COST-BENEFIT ASSESSMENT OF ON-GRID PV SOLAR SYSTEMS FOR BAITUL MUKARRAM NATIONAL MOSQUE BANGLADESH

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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Certification

This is to certify that this project and thesis entitled "**Cost-benefit assessment of on-grid pv solar systems for Baitul mukarram national mosque Bangladesh**" 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 20 January 2021.

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Dedicated to

Our Beloved Parents

CONTENTS

List of Table

LIST OF FIGURES

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
A	Ampere
V	Voltage
NPC	Net Present cost

IRR	Internal Return Rate

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ABSTRACT

For the development of a country, electricity 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 which 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 RETScreen. To design this study solar radiation, area, solar panel, and inverter price operation and management cost are considered. Total initial costs are BDT 34899013. We find a simple payback period of 6.7 years and an equity payback period is 4.7 years. An energy production cost is 4.986 BDT/kwh that's is lesser than the electricity purchase price. Annual life cycle saving is BDT/yr 2164381. 563.3 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.

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.

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].

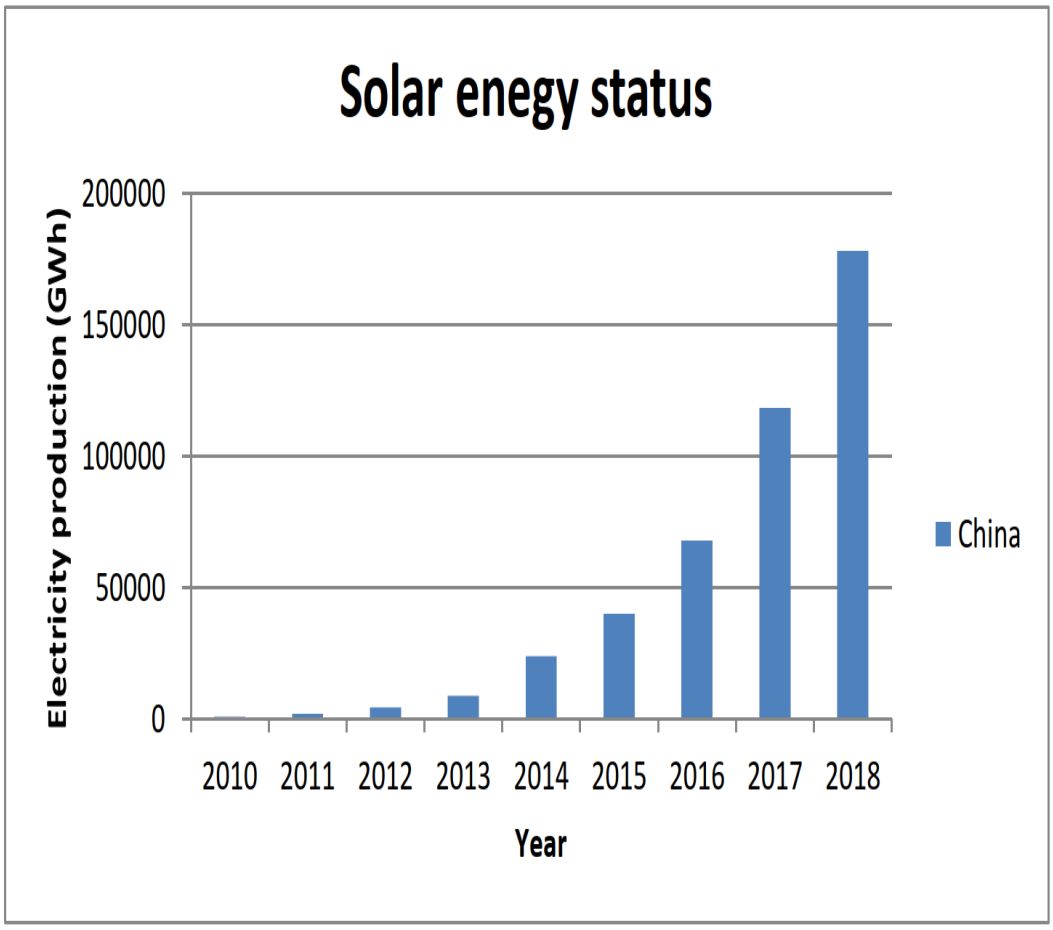

Fig.1. 1: Solar PV generation in China

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 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 .

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 can sale power 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 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.

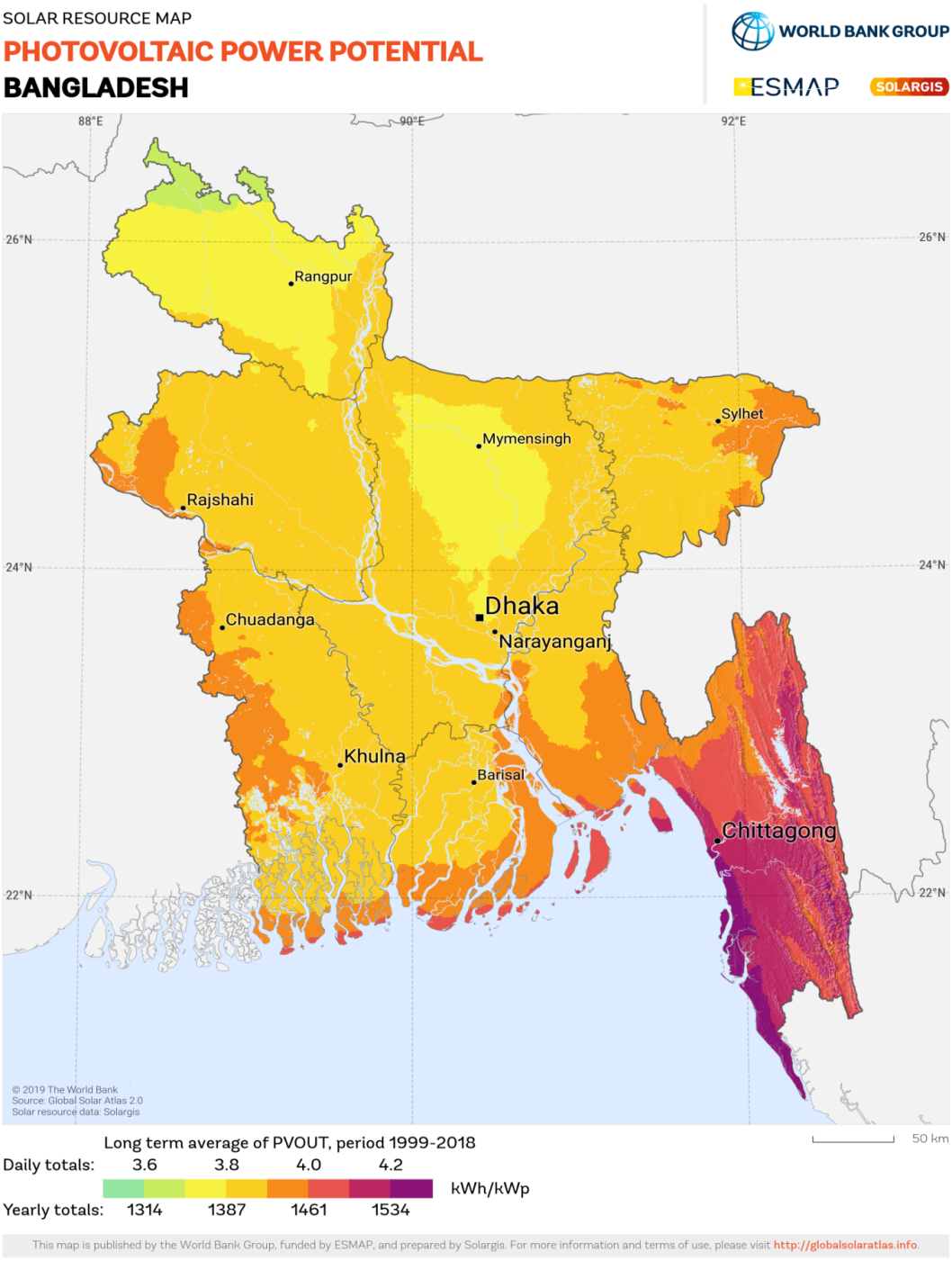

Fig.1. 2: Solar PV power Potential Bangladesh

1.4 Problem Statement

Bangladesh is at this time faced with challenges arising from inadequate energy. 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 the mosque?
- COE per unit generation.
- What is the difference between Generation cost and purchasing price from the gird?
- Find out the net preset cost for PV energy.
- How environmentally friendly the PV system is?

