ROOFTOP DC SOLAR SYSTEM FOR UNIVERSITY CAMPUS

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor Science in Electrical and electronic Engineering.

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CERTIFICATION

This is to certify that this thesis entitled "**ROOFTOP DC SOLAR SYSTEM FOR UNIVERSITY CAMPUS"** 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 17th December 2020.

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Dedicated to

Our Parents and our beloved Teachers.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

TPES	Total Primary Power Supply
TWh	Terawatt-hour
EIA	Energy Information Administration
BCAS	Bangladesh Center for Advanced Studies
IDCOL	Infrastructure Development Company Ltd
IFC	International Finance Corporation
SRS	Solar Residential System
PV	Photovoltaic
DC	Direct Current
AC	Alternating Current
GTI	Grid-Tie Inverter
HOMER	Hybrid optimization of Multiple Electric Renewable
DOE	Department of Energy
GEF	Grid Emission Factor
NREL	National Renewable Energy Limited

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ABSTRACT

Bangladesh is a developing country and the country's economy is dependent on agricultural work and industrial factories, it is constantly struggling to meet this growing energy demand. Most of Bangladesh's energy consumption comes from fossil fuels. And to meet this energy demand we have to rely mainly on natural gas and coal-based power plants. As a result, the pressure on fossil fuels is increasing and its amount is decreasing day by day which is not pleasant for us at all.

In order to solve this problem, we have tried to highlight in this study the use of solar power and the pioneering role it can play in meeting the national electricity demand. In our proposed system, we have compared the difference between solar panel-based power and the power generated from the national grid. From which it is found that the cost of solar panel-based electricity is less than the electricity generated from the national grid. Although its initial cost for solar panel-based power generation is a little higher, but after a certain period of time these costs can be recovered. Also, solar panel based solar power plants are environmentally friendly, meaning that it does no harm to the environment, as fossil fuel-based power plants do by producing carbon-dioxide. In this proposal we have used Hybrid Optimization of Multiple Energy Renewables (HOMER) software for cost analysis, energy analysis etc. and the results obtained from it have also been analyzed.

CHAPTER-1

Introduction

1.1 Introduction:

It has been an integral part of our lives since the discovery of electricity on Earth. Electricity continues to play an important role in the economic, social and overall development of a country starting from daily life. For a good reason, a country needs a lot of electricity for its development. The more electricity a country has, the more developed it is because uninterrupted power connections increase business, trade and factory production capacity, which in turn boosts the country's economy. Most of the electricity in the world is generated from non-renewable energy sources i.e. fossil fuels using coal, diesel, gas, nuclear etc. Due to this need for electricity, the demand for it has been increasing day by day, which has resulted in the increasing use of fossil fuels. [1]. According to a study by BP, energy demand will increase to 41 percent between 2012 and 2035, which will increase to 1.5% per year, even in Asia, where energy demand has increased by 2.6% [2].

1.2 Generation of electrical energy:

The process of making a product such as electrical apparel clothing, observation, or equipment will be celebrated at the ceremony. Just as a certain raw material, which is in nature and from which a certain product can be made, so electricity can be generated from a certain raw material, which exists in nature. Although other components or products can be used and stored at will after production, in the case of electrical energy, its production and use become instantly vital. Other products take much longer to produce but electricity can be generated instantly. The instantaneous production of electricity reminds us how important it is to us for technology and industrialization.

In nature, energy exists in various sources such as water pressure, chemical energy, nuclear energy, radioactive substances, etc. These energy sources can be converted into electrical energy through a specific process. In this process an alternator is connected to a prime mover. This prime mover is rotated through the use of different sources of energy such as burning fuel energy, water pressure, air flow etc. For example, fuel from chemical energy (such as coal) is used to evaporate water at high pressure and temperature. The steam is sent to the prime mover, which could be a steam engine or a steam turbine. This turbine converts steam energy into mechanical energy and subsequently mechanical energy is converted into electrical energy through alternators [3].

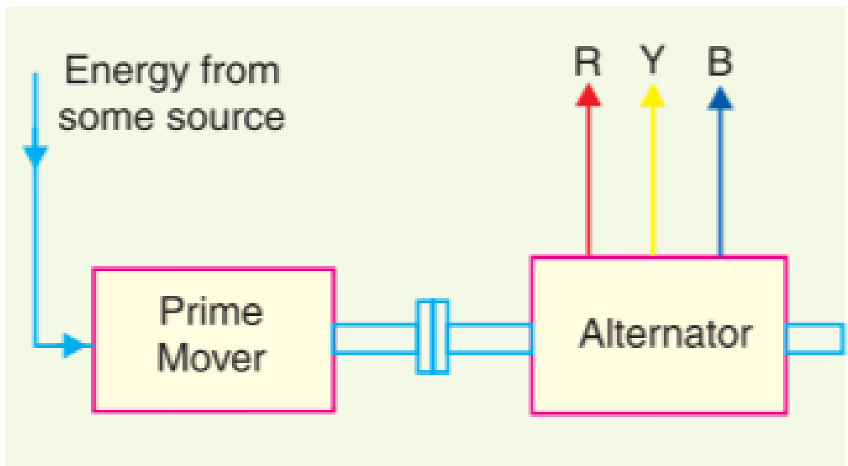


Fig. 1.2.1: The conversion of energy

1.3 Source of Energy:

Energy in nature comes from various sources such as:

1.The sun

2.Thewind

3. Water

4.Fuels and

5. Nuclear energy.

1.3.1 The Sun:

The sun is the main source of energy. The sun's photons can be used to generate electricity.

1.3.2 The Wind:

Here wind flows can be used to generate electricity through windmills. This process is possible where the airflow is running all the time.

1.3.3 Water:

When water is stored in a certain place, pressure is created in between. The prime mover is rotated by the flow of water at high pressure, which generates mechanical energy, which is then converted into electrical energy by means of an alternator. Currently this process of power generation is very popular.

1.3.4 Fuels:

The main sources of energy are fuels such as coal, oil, natural gas etc. Mechanical energy is generated from these fuels. The mechanical power is then converted into electrical energy by connecting the prime mover to the alternator.

1.3.5 Nuclear Energy:

Towards the end of World War II, it was discovered that a large amount of heat was generated by fission reactions from uranium or all radioactive substances. It is estimated that 1 kg of nuclear fuel produces the same amount of heat energy as burning 4500 tons of coal.

1.4 Type of Energy:

Electric energy can be generated by utilizing the thermal energy of radioactive material. Power sources can usually be divided into two parts.

1.4.1 Non-renewable Energy:

A source of renewable energy is a source of energy that cannot be reused once used. The amount of non-renewable energy sources is decreasing day by day, such as coal, natural gas, oil, nuclear energy, etc. A 2016 study found that about 95% of the world's energy comes from non-renewable energy sources (coal, natural gas, oil, nuclear energy [4].

1.4.2 Renewable Energy:

A renewable energy source is a source of energy that will never run out. This energy source can be used to generate electricity repeatedly, such as sun rays, wind currents, water pressure, water currents etc. A 2016 study found that only 5% of the world's energy comes from renewable energy sources (sunlight, wind, water, water pressure etc.) [4].

1.5 World Energy Demand:

Electricity is the main driving force of the modern economy and the lion's share of energy services are supplied by electricity. The demand for electricity is increasing day by day due to the development of modern transport system, production and use of modern equipment and increasing use of these equipment's in human life system. The amount of electricity generated in 2018 to meet the growing electricity demand of the people, as a result of the record amount of carbon dioxide emitted from the power sector into the environment [6].

