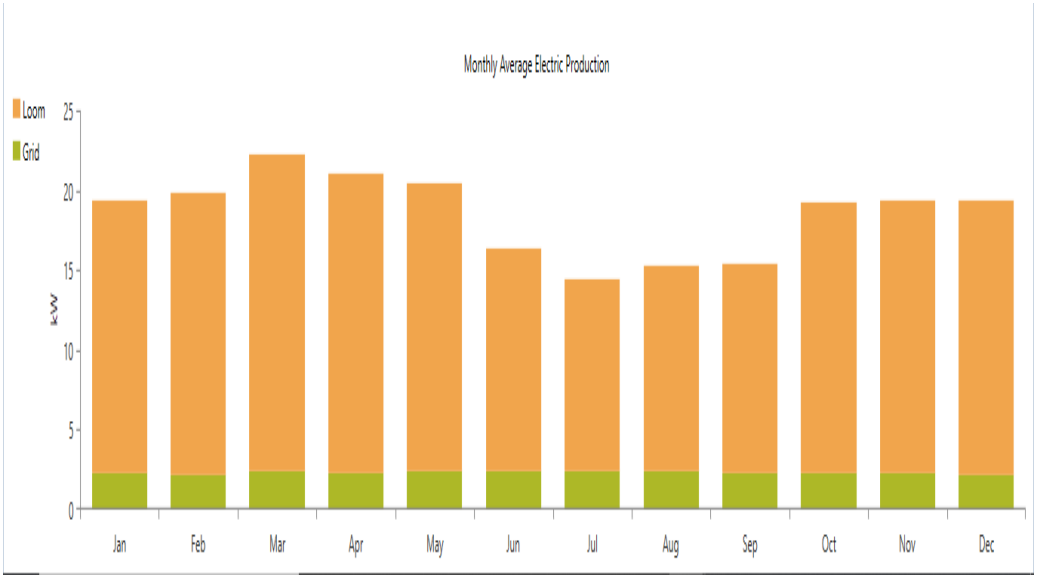

Fig.4. 3:Monthly Average Electric Production.

4.6 PV Power Output

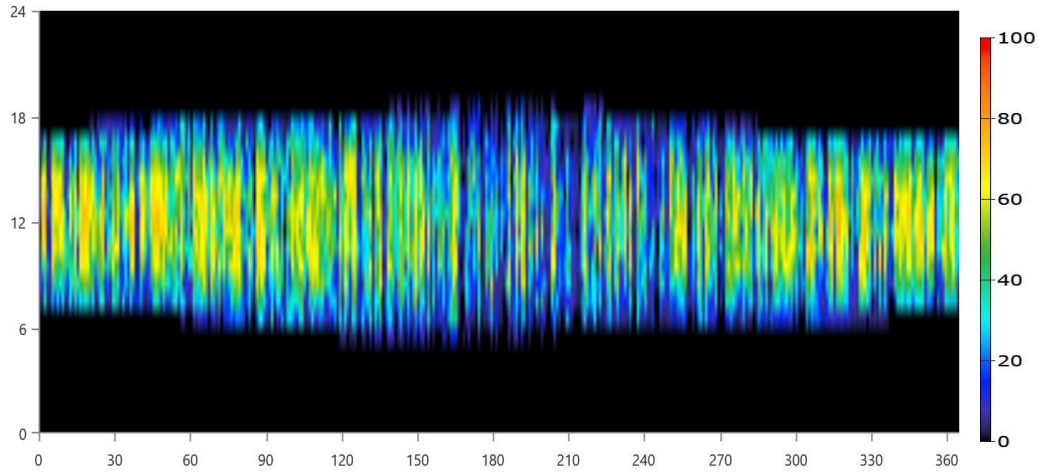

Fig.4. 4: PV Output power.

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Fig 4.4 shows PV power output. Maximum energy output from March to May. Because temperature is low and solar radiation in maximum. Fig 4.5 Shows energy purchase from grid when there is no PV generation. Form Mach to September solar purchase from grid is maximum.