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 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 investigate the PV potentialities of Baitul Mukarram National Mosque Bangladesh
- 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 analyze the economic and environmental feasibility of the proposed model in different modes of operation.
- To quantify a number of greenhouse gas emission from different systems of model.
- To introduce Renewable Energy (RE) as an substitute solution for power generation.

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 . 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. So big commercial and a big mosque like Baitul Mukarram National Mosque Bangladesh has a great chance to produce electricity through net metering.

1.8 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

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

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

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.

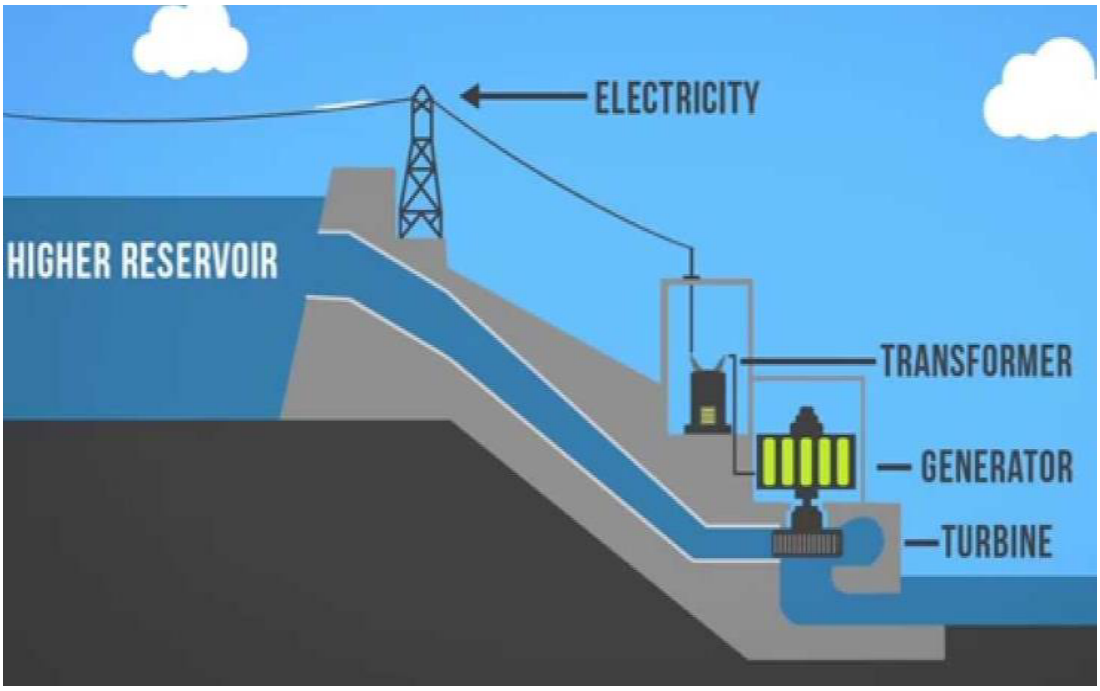

Fig.2. 3: Hydroelectric Power Plant

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 Sylhetregion. 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 Sangu and Matamuhuri should be measured with due 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].

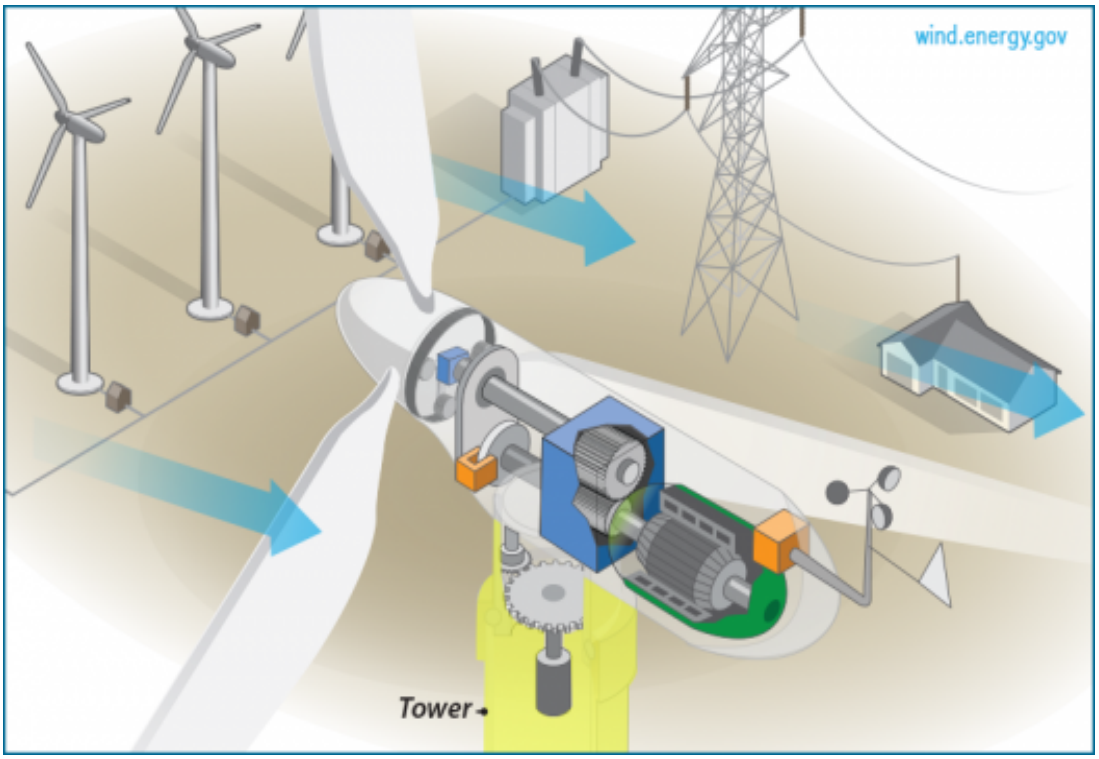

Fig.2. 4: Wind Turbine

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 .

Fig.2. 5: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 .

Fig.2. 6 :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 environment is 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.
- When we consume power within a short period time it's can be punished. So it's a very good advantages for us.
- In the most of the resources are available locally and fairly non-polluting.
- In the one of the best advantages is it's maintain cost is too little and the repair cost also 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

The renewable 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.

So we see that if we want to avoid this problem or disadvantages we should take more steps before the power plant installation. If we exactly solve this problem then the renewable energy is helpful for us.

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.

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. Se 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

2.12Summery

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.