According to the State Policy Scenario, the demand for electricity will increase by 2.1% per annum by 2040, which is 2 times that of primary energy. The amount of electricity at the Total Final Energy Consumption will increase from 19% in 2018 to 24% in 2040. This demand for electricity is going to be stronger, especially for developing economies. Electricity plays such an important role in sustainable development that it occupies 31% of the total energy consumption [6].

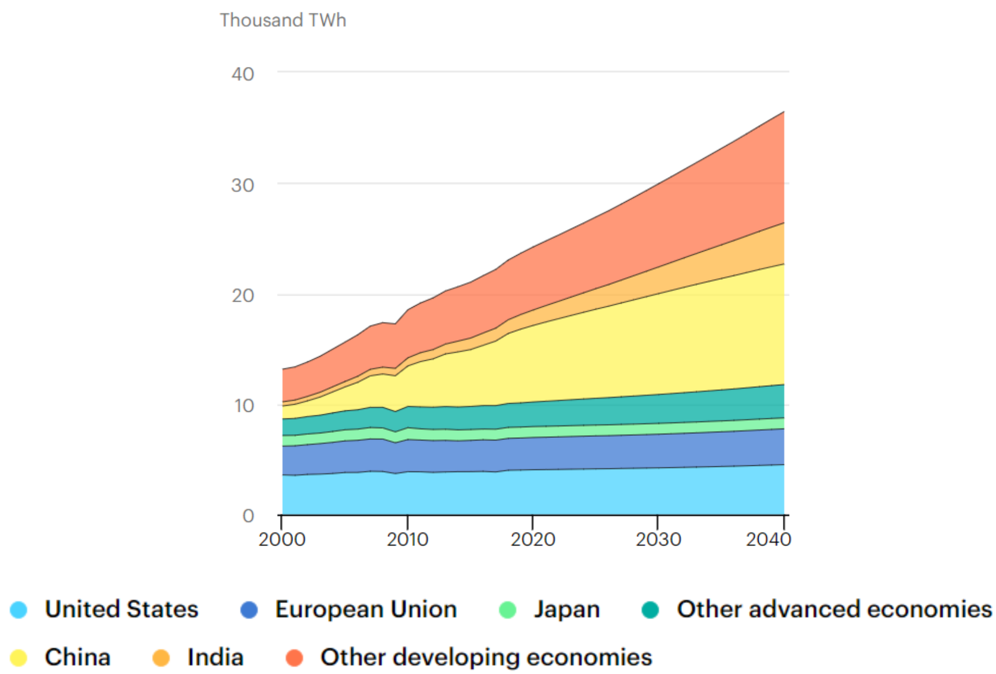


Fig. 1.5.1: Global electricity demand by region in the Stated Policies Scenario, 2000-2040

The demand for electricity complies with two separate regional terms. Developed economies are heavily involved in digitalization and electrification, and digitalization and electrification depend on increasing energy efficiency, so in order to enrich the economy, energy efficiency must be increased. In a developing economy, growing income, mills and refineries are increasing the demand for electricity. According to the State Policy Scenario, the demand for electricity in developing economies is expected to exceed 90% by 2040, but will be 60 percent lower per capita than in developed economies [6].

Today, global demand for electricity for industrial and urbanization has grown by 90 percent, with less than 2 percent of electricity used in transportation [6].

According to the State Policy Scenario, the main reasons for the increase in electricity demand are the development of the motor industry (more than 30% of total development by 2040), space cooling (17%), use of large machinery, small machinery and electric vehicles (10%) [6]. For the first time when electricity was supplied to 530 million people which was only 2% of the demand [6]. Electric vehicles are the main cause of electricity demand for sustainable development [6].

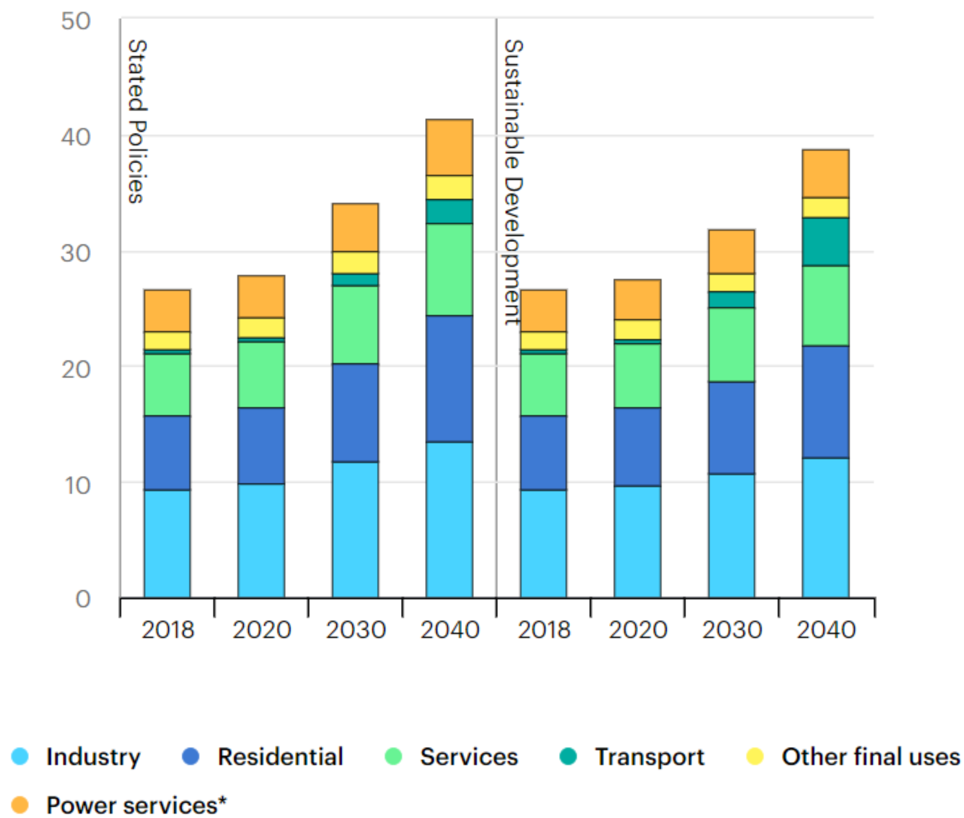


Fig. 1.5.2: Electricity demand by sector and scenario, 2018-2040

1.6 World energy demand for COVID19:

Currently the world is in crisis for the Covid-19 epidemic. As of April 28, about 30 million people had been affected by the epidemic and about 2 million had died [6]. This epidemic has led to an economic crisis in the world today. The epidemic also affects fuel consumption and carbon dioxide emissions. One study found that by mid-April 2020, the average weekly demand for electricity in countries with full lockdowns fell by 25% and in countries with partial lockdowns by an average of 18% per week [6]. As of April 14, 2020, daily data from 30 countries show that more than two-thirds of fuel demand is dependent on imports and exports [6]. This shows that the market price of fuel oil in the Middle East has come down to almost zero [6]. In March 2020, almost all countries in North America and Europe were affected by the Covid-19, resulting in a 3.8% drop in global fuel oil demand [6].