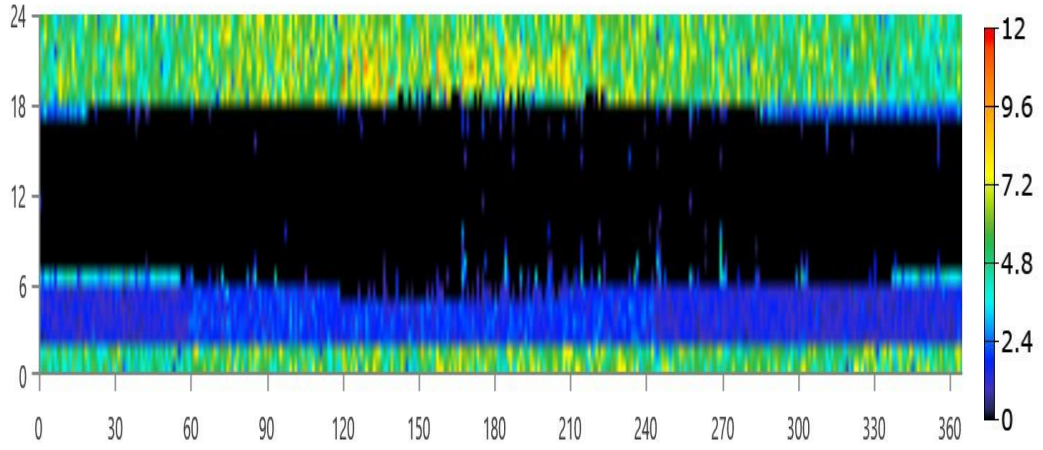

Fig.4.5: Energy Purchased From Grid.

Fig 4.6.Shows energy sold to grid. Energy sold is maximum March to May and minimum form June to August. Annually 95,400 KWh energy sold to grid.

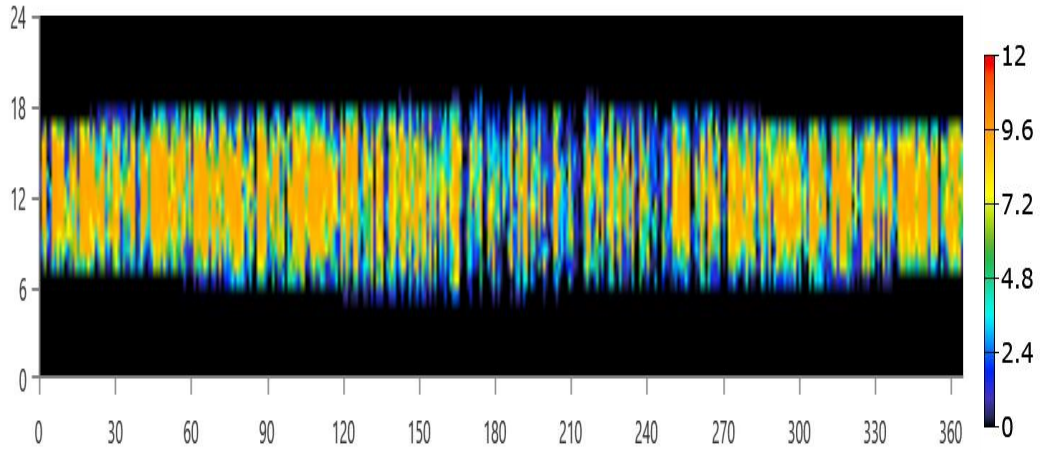

Fig.4. 6: Energy Sold To Grid

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Table 4.4. Monthly energy purchased , sold and energy charge table .

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Demand (kW)	Energy Charge
January	1,687	10,185	-8,499	9.36	-$679.88
February	1,434	9,598	-8,164	8.74	-$653.11
March	1,764	11,801	-10,036	9.42	-$802.90
April	1,673	11,285	-9,612	10.2	-$768.97
May	1,753	11,147	-9,394	11.2	-$751.55
June	1,726	8,203	-6,477	11.3	-$518.17
July	1,781	7,060	-5,279	11.3	-$422.31
August	1,748	7,702	-5,954	9.58	-$476.33
September	1,630	7,669	-6,039	9.09	-$483.08
October	1,655	10,554	-8,899	8.69	-$711.93
November	1,606	9,881	-8,275	9.49	-$662.01
December	1,643	10,415	-8,772	8.22	-$701.74
Annual	20,100	115,500	-95,400	11.3	-$7,632

4.7 Optimum Results

In this study, we have considered residential load. Assuming that, lifetime of whole project is 25 years. Fig. 4.7 and Fig.4.8 shows the categorized optimization results overall optimization respectively. Optimization process are carried out through every possible selection of variables in this PV power system without considering the sensitivity variables. COE is $0.0239 & NPC is $52639.

			Loom (kW)	Fron27 (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Capital Cost ($)	Production (kWh/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
			75.0	51.0	CC	$0.0239	$52,639	-$4,162	$114,580	75,000	142,064	20,100	115,500
					CC	$0.214	$104,455	$4,873	$31,930			32,726	0

Fig.4.7: Categorized Optimization.