CHAPTER 3

METHOD AND PARAMETER

3.1 Introduction:

In this thesis , on grid PV system is proposed for Baitul Mukarram National Mosque. Baitul Mukarram Mosque is not only National Mosque of Bangladesh but also largest mosque . Monthly average solar radiation and temperature data is collet from NASA surface meteorology. To design this study RETScreen Software is used . RETscreen is used for the energy balance calculation for each system configuration that can be considered. 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, capital recovery factor, replacement cost, operation, maintenance, fuel, possibly lowest cost and greenhouse gas emission in terms of tons/year. 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 RETScreen 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 data are taken from the RETScreen software.

3.2 Data Location

For select the data nearest location is considered .Solar radiation and temperature data is collet 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. The data location details is shown in Table 3.1.

Table.3. 1: PV Data location

	Unit	Climate data location	Facility location	Source
Latitude		23.7	23.7	
Longitude		90.4	90.4	
Climate zone		1A - Very hot - Humid		NASA
Elevation	m	3	13	NASA – NASA
Heating design temperature	°C	14.7		NASA
Cooling design temperature	°C	31.7		NASA
Earth temperature amplitude	°C	14.2		NASA

3.3 Solar radiation and Temperature

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 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 .

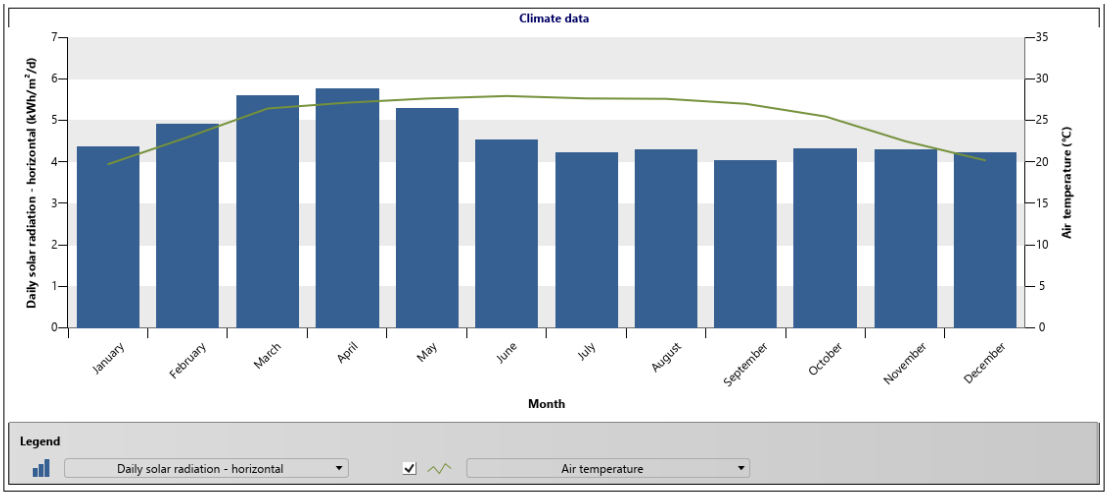

Fig.3.1: Solar radiation and temperature .

3.4 Study Area

Rooftop area of Baitul Mukarram National Mosque is selected for this analysis . Specific part of rooftop area of Baitul Mukarram National Mosque is consider for this study . 3180 square meter rooftop area is selected for this study with 620KW installation capacity . 50% area of total selected can be used for PV installation [18].

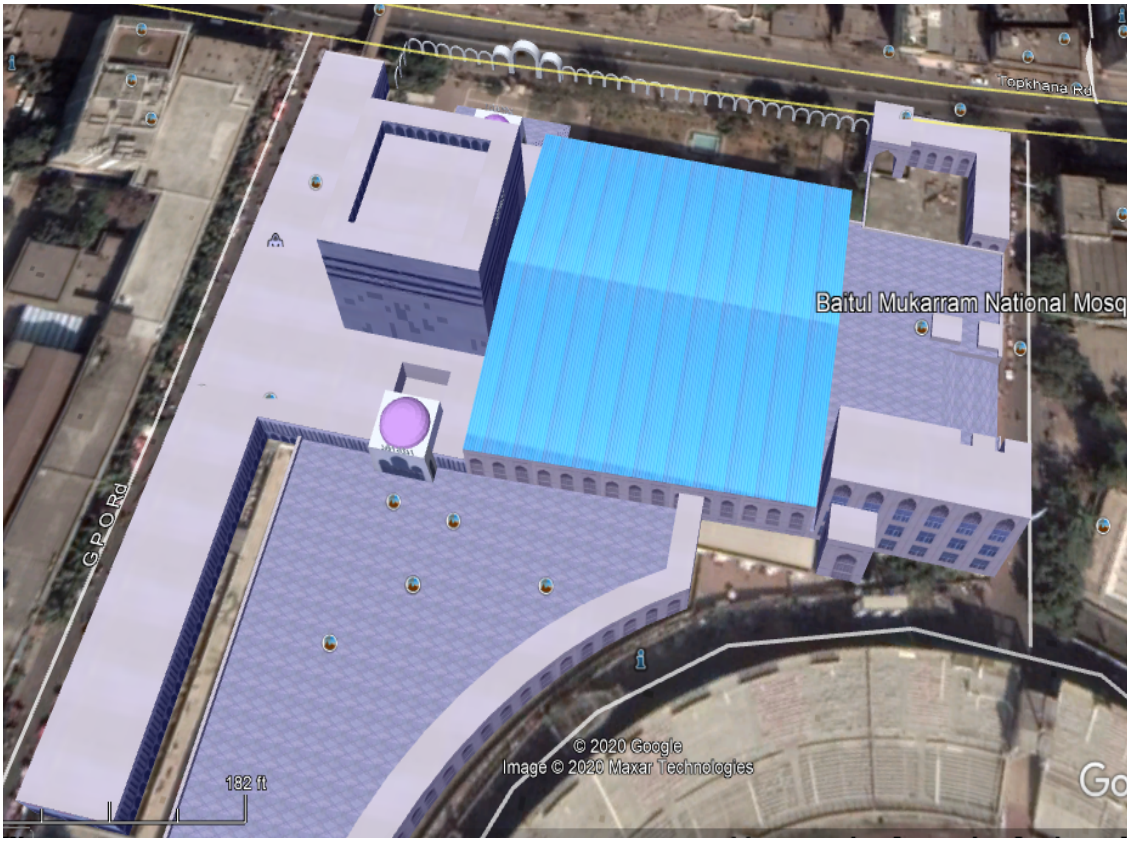

Fig.3. 2: Rooftop area of Baitul Mukarram National Mosque.

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 .