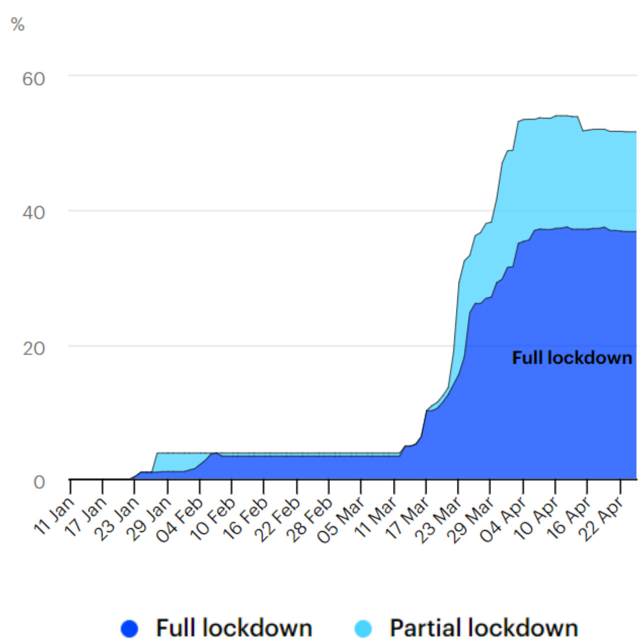


Fig. 1.6.1: Share of global primary energy demand affected by mandatory lockdowns, January-April 2020

1.6.1 Oil demand:

In the first three months of 2020, oil demand fell 5 percent. Because of the lockdown in different countries, the movement of aircraft and vehicles was stopped. Where 60 percent of the total demand was used for the movement of aircraft and vehicles [6].

1.6.2 Gas demand:

Covid-19 also has an impact on gas demand. In early 2020, gas demand fell by about 2% [6].

1.6.3 Renewables demand:

The only renewable energy was not affected by covid-19. Because of the lockdown in various countries, the import and export of coal, oil, gas etc. was stopped and the whole world realized the need for renewable energy and focused on its widespread expansion [6].

1.6.4 Electricity demand:

The impact of the lockdown has also led to a sharp decline in electricity demand. Although residential demand increased during the lockdown, electricity demand fell by 20% or more as commercial and industrial management systems were shut down throughout the lockdown in several countries [6]. As demand decreases, renewable energy production declines slightly, although the output of renewable energy generation is not affected. Power generation from other energy sources such as oil, gas, nuclear energy, coal, etc. is greatly reduced [6].

1.7 World energy consumption:

World energy consumption refers to the total amount of energy produced and consumed by mankind. Generally, an account is kept of how much energy is generated from the sources of energy production and how much energy is consumed each year.

This accounting sector accounts for each country's industrial, technology sector and each energy sector used in human life. It does not take into account the energy generated from food and biomass. Since the source of energy is one of the elements in the development of civilization, the application of global energy has a profound effect on people's socio-economic and political life. The world's Total Primary Power Supply (TPES) is different from the world's primary energy. Because the energy that we use is made usable by various processes to make it usable. In the process of making energy usable, some energy is lost otherwise. For example, when oil is extracted from the ground, it is then refined into gasoline so that it can be used and transported to various gas stations over long distances so that customers can use it [4].

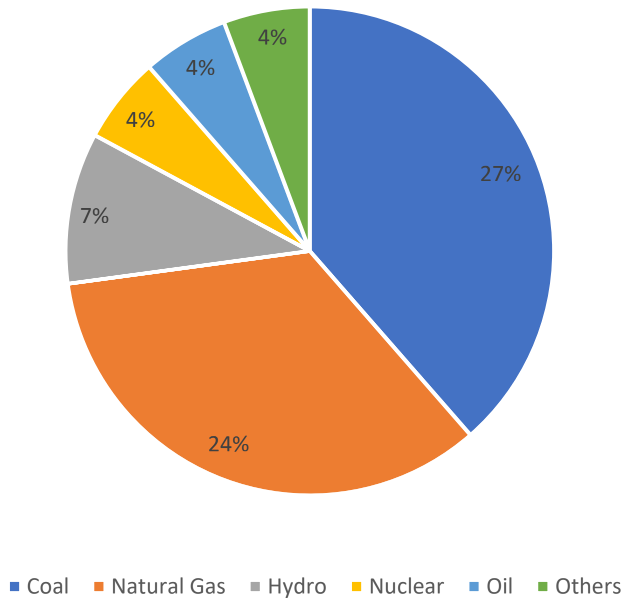


Fig. 1.7.1: World energy consumption

1.7.1 Energy supply, consumption and electricity:

We have to keep in mind that energy has different properties. By using this energy, we generate electricity and do other things. Heat is a relatively low temperature and low-quality energy, although electricity is a high-quality energy yet it takes about three kilowatt hours of heat to generate one kilowatt of electricity. But using this one kilowatt-hour of electricity, a few kilowatt hours of heat can be pumped with the help of heater pump. Electricity can be generated in many ways without using heat. The energy loss during power generation is not the same as the resistance loss of an electrical transmission line. According to a 2014 census, the world's energy supply was about 1,055,481 terawatt-hour (TWh), equivalent to 13,500 140 million tons of oil, where the energy consumption of the whole world was 109,613 TWh which is 29.5% less than the total supply of the whole world [4]. Here is the table-1.7.1 of world primary energy supply, Final energy consumption and Electricity generation yearly.

Key figures (TWh)

Year	primary energy supply	Final energy consumption	Electricity generation
2010	147,899	100,914	21,431
2011	152,504	103,716	22,126
2012	155,505	104,426	22,668
2013	157,482	108,171	23,322
2014	155,481	109,613	23,816
2015	158,715	109,136	
2017	162,494	113,009	25,606

Table-1.7.1 world primary energy supply, Final energy consumption and Electricity generation yearly.

According to the U.S. Energy Information Administration (EIA), the estimated cost of energy worldwide in 2013 was 5.67 * 10 ^ 20 joules, or 157,481 TWh [4].

The IEA agency cites data from several other years, including the estimated energy consumption in 2008 was 143,851 TWh, in 2005 133,602 TWh, in 2000 117,687 TWh, in 1990 1 lakh 2 thousand 569 TWh[4].According to one source, in 2012, 22% of the world's energy was used in North America, 5% in Central and South America, 23% in Europe and Eurasia, 3% in Africa and 40% in the Asia-Pacific region[4].

1.7.2 Electricity generation:

According to the EIA, worldwide electricity consumption in 2013 was 19,504 TWh, in 2008 16,503 TWh, in 2005 15,105 TWh, and in 2000 12,116 TWh [4]. According to a 2014 data, the total power generation capacity worldwide was about 6.4 million watts, which was only connected to the local grid [4].

In addition, electricity was required for the operation of isolated villages and isolated industrial cities and electricity was generated which was beyond this information. According to 2014 data, 41% of the world's electricity is generated from coal, 22% from natural gas, 11% from nuclear, 16% from hydro, 4% from oil, and 6% from other energy sources [4]. Coal and natural gas generated the most electricity. In 2012, 18608 TWh of electricity was used worldwide. Due to grid losses, storage losses, and the power plant's own consumption, this number was 18% lower than the electricity generated worldwide. Co-generation power stations sometimes use some thermal energy that cannot be used in residential buildings or the industrial sector, and is wasted.

In 2016, 80% of the world's energy comes from fossil fuels, 10% from biofuels, 5% from nuclear energy and 5% from renewable energy sources (water, wind, solar, geothermal [4]. Only 18% of the world's energy was in the form of electricity, and the other 82% was used for heating and transportation [4].