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Architecture				Cost				Loom		Grid	
Loom (kW)	Fron27 (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Capital Cost ($)	Production (kWh/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
75.0	51.0	CC	$0.0239	$52,639	-$4,162	$114,580	75,000	142,064	20,100	115,500
75.5	51.0	CC	$0.0238	$52,640	-$4,193	$115,049	75,469	142,952	20,097	115,960
74.5	51.0	CC	$0.0239	$52,644	-$4,130	$114,111	74,531	141,176	20,103	115,035
75.9	51.0	CC	$0.0237	$52,646	-$4,224	$115,518	75,938	143,840	20,093	116,415
74.1	51.0	CC	$0.0240	$52,659	-$4,097	$113,643	74,062	140,288	20,107	114,563
76.4	51.0	CC	$0.0237	$52,660	-$4,255	$115,986	76,406	144,728	20,090	116,865
76.9	51.0	CC	$0.0236	$52,679	-$4,285	$116,455	76,875	145,616	20,087	117,309
73.1	51.0	CC	$0.0242	$52,706	-$4,031	$112,705	73,125	138,512	20,114	113,602
74.8	50.9	CC	$0.0239	$52,720	-$4,139	$114,331	74,766	141,620	20,102	115,166
75.2	50.9	CC	$0.0239	$52,720	-$4,171	$114,800	75,234	142,508	20,098	115,627
75.7	50.9	CC	$0.0238	$52,725	-$4,202	$115,269	75,703	143,396	20,095	116,083
75.0	50.8	CC	$0.0240	$52,800	-$4,149	$114,551	75,000	142,064	20,100	115,294
74.5	50.8	CC	$0.0240	$52,801	-$4,117	$114,082	74,531	141,176	20,103	114,833
75.5	50.8	CC	$0.0239	$52,804	-$4,180	$115,020	75,469	142,952	20,097	115,751
75.9	50.8	CC	$0.0238	$52,815	-$4,211	$115,488	75,938	143,840	20,093	116,203
78.8	51.0	CC	$0.0234	$52,823	-$4,401	$118,330	78,750	149,167	20,074	119,031

Fig 4.8: Overall Optimization.

Fig. 4.8 shows the overall optimization results with many possible system configurations whose total NPC is only slightly higher than that of the optimal configuration. Fig. 4.7 presents optimization result by category. It shows top-ranked, least-cost systems from each optimal system configuration. The levelized COE and NPC of the optimal system configurations are shown.

4.8 Emission analysis

For emission analysis T&D losses of Bangladesh is 7.0% considered. For base case GHG emission reduced is 1270 tCO_2.For transmission and distribution losses GHG emission reduced 563.3 tCO_2. Reduction of Sulfur Dioxide is 55.1 kg/yr & Nitrogen Oxide 26.9 kg/yr.

Table 4.5: Emission analysis

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Quantity	Value	Units
Carbon Dioxide	1270	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	55.1	kg/yr
Nitrogen Oxide	26.9	kg/yr

4.9 Revenue and Financial viability

Metric	Value
Present worth ($)	$51,816
Annual worth ($/yr)	$3,481
Return on investment (%)	6.9
Internal rate of return (%)	10.0
Simple payback (yr)	8.70
Discounted payback (yr)	12.16

Fig .4.9:Cost ,Saving and Revenue.

For this study, the total NPC is $52639. Total O&M cost is $1,500.00. O&M and debt payment is selected according to the guideline of SREDA. According to the financial viability IRR of equity is 10%. The simple payback period is 8.7 years and the discounted payback period is 12.16 years. The net present value is $52239 and Annual worth is $/year 3481 In this research, we found the energy production cost is $0.0239.

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4.10 Summary

In this chapter, output data for various models are shown and these gives the comparative results. By analyzing outputs, various comparison are made. It is shown that, the output data is feasible for investment . Capital rises at one-fifth of the total time, and the remaining four-quarters is added as a benefit. I

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CHAPTER 5

CONCLUSION

5.1 Conclusion

A cost benefit analysis has been conducting in this thesis to explore the cost-effective solar PV system for a two storey Building in Bangladesh by using HOMER Pro. For the objective function for the optimization, initial system cost, annual reduction of CO2 emissions, cost-effectiveness, cost of energy (COE) and net present cost(NPC) are considered. For this study, BDT 8.00 is considered an energy export rate. Credit from Greenhouse gas is not considered but the amount of greenhouse gas emissions that have been reduced has been found out.

Based on the achieved result We find the the total NPC is $52639. Total O&M cost is $1,500. This thesis focused on-grid system and find the energy production cost is $0.0239. The internal rate of return equals 10% and the simple payback time equals to 8.7 years, and the discount payback time equals 12.16 years. The total annual revenue is $7,632. Greenhouse gas emission reduced equivalent to a total of 1270 tCO2/year gas.

HOMER Pro is a widely used software tool used to evaluate the feasibility of renewable energy technologies and its performance has been validated. The government focused on the on-grid system, the reduction in the price of global photovoltaic systems may help the government to provide extra investment motivation in this area as electricity prices increase and approach actual costs. This study proposed an on-grid solar PV power generation potential for the mosque and identified it's per unit generation cost and annual benefit.

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