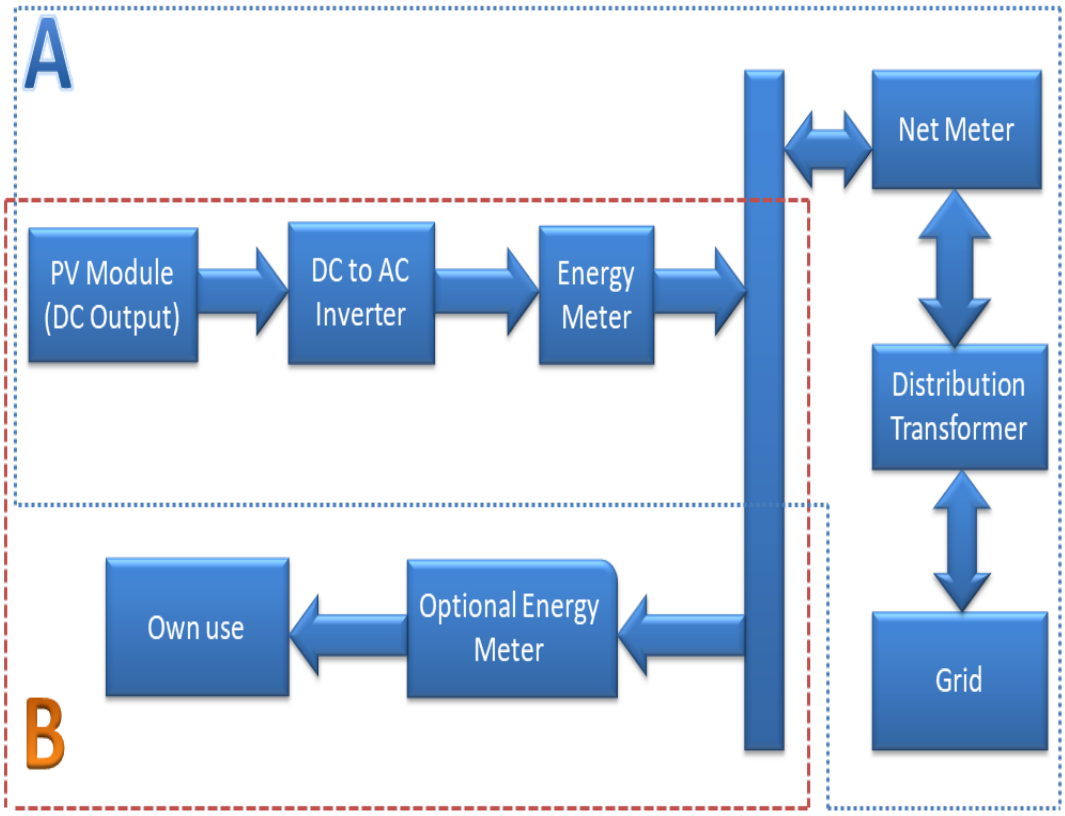

Fig.3. 3: Block diagram of proposed model

3.6 Selection of Component

To design the solar PV power system, we used RETScreen software. The components that we took for simulation are- PV array, Inverter , Grid ,and bidirectional meter. RETScreen 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.

3.6.1 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]

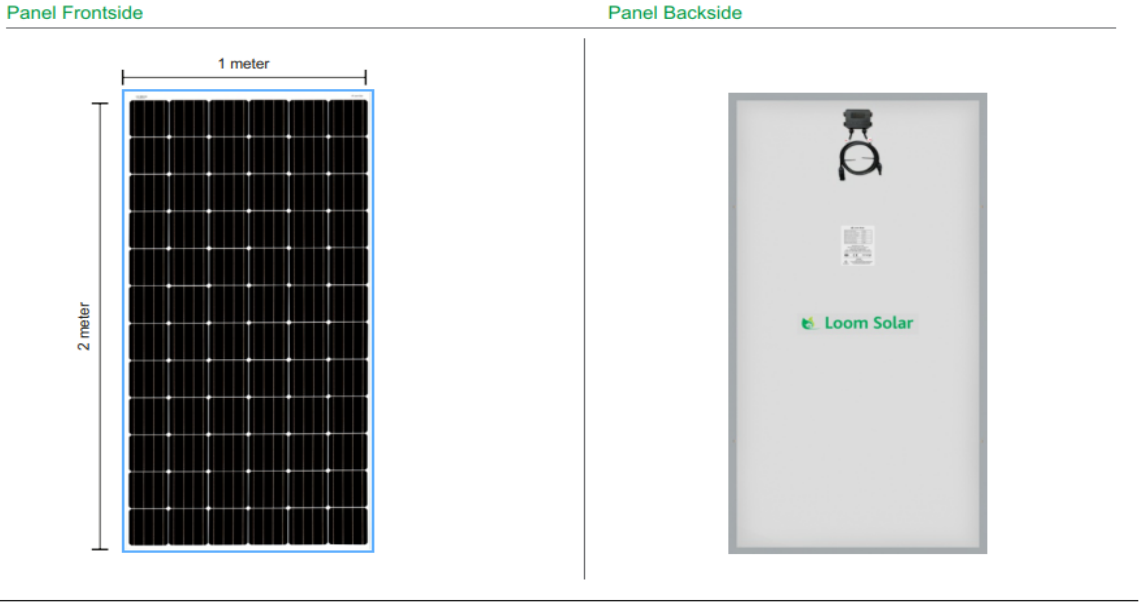

Fig.3. 4:Loom Sonar Panel

Loom is mono crystalline solar Panel . It's output Voltage is 24V and Plant capacity is 620 KWh. Efficiency of solar PV is 19.5% , Lifetime is 25 years and capital cost is 38870 USD/KWh.

Table.3. 2: Electrical data of the installed panels for the university PV system.

Parameter	Unit	Value
Pannel voltage	Volt	24
Total Capacity	(kWh)	620
Efficiency	Percent (%)	19.50%
Pannel Power	W	375
Capital cost	USD/kWh	38,837
Replacement cost	USD/kWh	38,837.00
Lifetime	Year	25

3.6.2 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 95-98% efficient, so they only lose about 2-5% of the electricity during the conversion process.[20]

Table.3. 3: Specification of the applied charge controller for the university PV systems.

Parameter	Unit	Value
Inverter efficiency	Percent (%)	96.8
Capital cost	USD/KW	85
Operation and maintenance cost	USD/Year	10
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].

3.6.3 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.

3.6.4 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.

3.6.5 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

3.7 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 .

3.7.1 Declination

The declination is the angular position of the sun at solar noon, with respect to the plane of the equator. Its value in degrees is given by Cooper's equation:

$\delta = 23.45 \sin(2\pi(284+n)/365)$……3.1

where n is the day of year (i.e. n =1 for January 1, n = 32 for February 1, etc.). Declination varies between -23.45° on December 21 and +23.45° on June 21.

Table.3. 4: Input PV parameter .

Resource assessment		
Solar tracking mode		Azimuth
Slope	°	25.39
Show data		
Photovoltaic		
Type		Other
Power capacity	kW	620
Manufacturer		12
Model		
Number of units		1
Efficiency	%	19.5%
Nominal operating cell temperature	°C	47
Temperature coefficient	% / °C	0.43%
Solar collector area	m²	3,179
Miscellaneous losses	%	5%
Inverter		
Efficiency	%	97.2%
Capacity	kW	260
Miscellaneous losses	%	8%

3.7.2 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:

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

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:

$$K_T = H/ H_0 \quad \text{.....3.3}$$

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 On-Grid Model

The on-grid model is the simplest system model .In particular no load is specified and no array size is suggested. Instead, the latter is suggested by the user. The suggested inverter is simply equal to the nominal array power. The energy available to the grid is what is produced by the array, reduced by inverter losses:

$$E_{grid} = E_A \eta_{inv} \quad \text{.....3.4}$$

where η_{inv} is the inverter efficiency. Depending on the grid configuration not all this energy may be absorbed by the grid. The energy actually delivered is:

$$E_{dlvd} = E_{grid} * \eta_{abs} \quad \text{……3.5}$$

where η_{abs} is the PV energy absorption rate.

3.9 Economic data

RETScreen 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 diversification 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.

3.10Financial Calculation

The feasibility of a project can be assessed by a number of standard financial criteria, applicable to initiatives of all natures. For a solar PV project, such indicators are calculated via RETScreen model set up in this investigation. This selection considers the fact that they are directly influenced by policy definitions, as well as an established relevance for general financial analyses.