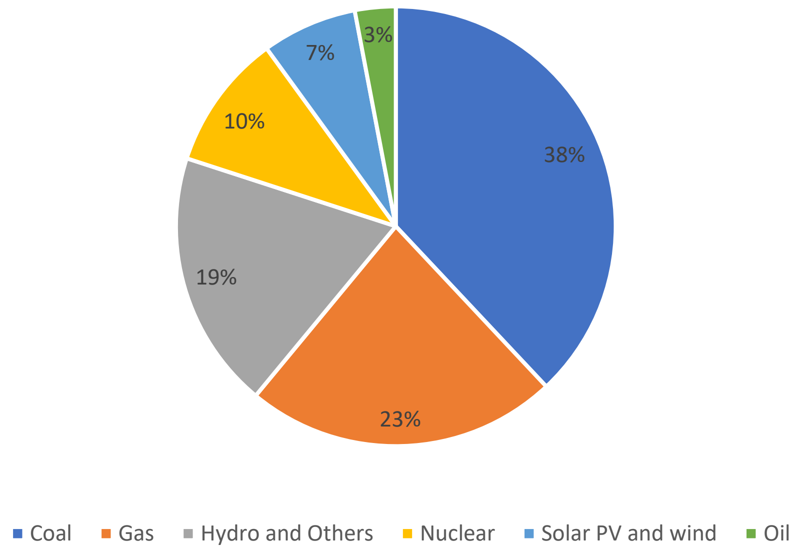


Fig. 1.7.2: 2018 World electricity generation (26,700 TWh) by source (IEA, 2019)

1.8 World Non-renewable Energy consumption:

In the twentieth century the demand for energy has increased so much that the amount of fossil fuels used in energy production has multiplied.

1.8.1 Coal:

As of 2000, China accounted for 28% of the world's coal use, 19% for other Asians, 25% for North America, and 14% for the European Union. Meanwhile, China is the world's largest coal consumer. China's coal use increased from 28% in 2000 to 48% in 2009 and more than 70% in 2019.In fact, most of the increase in coal use has been in China and the rest in other parts of Asia [5]. The world's annual coal production increased by 1905 metric tons or 32% in the six years between 2005 and 2011, where it was 70% in China and 8% in India [7]. Coal production in 2009 was 6,903 metric tons, in 2011 7783 metric tons, in 2019 7921 metric tons [6].

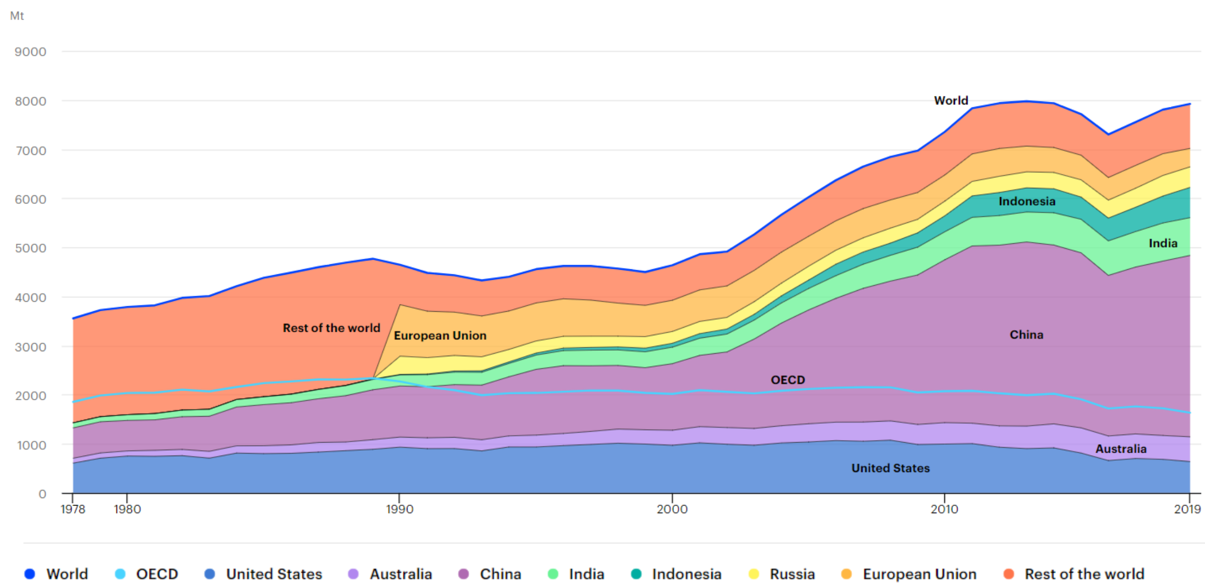


Fig. 1.8.1: World total coal production, 1978-2019 provisional

1.8.2 Oil:

Coal drove the Industrial Revolution of the 18th and 19th centuries. But in the twentieth century, with the proliferation of automobiles, aircraft, and electricity, oil became an important fuel. It is estimated that 100 to one 150 billion tons of oil have been taken in since 1850 to the present [8].

1.8.3 Natural Gas:

From 2000 to 2009, the use of natural gas in the world increased by 30%. This 66% increase in natural gas use was in the European Union, North America, Latin America, and Russia [9].

1.8.4 Nuclear power:

The use of nuclear energy for power generation is no exception. There were about 444 operable electric grids in the world as of July 1, 2016, which were powered by nuclear fission reactors, as well as 66 more nuclear power plants under construction [10]. But the annual production of nuclear power has been declining since 2007, declining 1.8% in 2009 to 2558 TWh, and in 2011 decreased by another 1.6% to 2518 TWh. Nuclear power met 11.7% of the world's electricity demand in 2011 and increased to 18% in 2018[39]. Although all commercial reactors use nuclear fusion energy, there are plans to use nuclear fusion energy in future power plants [4].

1.9 World Renewable Energy consumption:

Renewable energy sources are all sources of energy that can be used repeatedly. Such as air flow, water pressure, water currents, sunlight etc. Combustion of renewable energy sources such as oil, coal, gas, etc. emits toxic gases such as carbon dioxide, carbon monoxide, etc. which are very harmful to the environment and the atmosphere. So, it is currently focusing on reducing the use of non-renewable energy and gradually using renewable energy. This energy, for example, generates 7.5% from biomass, 4.2% from heat energy (non-biomass), 1% from wind-fuel, 3.2% from hydro, and 2% from wind [4]. Huge sums of money are currently being spent on renewable energy production. Which amounted to about $ 289 billion in 2018[11]. Today, about 11% of the world's electricity is generated from sunlight and about 40% from hydro. Between 2000 and 2013, the world's total energy consumption increased by 40,500 TWh, of which renewable energy consumption increased by 6450 TWh [4]. Here, is a table-1.9.1 of world Renewable energy production and use by type:

Source: Ref [12]

	2010	**2020**	**2035**
Electricity generation (TWh)	**4206**	**6299**	**11342**
Bioenergy	331	696	1487
Hydro	3431	4513	5677
Wind	342	1272	2681
Geothermal	68	131	315
Solar PV	32	332	846
Concentrating solar power	2	50	278
Marine	1	5	57
Share of total generation	**20%**	**25%**	**31%**

Table-1.9.1: world Renewable energy production and use by type

1.9.1 Hydro:

Hydroelectricity refers to the generation of electricity from water. In this process electricity is generated by utilizing the flow of water. About 16.6% of the world's total electricity generation in 2015 was generated by hydro power, which is about 70% of renewable power generation [4].

Hydro-power is used to generate electricity in about 150 countries around the world [4]. In 2010, about 32% of the world's hydroelectric power generation was generated in the Asia-Pacific region. China is the most advanced country in terms of hydropower generation. In 2010, China generated about 720 TWh of electricity, which is about 17% of China's total electricity generation [13].

1.9.2 Marine energy:

Marine energy is also called ocean energy, hydro kinetic energy etc. Marine energy is created by utilizing ocean tides, waves, currents, etc. which creates a new possibility in renewable energy [4].

1.9.3 Wind:

Wind power is increasing at a rate of about 17% per year. In 2015, wind generated about 432,883 megawatts (MW) of electricity [14][15][16]. In Europe, Asia and America, large amounts of wind are used to generate electricity. Some countries in the world have been very successful in using the wind to season. In 2010, Denmark generated 21%, Portugal 18%, Spain 16%, Ireland 14%, and Germany 9% electricity using wind [17][18]. About 3% of the electricity generated on Earth in 2016, is generated by wind flow [19].

1.9.4 Solar:

People have been using solar energy since ancient times. Electricity is generated by using the rays coming from the sun. Solar heating, solar photovoltaics, solar concentrated, solar architecture, etc. are several technologies of solar energy. Many of the world's problems can be solved by using these technologies. The International Energy Agency estimates that by 2060, one-third of the world's energy will be generated from solar energy. This will reduce the amount of carbon dioxide emissions into the environment at an incredible rate [20]. Solar technologies can be identified as active solar or passive based on the reception, distribution, and conversion of solar energy. Power generation using photovoltaic systems and solar thermals is done with active solar technology. The work of passive solar technology is to generate energy by utilizing the material of windows, roofs or walls of a building (where sunlight always falls and air can come and go naturally). Between 2012 and 2016, the world's solar power generation capacity tripled and provided 1.3 percent of the world's solar energy [21].

1.9.5 Geothermal:

About 70 countries in the world use geological energy [22]. About 200 petajoules (56 TWh) of electricity was generated from geothermal energy in 2004. And the extra about 270 petajoules of geothermal energy were mostly used for space heating.

1.10 Energy Demand In BANGLADESH:

Bangladesh is a fast growing densely populated developing country in South Asia. So, the demand for electricity for rural economy, mills, readymade garment industry, and rural and urban housing in this fast-developing country is increasing day by day. Energy demand in Bangladesh has increased by 10% in the last one decade [23]. Bangladesh's power generation capacity in 2017 was 15,351 MW and in 2018 it exceeded 20,000 MW [24][25]. The industrial and residential sectors use most of the electricity generated in Bangladesh, followed by the commercial and agricultural sectors [26]. According to 2015 data, 92% of the urban population and 62% of the rural population had access to electricity [27]. According to the Bangladesh Power Development Board, in 2018, 90% of the total population of the country have access to electricity. However, per capita electricity consumption in Bangladesh is considered low [28]. By 2030, the country will need 34,000 MW of electricity to sustain Bangladesh's economic growth of 7% [29].

1.11 Energy Consumption In BANGLADESH:

Bangladesh's economy is dependent on agricultural work and mills. Bangladesh is largely dependent on fossil fuels such as coal, gas, diesel and hydropower for power generation. 99% of the electricity demand of rural life system of Bangladesh is generated from fossil fuels. Although the cost of electricity generated from fossil fuels is very high and has an adverse effect on the environment, it has become a catastrophic threat to the environment and even the world's climate change. So, the solution to this problem is to generate electricity from renewable energy sources, which is very readily available at very low cost and without harming the environment [30]. Sources of renewable energy include geothermal, ocean currents, wind power, solar energy, etc.

Bangladesh is largely dependent on natural gas for power generation. About 80 percent of the total electricity generation in Bangladesh is generated by natural gas. Bangladesh has about 201532.1 trillion cubic feet of gas reserves [31]. It also has about 2797 megatons of coal reserves, which is equivalent to about 37 million cubic feet of gas[32].During the last operation on September 21-22, 2015, it was learned that Bangladesh has about 2725 million cubic feet of gas and 9263.7 million cubic feet of condensate reserves in its own gas field[33].In 2015, the growth rate of power generation in Bangladesh was about 15%[34]. Bangladesh Power Development Board (BPDB) expected that power generation in Bangladesh would increase by about 1000 MW in 2015.

The table-1.11.1 below shows Bangladesh's electricity scenario in 2018:

Source: Ref [35][36]

Item	January 2018
Power Generation Capacity	17060 MW
Access to Electricity	79%
Distribution Line	341,000 km
Transmission Line	15665 circuit km
Per Capita Power Generation	460 kWh
Average System Loss	15%

Table-1.11.1: Bangladesh's electricity scenario in 2018

According to a 2016 survey, about 65% of the total primary energy consumption in Bangladesh comes from gas, 5% from imports, 2% from coal, 5% from renewable energy, 7% from high speed diesel (HSD) and 18% from heavy fuel oil (HFO).

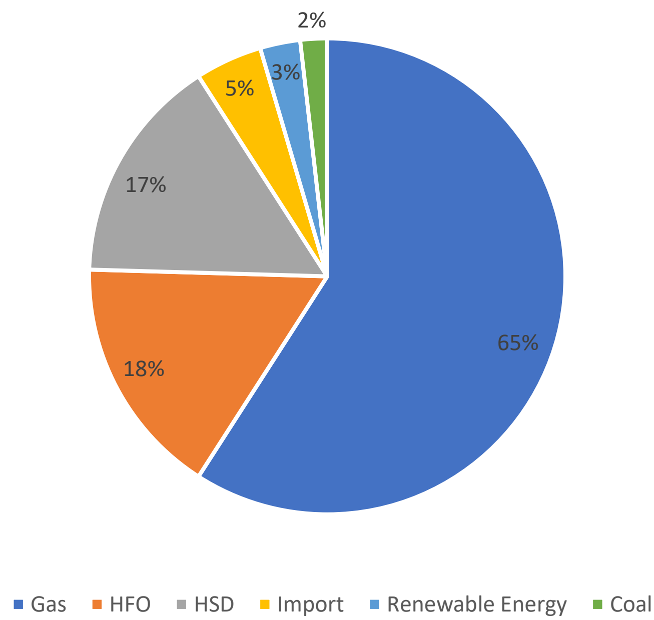


Fig. 1.11.1: Primary energy consumption in Bangladesh

1.12 Renewable Energy Consumption In BANGLADESH:

Renewable energy sources are environmentally friendly, sustainable, clean. So, the sources can be reproduced at any time without any duration. The amount of fossil fuel in the world is decreasing day by day. The renewable energy source does not allow the fossil fuel reduction effect. Renewable energy sources can counteract the damage caused to the environment by burning fossil fuels. For a low-income country like Bangladesh, greenhouse gas emissions are not the primary initiative. However, as the amount of fossil fuels from the world is declining rapidly, Bangladesh is focusing on renewable energy sources. Due to the geographical location of Bangladesh, there is a lot of potential for renewable energy, one of which is solar power, besides some potential for hydropower [37]. In the absence of sufficient funds, it is somewhat difficult to measure wind power generation [38]. Renewable energy sources generate about 433 MW of electricity in Bangladesh, which is only 3.5% of the total electricity generation in Bangladesh. In 2015, Bangladesh was supposed to generate 5% of electricity from renewable energy sources, but failed to meet the target in the Bangladesh Policy of Renewable Energy (BPRE). Only 3.5% of electricity was generated in 2015.However, the Government of Bangladesh is working to generate 10% of Bangladesh's total electricity generation from renewable energy by 2020[38].