3.10.1 Internal rate of return (IRR) and return on investment (ROI)

The internal rate of return IRR is the discount rate that causes the Net Present Value (NPV) of the project to be zero. It is calculated by solving the following formula for IRR:

$$\sum_{n=0}^{N} \frac{Cn}{(1+IRR)^{n}} \quad \ldots 3.6$$

Where N is the project life in years, and Cn is the cash flow for year .The pre-tax IRR is calculated using pre-tax cash flows, while the after-tax IRR is calculated using the

after tax cash flows. Note that the IRR is undefined in certain cases, notably if the project yields immediate positive cash flow in year zero.

3.10.2 Simple Payback

The simple payback SP is the number of years it takes for the cash flow (excluding debt payments) to equal the total investment (which is equal to the sum of the debt and equity):

$$SP= (G-IG)/((C_{ener} + C_{capa} + C_{RE} + C_{GHG})-(C_{O\&M} + C_{fuel}))\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

where all variables were previously defined.

Table.3. 5: Total Initial cost and other cost parameter.

Initial costs (credits)	Unit	Quantity	Unit cost		Amount		Relative costs
Feasibility study							
Feasibility study	cost	1	BDT	30,000	BDT	30,000	
Transportation	cost	1	BDT	200,000	BDT	200,000	
Subtotal:					**BDT**	**230,000**	0.7%
Development							
	cost				BDT	-	
Subtotal:					**BDT**	-	
Engineering							
Engineering	cost	1	BDT	300,000	BDT	300,000	
Subtotal:					**BDT**	**300,000**	0.9%
Power system							
Photovoltaic - 1000 kW	kW	620	BDT	38,826.6667	BDT	24,072,533	
Road construction	km				BDT	-	
Transmission line	km	1	BDT	1,200,000	BDT	1,200,000	
Substation	project	1	BDT	300,000	BDT	300,000	
Energy efficiency measures	project				BDT	-	
Net meter	cost	1	BDT	30,000	BDT	30,000	
Energy meter	cost	1	BDT	10,000	BDT	10,000	
Carport Mounting System	cost	1	BDT	5,000,000	BDT	5,000,000	
Inverter	cost	26	BDT	144,480	BDT	3,756,480	
Subtotal:					**BDT**	**34,369,013**	98.5%
Balance of system & miscellaneous							
Spare parts	%				BDT	-	
Transportation	project				BDT	-	
Training & commissioning	p-d				BDT	-	
User-defined	cost				BDT	-	
Contingencies	%		BDT	34,899,013	BDT	-	
Interest during construction			BDT	34,899,013	BDT	-	
Subtotal:					**BDT**	-	
Total initial costs					**BDT**	**34,899,013**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost		Amount
O&M					
Show data					BDT 810,900
Parts & labour	project				BDT -
User-defined	cost				BDT -
Contingencies	%		BDT	810,900	BDT -
Subtotal:					**BDT** **810,900**

Annual savings	Unit	Quantity	Unit cost	Amount
User-defined	cost			BDT -
Subtotal:				**BDT** -

Periodic costs (credits)	Unit	Year	Unit cost		Amount
Periodic costs	cost	13	BDT	3,756,480	BDT 3,756,480
End of project life	cost				BDT -

3.10.3 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 6.02% and discount rate have been taken 10% for economic analysis.

3.10.4 Net present value (NPV)

The net present value NPV of a project is the value of all future cash flows, dis-counted at the discount rate, in today's currency. It is calculated by discounting all cash flows as given in the following formula:

$$NPC= \sum_{n=0}^{N} \frac{Cn'}{(1+r)^n} \quad \text{.....3.8}$$

where r is the discount rate.

3.10.5 Benefit-Cost (B-C) ratio

The benefit-cost ratio, B-C , is an expression of the relative profitability of the project. It is calculated as a ratio of the present value of annual revenues (income and/or savings) less annual costs to the project equity:

B-C= (NPV+(1+fd)C)/ (1-fd)C……...……3.9

3.10.6 Energy production cost

The energy production cost is the avoided cost of energy that brings the net present value to zero. This parameter is not included in the Combined Heat & Power Model, since there are potentially many types of energy produced, each potentially having a distinct production cost . The energy production cost, C_{prod} , is thus obtained by solving for:

$$0= \sum_{n=0}^{N} \frac{Cn'}{(1+r)^n} \quad \text{……3.10}$$

Where ,

$Cn' = Cn - Tn$

$Cn = C_{in,n} - C_{out,n}$

$C_{in,n} = C_{prod}(1+r_e)^n + C_{capa}(1+r_i)^n + C_{RE}(1+r_{RE})^n + C_{GHE}(1+r_{GHE})^n$

3.10.7 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 .All of them including total annual cost BDT 34899013.

3.10.8 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. But for net metering project is consider for Bangladesh is 20 years.

3.11 Greenhouse gas emissions

The annual GHG emission reduction is estimated in the GHG Emission Reduction Analysis worksheet. The reduction ΔGHG is calculated as follows:

$$\Delta_{GHG} = (e_{base} - e_{prop}) E_{prop} (1-\lambda_{prop}) (1-e_{cr}) \quad \text{..... .....3.11}$$

where ebase is the base case GHG emission factor, e_{prop} is the proposed case GHG emission factor, E_{prop} is the proposed case annual electricity produced, λ_{prop} is the fraction of electricity lost in transmission and distribution (T&D) for the proposed case, and e_{cr} the GHG emission reduction credit transaction fee. Note that for both the base case and proposed case system, the transmission and distribution losses are

deemed to be nil for on-site generation, e.g. for off-grid and water-pumping PV applications.

3.12 Sensitivity and Risk Analysis Models

The RETScreen Sensitivity and Risk Analysis Models, found in the Sensitivity and Risk Analysis worksheet of the RETScreen Software, help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This worksheet contains two main sections: Sensitivity Analysis and Risk Analysis. Each analysis provides information on the relationship between the technical and financial parameters and the financial indicators, showing the parameters which have the greatest impact on the financial indicators. Both the sensitivity and the risk analyses are optional, and the related inputs or outputs do not affect results in other worksheets.

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 Baitul Mukarram National Mosque. All outputs shown in graphically and tabular form. Also the economic comparison has been made on the basis of NPE, Energy production cost , percentages of renewable fraction, 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

General		
Inflation rate	%	6%
Discount rate	%	10%
Project life	yr	25
Finance		
Debt ratio	%	70%
Debt	BDT	24,429,309
Equity	BDT	10,469,704
Debt interest rate	%	5%
Debt term	yr	10
Debt payments	BDT/yr	3,163,707

Form RETScreen calculation debt ration found 70% and the debt is BDT 24429309 . Where equity is BDT 10469704 . Debt Interest rate is 5% and debt term is 10 year . All the parameter is selected according to the guideline of SREDA and otpit result of RETScreen software [8, 23].

4.3 Annual Revenue

Annual revenue is calculate base of total production cost and electricity export rate to the grid . Electricity production cost is 4 taka . Annually 1000 MWh electricity will exported to grid . And predicted electricity export revenue is BDT 5997195 only . For this calculation electricity export escalation rate is 2% considered .

Table.4. 2: Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	1,000
Electricity export rate	BDT/kWh	6
Electricity export revenue	BDT	5,997,195
Electricity export escalation rate	%	2%

4.4 Cash Flow

RETScreen software analysis two kinds of class flow. Frist is Pre-tax cash flow. another is cumulative cash flow. In pre-tax analysis per year, the benefit is calculated. In Fig 4.1 Pre-tax fig is shown. In fast year cash flow is negative because most of the investment is held on 1st year as a capital cost, it's more than BDT 10000000. From second year only O &M cost is required. So from second-year benefit is positive. From the second year to the tenth year, cash flow increases at a small rate because debt is for 10 years. After the deft period, benefit increases at a significant rate.