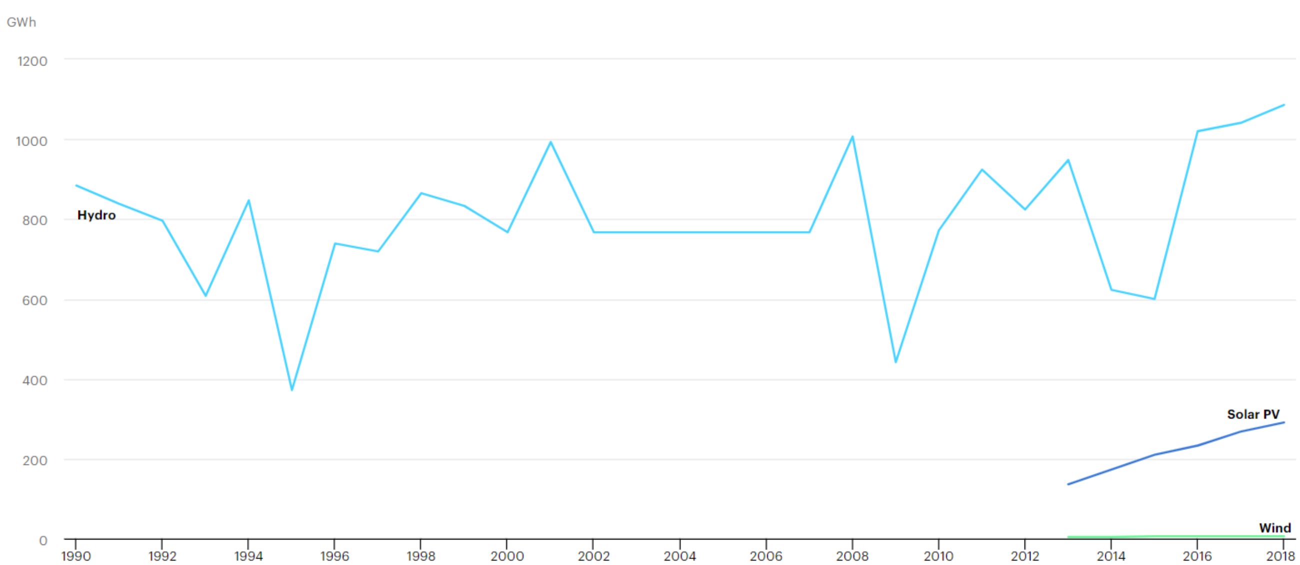


Fig. 1.12.1: Renewable electricity generation by source (non-combustible), Bangladesh 1990-2018

Here is the table-1.12.1 of Installed renewable energy technologies in Bangladesh.

Source: Ref [39]

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Biogas to electricity	5	-	5
Biomass to electricity	1	-	1
Hydro	-	230	230
Solar PV	184	1	185
Wind	1	.9	1.9
Total	**191**	**232**	**423**

Table-1.12.1: Installed renewable energy technologies in Bangladesh

Here is the table-1.12.2 of Measures of renewable technology installed in Bangladesh.

Source: Ref [39]

Type	Number
Solar home system	3.6 million
Solar irrigation pump	366
Solar water heater	-
Solar drinking water system	140
Biogas plant	38000
Improved cook stove	20,00,000
Improved rice parboiling system	68
Total	**5.63 million**

Table-1.12.2: Measures of renewable technology installed in Bangladesh

1.12.1 Solar:

In terms of geographical location, Bangladesh is located 84.04 and 92.44 degrees east and 20.30 and 26.38 degrees north. So solar energy can be retained and used very easily [40][41]. As a result, Bangladesh gets less sunlight for 10 hours a day throughout the year. The average solar energy intensity in Bangladesh is about 5 kwh / m2 / day [41][42]. As a result, solar power plants can play an important role in increasing power generation in the national grid of Bangladesh. Since solar energy is very readily available, and it does not produce any gas i.e. pollution free, its maintenance cost is low, the only problem is that it fails to generate electricity in cloudy skies, but its efficiency is much higher than that of other renewable energy sources.

Bangladesh has already gained accurate and successful experience in generating electricity using solar energy [43]. The country has the capacity to generate 50,174 MW of electricity using solar energy alone [44]. Bangladesh has the largest solar home system in the world with about five million solar home systems. Bangladesh is generating and supplying 3 MW power to the national grid using only rooftop panels. However, the total amount of electricity generated from solar power in Bangladesh is 500 MW and the total renewable energy is 39.5% [35]. Bangladesh's state-owned infrastructure development agency (IDCOL) has already installed 3 million solar home systems to provide electricity to 13 million rural people. Most recently, Bangladesh has installed the country's largest solar power plant at Teknaf with a capacity of 28 MW, from which 20 MW will be added to the local sub-station.

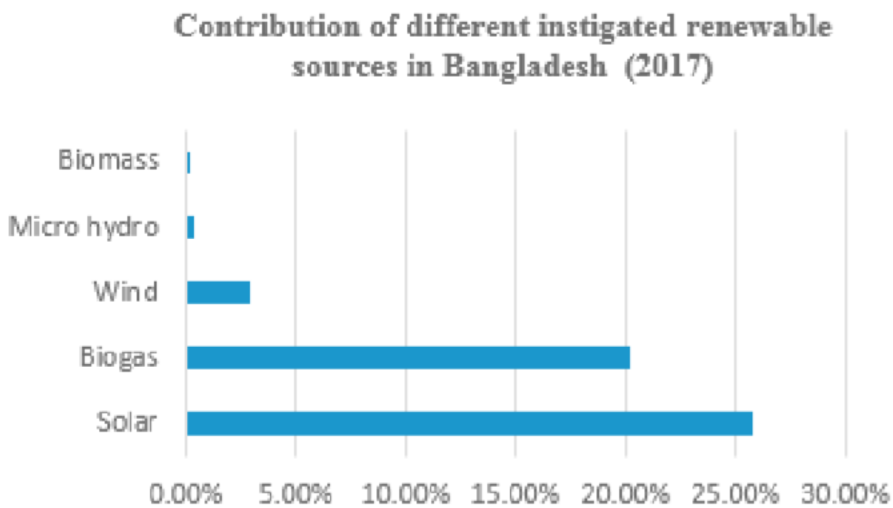


Fig. 1.12.2: Contribution of different instigated renewable source in Bangladesh.

1.12.2 Biofuel/biomass/biogas:

Biofuels or biomass or wind gas are used for energy production. Biofuel is an environmentally friendly fuel that is used as a renewable energy [45]. Biofuels are usually produced from lard, tallow, white or yellow grease, poultry fat, fish oil etc. [46]. Biogas or biomass is very popular in Bangladesh. There are about 350 oil factories in Bangladesh which produce biofuel, from biofuels like sunflower, sesame, castor, cotton seeds etc.

Here is the table-1.12.3 of Biogas Technical Potential.

	Technical Potential (MWh*)		Estimated Capacity Potential (kW**)	
Division	Commercial Cattle and Buffalo	Commercial Fowl and Duck	Commercial Cattle and Buffalo	Commercial Fowl and Duck
Barisal	1,989	16,189	45	370
Chittagong	11,364	69,243	259	1,581
Dhaka	18,452	188,138	421	4,295
Khulna	11,095	26,983	253	616
Rajshahi	15,999	33,193	365	758
Sylhet	1,383	18,946	32	433
Total	**60,282**	**352,692**	**1,376**	**8,052**

*Based on a heating rate of 10,000 btu/kWh, **Determined by assuming an efficiency of 50%.

Table-1.12.3: Biogas Technical Potential.

1.12.3 Wind energy:

The world is moving very fast in the field of wind energy generation. Usually a turbine is used to generate electricity from wind energy. Bangladesh is using wind energy to generate about 900 Kw of electricity from Sonagazi Muhuri Dam in Feni and about 1000 Kw from Kutubdia Island [47]. Grameen Shakti, Bangladesh Center for Advanced Studies (BCAS), Bangladesh Army, IFRD, is generating about 19.2 KW of electricity from wind power using coastal areas of Bangladesh [48]. Bangladesh is located on the largest beach in the world about 724 km long. Bangladesh is planning to use this long beach to generate electricity from bio energy. BPDB has identified about 22 places in the coastal areas of Bangladesh, from which plans are underway to generate 50-200 MW of electricity, and plans to generate about 15 MW of electricity from Muhuri Dam [48].

The table-1.12.4 bellow shows different places in Bangladesh for Wind energy.

Site	Reference Height (m)	Annual-Average Wind Speed (m/s)
Cox's Bazaar	10	2.42
Sandip Island	5	2.16
Teknaf	5	2.16
Patenga Airport	5	2.45
Comilla Airport	6	2.21
Khepupara	10	2.36
Kutubdia Island	6	2.09
Bhola Island	7	2.44
Hatia Island	6	2.08

Table-1.12.4: Different places in Bangladesh for Wind energy.

1.12.4 Hydro Energy:

Hydropower is a natural renewable energy source. By making a reserve of water, the turbine is rotated by converting the water head into kinetic energy. The mechanical energy generated at the turbine is then converted into electrical energy by means of an alternator [49].

Bangladesh's sources of hydropower are less than the world's rate of hydropower generation [50]. At the end of 2014, hydropower generation was 879 MTOP, which is 3.3% of the average hydropower generation in the last 10 years. In 2014, the world's total hydropower generation was 406.83%, most of which was generated in China (27.4%) [51]. In 2014, Bangladesh's hydropower generation capacity was 230 MW, which is very low compared to other countries in the world [51].

Here is the table-1.12.5 of Bangladesh Hydro power sector.

Source: Ref [51]

Name of the River	**Potential of Electrical Energy in MW**
Kaptai	100
Shangu river	100
Matamuhuri river	100
Mohamaya	23-65
Lohajari	4.5

Table-1.12.5: Bangladesh Hydro power sector.

1.12.5 Geothermal Energy:

Geothermal energy is the main energy of the earth and one of the sources of renewable energy. Bangladesh has the potential to generate energy from geothermal energy, with warm water areas in Rangpur (700 m below), Madhupur (20 m), Kuchma and Bogra (60-125 km), and Thakurgaon being the main sources of geothermal energy. Meanwhile, the Government of Bangladesh and Anglo MGH have jointly planned to build a 200 MW geothermal power plant at Thakurgaon [52].

1.13 Rooftop solar system:

A rooftop solar system or PV system is a process where electricity is generated through solar panels on the roofs of residential and commercial buildings, and the generated power is used in that residential or commercial building [53]. Accessories such as photovoltaic modules, mounting systems, cables, solar inverters, etc. are one of the components of rooftop solar systems [54].

Due to the geographical location of Bangladesh, rooftops may be able to generate enough electricity using solar systems. The Bangladesh government is planning to generate about 300 MW of electricity on the roofs of government factories and various companies using rooftop solar systems, which will reduce dependence on fossil fuels and reduce carbon emissions [55]. The Government of Bangladesh also introduced the Net Metering Guideline on 28 July 2018 to take the rooftop solar system forward. Rooftop Solar is directly connected to the grid, in the process the electricity generated goes to the grid after meeting the customer's demand and can get the price of electricity generated at the end of the year [55].

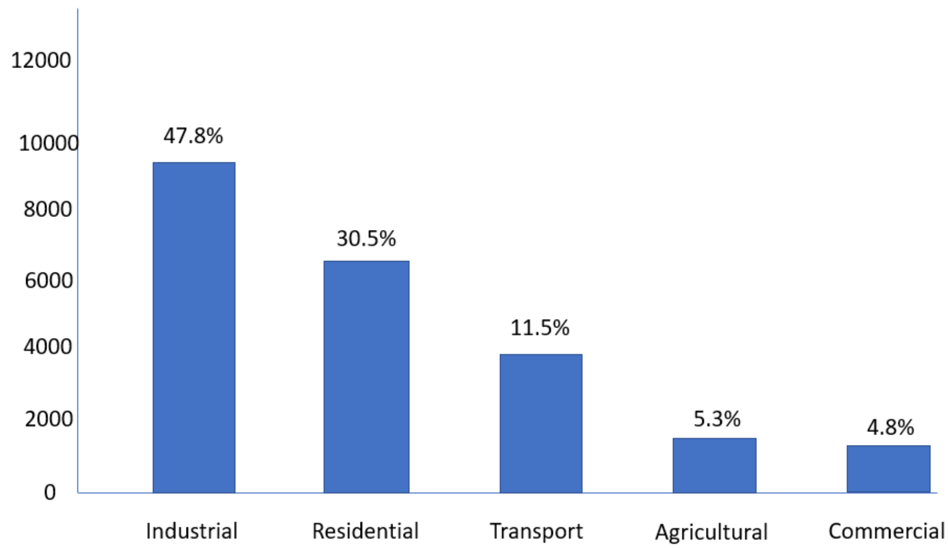


Fig. 1.13.1: Primary energy consumption in different sector.

A review of our country's power sector shows that about 30.5% of electricity is used in the residential sector, which is the second highest utilization sector in our country [56]. There is huge potential for rooftop solar in this residential area, although not all homeowners can afford solar power. To solve this problem, each building needs to have a net meter.

For the residential sector, according to the rules of net metering, the generating capacity of each building should not exceed 100 kW, which is an unnecessary constraint. SHS is a type of rooftop based solar system. Rooftop solar systems have a huge success story in rural Bangladesh. The project has been dubbed as the largest and fastest growing renewable energy program in the world [57]. SHS can be successfully installed in urban areas of Bangladesh [57].

Bangladesh has great potential to accelerate power generation through grid-connected solar photovoltaic systems [58]. This is a good idea for those who want to reduce their electricity bills. It will cost extra to install net metering, but customers can save a lot more money for life. Bangladesh on-grid system installation capacity is at least 42 MW. But not all of these are connected to the net metering system.

The table gives an example of an on-grid solar power project in Bangladesh.

Source: Ref [59].

Project name	Technology Type	Capacity (MW)	Location	Completion Date	Present Status
Rooftop solar at Kodda 150 MW dual fuel power plant	Rooftop solar (on-grid)	0.02	Gazipur	28/06/2017	Completed & running
Army solar project	Rooftop solar (on-grid)	0.25	Dhaka	31/12/2015	Completed & running
BCSIR solar power plant01	Rooftop solar (on-grid)	0.06	Dhaka	01/07/2014	Completed & running
BCSIR solar power plant02	Rooftop solar (on-grid)	0.06	Joypurhat	01/07/2012	Completed & running

Table-1.13.1: On-grid solar power project in Bangladesh.

A review of the power sector in Bangladesh shows that about 47.8% of the power is used in the industrial sector. Which is the largest used power sector in Bangladesh [60]. As of June 2019, rooftop solar systems have been launched in about 286,469 industrial establishments in Bangladesh. 1 kilowatt peak rooftop solar system requires about 100 square feet or 10 square meters of rooftop [61]. The popularity of rooftop solar system is increasing day by day in Bangladesh industries. Most industries are currently using solar power. Industrial solar power systems are very cost-effective and suitable for readymade garments, textile, cement, paper, chemical and ceramic industries.

The cost of electricity generated from solar power for a 30 year life is less than Rs 5 per unit, which is less than the cost of electricity generated from gas[62].According to IDCOL (Infrastructure Development Company Ltd.), the members of 1500 textile mills in Bangladesh have about 42 million square feet of rooftop space, from which it is possible to generate about 400 MW of electricity. According to an IFC (International Finance Corporation) study, mills and factories can reduce grid power consumption by about 5 to 20 percent through rooftop solar systems.

The table below shows Some examples of industrial &commercial rooftop solar projects in Bangladesh.