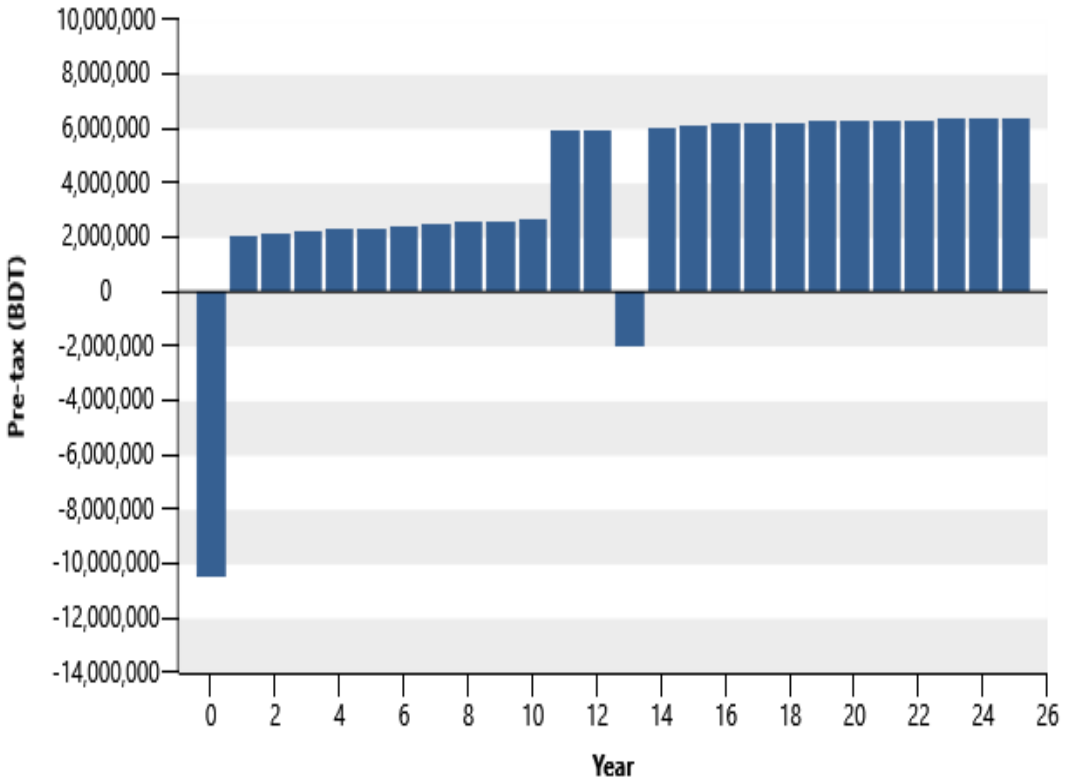

Fig.4. 1: Pre-tax clash flows

This high rate is available for only two years after the lifetime of the inverter will finish. So additional cost added with the system for that year. From fourteen-year cash flow is as usual. Benefit after thirteen years is large in amount.In Fig.4.2.cumulative cash flows is shown. According to the figure, the project will be profitable after 5 years and the mosque will continue to generate revenue. After 10 years, the graph of cumulative cash group is more upbeat because the debt burden will not be after 10 years. After 12 years the graph goes down because at this time the lifetime of inverter expires and a new on-grid inverter is added to the system. After 14 years, there is no new cost, so the cumulative cash flow continues to grow at the same rate . Value of pre-tax and cumulative cash flow is shown in Table.4.3. At the end of 25 year cumulative cash is BDT 98494073 .So On-grid system is financially viable .

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

Target

	Electricity exported to grid MWh	Electricity export revenue BDT	GHG emission reduction tCO_2
Proposed case	1,000	5,997,195	563

The main results are as follows:

Cash flow - Cumulative

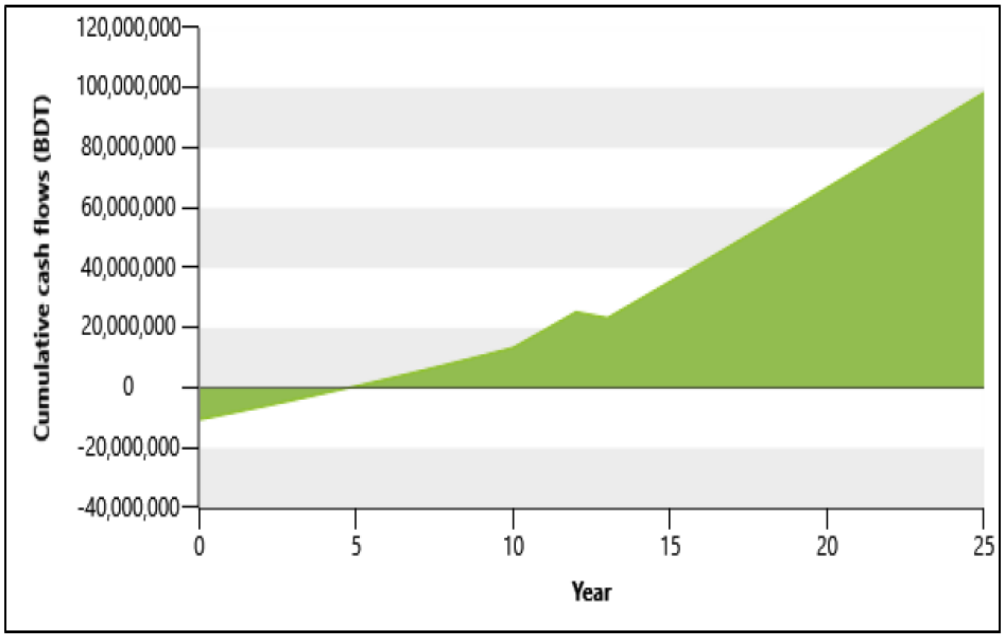

Fig.4. 2:Cumulative cash flows

Table.4. 3: Yearly Cash Flows

Year #	Pre-tax BDT	Cumulative BDT
0	-10,469,704	-10,469,704
1	2,093,716	-8,375,988
2	2,164,304	-6,211,685
3	2,234,223	-3,977,462
4	2,303,334	-1,674,128
5	2,371,490	697,362
6	2,438,529	3,135,891
7	2,504,280	5,640,170
8	2,568,559	8,208,730
9	2,631,170	10,839,899
10	2,691,900	13,531,799
11	5,914,230	19,446,029
12	5,970,505	25,416,535
13	-2,007,805	23,408,730
14	6,074,956	29,483,686
15	6,122,559	35,606,245
16	6,166,665	41,772,910
17	6,206,937	47,979,847
18	6,243,015	54,222,862
19	6,274,512	60,497,374
20	6,301,019	66,798,393
21	6,322,098	73,120,491
22	6,337,280	79,457,771
23	6,346,068	85,803,839
24	6,347,931	92,151,770
25	6,342,303	98,494,073

4.5 Revenue and Financial viability

Table.4. 4:Cost ,Saving and Revenue

Costs | Savings | Revenue

Initial costs			
Feasibility study	0.66%	BDT	230,000
Engineering	0.86%	BDT	300,000
Power system	98.5%	BDT	34,369,013
Total initial costs	100%	BDT	34,899,013
Annual costs and debt payments			
O&M		BDT	810,900
Debt payments - 10 yrs		BDT	3,163,707
Total annual costs		BDT	3,974,607
Periodic costs (credits)			
Periodic costs - 13 yrs		BDT	3,756,480
Annual savings and revenue			
Electricity export revenue		BDT	5,997,195
Total annual savings and revenue		BDT	5,997,195

Financial viability

Pre-tax IRR - equity	%	24.6%
Pre-tax IRR - assets	%	8.6%
Simple payback	yr	6.7
Equity payback	yr	4.7
Net Present Value (NPV)	BDT	19,646,176
Annual life cycle savings	BDT/yr	2,164,381
Benefit-Cost (B-C) ratio		2.9
Debt service coverage		1.7
Energy production cost	BDT/kWh	4.986

For this study, the total initial cost is BDT 34899013. Total O&M cost is BDT 810,900 and debt payments are BDT 3163707. O&M and debt payment is selected

according to the guideline of SREDA. The total annual cost is BDT 3974607 and the periodic cost after 12 years is BDT 3756480. The total cost is estimated by counting all the costs mentioned above.

According to the financial viability pre-tax IRR of equity is 24.6%. The simple payback period is 6.7 years and the equity payback period is 4.7 years. The net present value is BDT 19646176 and annual life cycle savings are BDT/year 2164381. In this research, we found the energy production cost 4.986 BDT/KWh.

4.6 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

CHAPTER 5

EMISSION & SENSITIVITY

5.1 Emission analysis

For emission analysis T&D losses of Bangladesh is 7.0% considered. For base case GHG emission is 605.6 tCO_2 . At the time of power generation theoretically emission reduced 605.6 tCO_2 .For transmission and distribution losses GHG emission reduced 563.3 tCO_2. In proposed case GHG emission is 42.4 tCO_2.

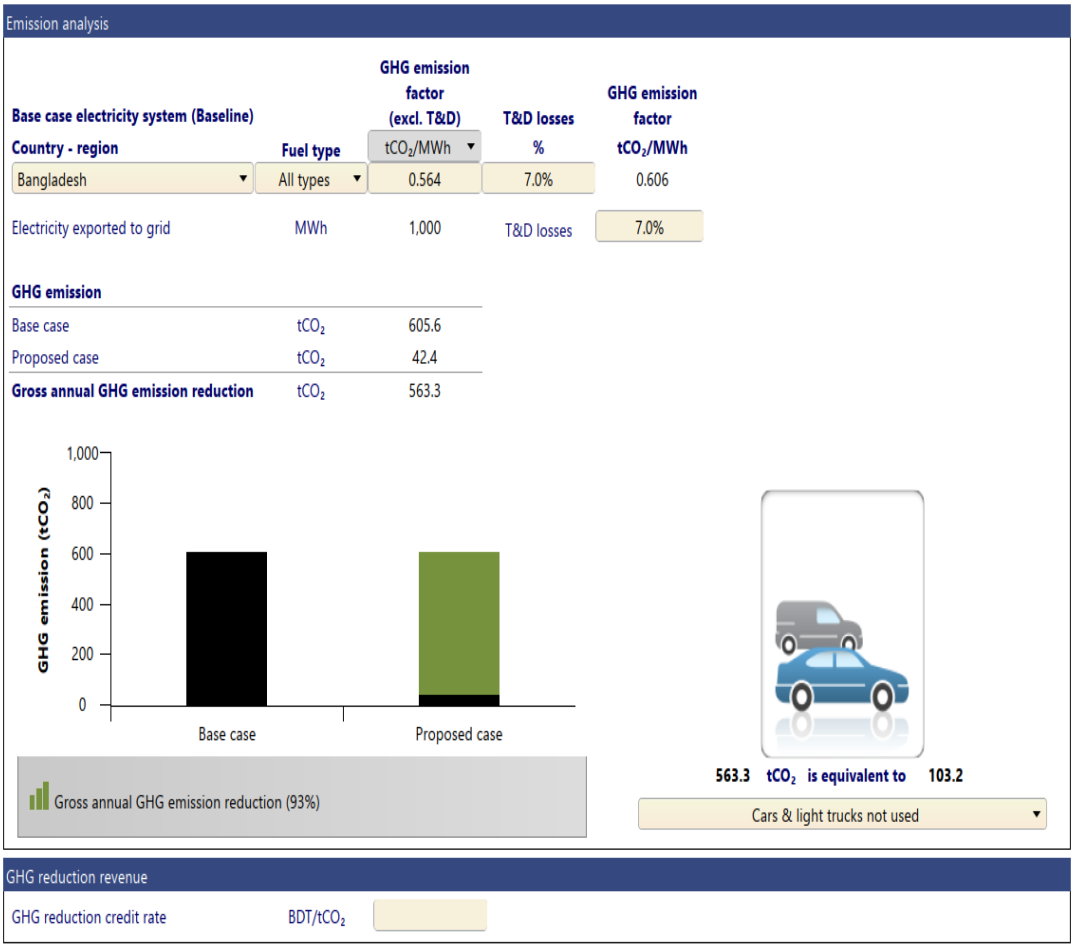

Fig.5. 1: Emission analysis

5.2 Sensitivity analysis

The level of uncertainty associated with the project during analysis is a measure of the level of uncertainty of the inputted variables which has effects on the level of uncertainty on the calculated financial variables. The sensitivity analysis worksheet is where the level of uncertainty can be reduced by considering two inputted parameters against the calculated financial variables. The sensitivity analysis was done for the Net Present Value (NPV) of the project by varying the initial cost against the debt interest rate by ± 30% for scenario 1 and the initial cost against the electricity exported to the grid by the same range for scenario 2 as shown in fig.5.2.

Sensitivity analysis

Perform analysis on	Net Present Value (NPV)
Sensitivity range	30%
Threshold	0 BDT

- Remove analysis

Initial costs — BDT

Electricity export rate		24,429,309	29,664,161	34,899,013	40,133,865	45,368,717
BDT/MWh		-30.0%	-15.0%	0.0%	15.0%	30.0%
4,200.00	-30.0%	9,153,195	4,666,798	180,400	-4,305,997	-8,792,395
5,100.00	-15.0%	18,886,083	14,399,686	9,913,288	5,426,891	940,493
6,000.00	0.0%	28,618,971	24,132,574	**19,646,176**	15,159,779	10,673,382
6,900.00	15.0%	38,351,859	33,865,462	29,379,064	24,892,667	20,406,270
7,800.00	30.0%	48,084,747	43,598,350	39,111,952	34,625,555	30,139,158

- Remove analysis

Electricity exported to grid — MWh

Electricity export rate		699.67	849.60	999.53	1,149.46	1,299.39
BDT/MWh		-30.0%	-15.0%	0.0%	15.0%	30.0%
4,200.00	-30.0%	-13,445,643	-6,632,621	180,400	6,993,422	13,806,443
5,100.00	-15.0%	-6,632,621	1,640,333	9,913,288	18,186,243	26,459,198
6,000.00	0.0%	180,400	9,913,288	**19,646,176**	29,379,064	39,111,952
6,900.00	15.0%	6,993,422	18,186,243	29,379,064	40,571,886	51,764,707
7,800.00	30.0%	13,806,443	26,459,198	39,111,952	51,764,707	64,417,461

Fig.5. 2: Sensitivity analysis result for the solar photovoltaic project.

For seneraio1, the initial cost is BDT 34899013 and electricity export rate is BDT 6000. Within ± 30% sensitivity, initial Cost varies from BDT 24429309 to BDT 45368717 and electricity export rate varies from BDT 4200 to BDT 7800. By recalculating the NPV for the combination of initial cost and debt interest rate holding all other parameters fixed. The software indicates the values of the NPV below the threshold of zero by orange color . Form sensitivity analysis when the initial cost is more than 15% and electricity export rate is 30% reduced then is can be viable. So the value of sensitivity shows that's it is very suitable for investment.

For seneraio2 , the sensitivity of electricity export to grid and electricity export rate is shown . It's result also shows that it's sensitivity range is high.

5.3 Risk analysis

Risk analysis is as same as sensitivity analysis but the basic difference is at the time of risk analysis there is a conclusion but for sensitivity there is no conclusion. The energy production cost is selected as the financial indicator and the range considered is ± 25% for all the parameters.

Table.5. 1:Risk analysis

Perform analysis on		Equity payback			
Number of combinations		500			
Random seed		No			
Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	BDT	34,899,013	25%	26,174,260	43,623,767
O&M	BDT	810,900	25%	608,175	1,013,625
Electricity exported to grid	MWh	999.53	25%	749.65	1,249.42
Electricity export rate	BDT/MWh	6,000.00	25%	4,500.00	7,500.00
Debt ratio	%	70.0%	25%	52.5%	87.5%
Debt interest rate	%	5.00%	25%	3.75%	6.25%
Debt term	yr	10	25%	8	13
Median				yr	5
Level of risk				%	10%
Minimum within level of confidence				yr	3
Maximum within level of confidence				yr	9.6

The RETScreen software performed a Monte Carlo simulation techniques for 5000 times by recalculating the energy production cost and the result gotten is displayed as the impact graph and the distribution graph as shown in Table 5.1 , Fig 5.3 &Fig5.4 . 10% level of risk is consider .

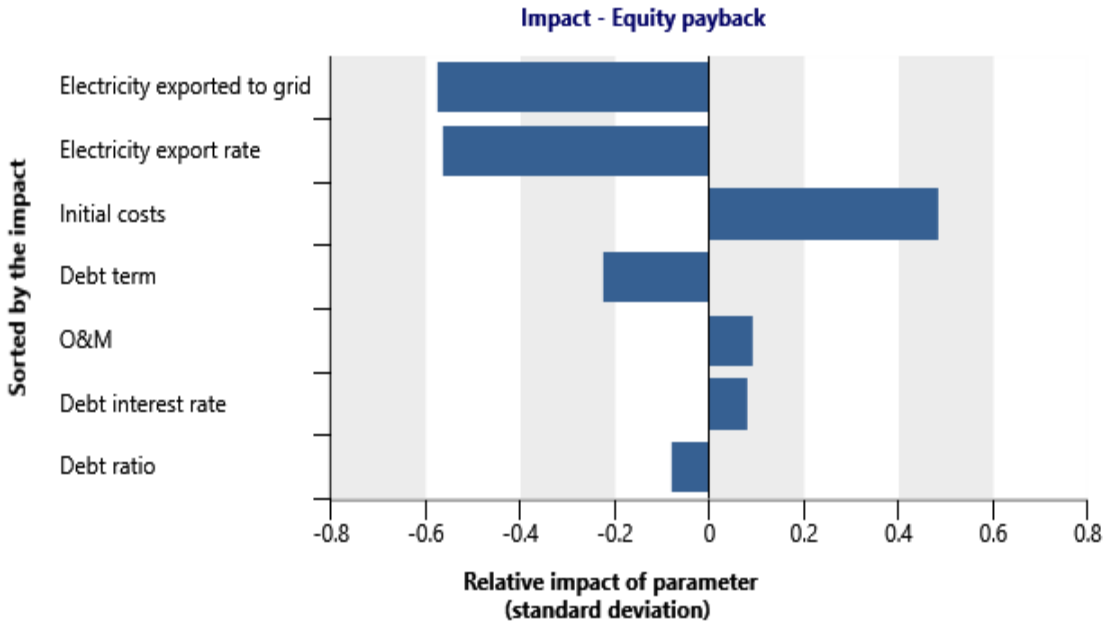

Fig.5. 3:Impact of Equity Payback

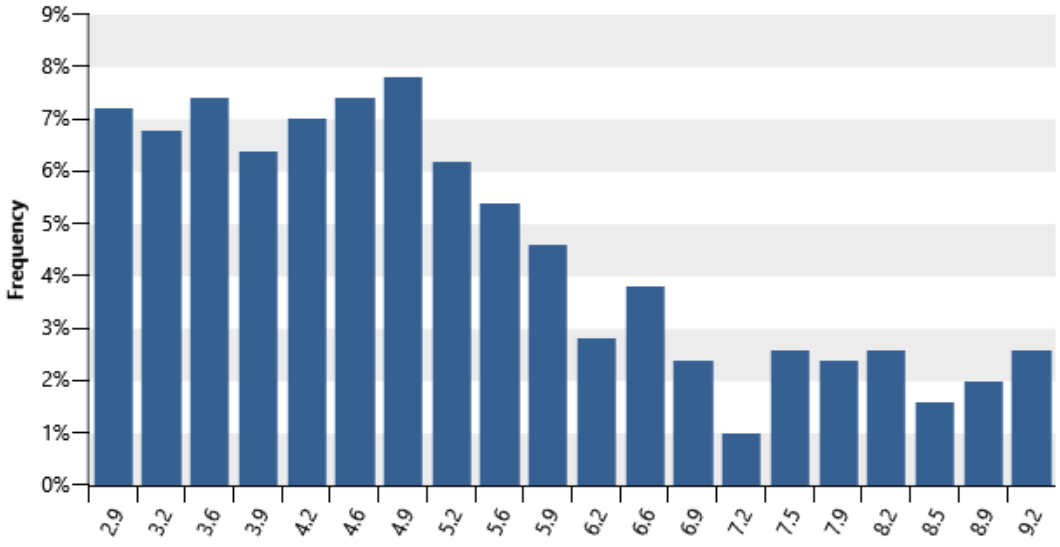

Fig.5. 4: Distribution of Equity payback

According to the Impact of Energy Production cost graph, the variation on the energy production cost varies concerning various parameters. The initial cost and the

electricity exported to the grid have a great impact on the project but in the opposite direction. When the initial cost increases the energy production cost also increased and when the electricity export to the grid decrees then energy production cost increases. According to the risk analysis the minimum within level of confidence is 3 yarr. and maximum within level of confidence is 9.6 year .

CHAPTER 6

CONCLUSION

6.1 Conclusion

A feasibility analysis has been conducting in this thesis to explore the cost-effective solar PV system at Baitul Mukarram National Mosque in Bangladesh by RETScreen software . For the objective function for the optimization, initial system cost, annual reduction of CO2 emissions, cost-effectiveness, and net present value (NPV) are considered. For this study, BDT 6.00 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 total initial cost BDT 34899013, annual O&M cost is BDT 810900, and the periodic cost is BDT 3756480. This thesis focused on-grid system and find the energy production cost of BDT 4.99. The internal rate of return equals 24.55% and the simple payback time equals to6.7 years, and the equity payback time equals 4.7 years. The total annual revenue is BDT 5997195. Greenhouse gas emission reduced equivalent to a total of 563.25 tCO2/year gas. Gross greenhouse gas reduced 14081 tCO2 for 25 years.

RETScreen 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.

6.2 Limitation

1. Load is not considered.

2. There is no additional battery backup.

3. Satellite solar radiation data is used.

6.3 Future scope

In this thesis, only the potential of solar at Dhaka, Bangladesh is included. This analysis can be extended to other places of Bangladesh where the renewable sources are available. Also it could be possible to design a model by taking other renewable energy sources like wind & hydro.

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