Source: [61,63]

Project name	Technology type	Location	Capacity	Present status
Rooftop solar for Paragon Poultry Ltd	Industrial rooftop solar	Gazipur	723.06kW	Completed & running
Rooftop solar FESIL	Industrial rooftop solar	Habiganj	1.1MW	Completed & running
Rooftop for Tosrifa industry ltd	Industrial rooftop solar	Dhaka	50kWp	Completed & running
Rooftop for M&U packaging industry	Industrial rooftop solar	Dhaka	200kWp	Completed & running
Rooftop for Bashundhara industrial complex	Industrial rooftop solar	Dhaka	2.46MW	Under implementation
Rooftop for Robintex group company	Industrial rooftop solar	Narayanganj	3.1MW	Under implementation
Rooftop for Dhaka stock exchange	Industrial rooftop solar	Dhaka	47kWp	Completed & running

Table-1.13.2: Some examples of industrial &commercial rooftop solar projects in Bangladesh.

1.14 Hybrid Solar System:

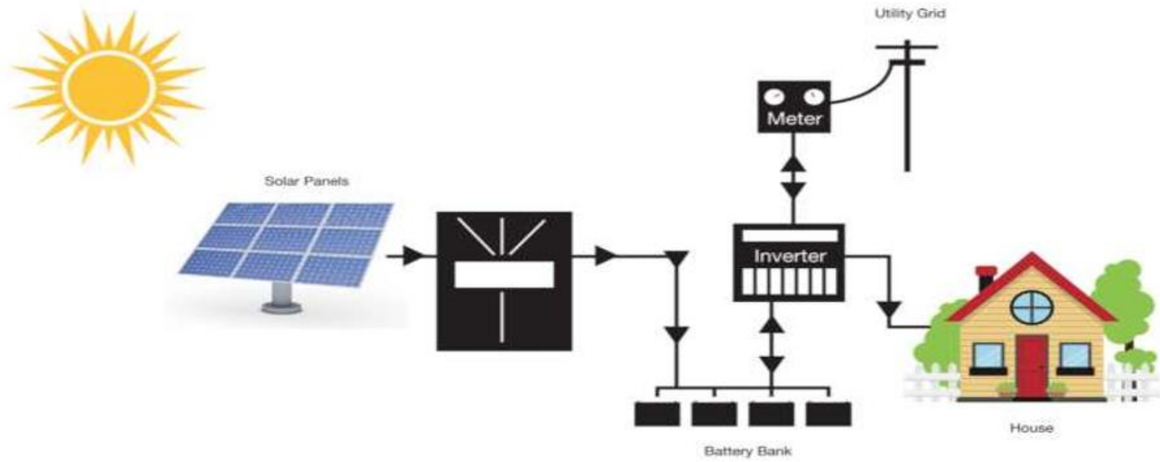


Fig. 1.14.1: Hybrid solar system.

The scheme is similar to an on-grid solar system with a hybrid inverter attached, allowing customers to use the grid only when they need electricity. One of its features is that this hybrid solar system provides power when the power goes out and in case of emergency [64]. Having a lot of light produces a lot of energy which is stored in the battery after meeting the demand. Hybrid solar systems with battery backup are dependent on sunlight, so the process does not generate much electricity in the winter. Due to the complexity of the hybrid solar system, installing batteries in it is quite expensive. This hybrid solar system is not very popular in Bangladesh due to its initial difficulties.

1.15 Problem Statement:

At present, global warming has become a major problem. Because the amount of carbon emitted into the atmosphere, and the polar ice caps melting, the extinction of various wildlife, reminds us that we are destroying the earth. So, the demand for clean energy is increasing day by day all over the world. It is now a popular means of generating electricity from solar radiation using sunlight as a source.

Although there are some obstacles in the process of generating electricity from solar. As it cannot generate energy at the same rate throughout the year, it has the effect of weather change. Until we can develop a solar system whose efficiency remains the same throughout the year, we must continue to work on solar system development. Because we can't think of a world where there will be people and no world.

1.16 Scopes:

Bangladesh is a developing country and so far, 100% of the people of the country have not got access to electricity. As fossil fuels are the main source of energy production in the country and its quantity is declining day by day, fossil fuels have adverse effects on the environment, and solar power can play an important role in moving the country towards future sustainable development. The country's residential and commercial buildings can generate electricity through rooftop solar systems, which reduces the pressure on the country's power generation, thereby reducing a large pressure on fossil fuels.

1.18 Objective of Thesis:

1.This could be a game changer for achieving sustainable energy development of Bangladesh.

2. Since the average income of the people of Bangladesh is low, to provide electricity facility at very low cost.

3. Reducing the pressure on the power plant through hybrid system.

4. Generating more and more electricity from renewable energy sources.

5. Reducing stress on fossil fuels.

6. Reducing the amount of carbon dioxide in the environment.

1.19 Thesis Outline:

1.Introduction

2.Literature review

3.Theory

4.Calculation

5.Result

6.Conculation

CHAPTER-2

Literature

Electricity is a very important element of our lives without which life has become almost impossible. Compared to the world energy, the condition of primary energy power of Bangladesh is not good at all. With most of Bangladesh's electricity generated from fossil fuels , access to electricity has become a major challenge. And to meet this challenge, Bangladesh can meet the demand for electricity by using solar energy. With solar, biomass, biogas, hydropower, wind power, etc. all around us, it is possible to develop rural and urban economies by generating electricity from these sources.

However, shifting to a renewable energy source reduces carbon emissions in nature, and on the other hand, aids in the goal of moving to an alternative source of energy. Renewable energy currently accounts for 17% of the world's total energy, with a target of 60% by 2070[65]. Due to its geographical location, solar energy has become a major source of renewable energy in Bangladesh. The popularity of hilly, coastal, rural national grid has increased day by day.

Considering the various opportunities and future possibilities of solar technology, the Government of Bangladesh and various NGOs are working together to understand and address the power shortage by encouraging the public to use the Solar Home System (SHS) in both off-grid and on-grid. According to the Renewable Energy Policy, solar panels should be used in cases where the power requirement exceeds 2 KW.

There is no alternative to reviewing, testing, and researching on the use of solar energy in Bangladesh, commercial production, increasing its use in factories, and for the overall economic development of the country, to further increase the efficiency of solar energy. Very little research has been done on the technology and economic evaluation of renewable energy sources in Bangladesh [66,67]. Hossain and his colleagues conducted a study on various marketing strategies for the solar business [68]. The study highlights the problems associated with Bangladesh's solar energy business.

Haldar studies the economic viability of three different power (20 Wp, 30Wp, 42Wp) solar home systems in two randomly selected villages in Bangladesh [69]. Khan and Matin review their research on various biogas digester technologies used in Bangladesh [70]. They have found in their research that it is possible to improve the quality and quantity of biogas, if different parameters (e.g., temperature, pH, movement, etc.) can be controlled.

On the other hand, Hussein and his colleagues have done research on power generation and chemical production from biomass [71]. Taskin Jamal and his colleagues have worked with rooftop solar panels. Where they highlight the various advantages and possibilities of rooftop solar panels [72]. Shahriar Ahmed and his colleagues have done research on the Solar rooftop. In the study, they compared the city of Dhaka in Bangladesh and some cities in Germany and pointed out the possibility of meeting the electricity demand through solar rooftops on different roofs of Dhaka city [73].

In this paper we have tried to highlight the aspect of meeting the demand for electricity through solar rooftops using the roofs of mills, commercial buildings, residential buildings located in Dhaka city.

On the main building of our university (Daffodil International University) located in Dhaka city, we have conducted an experiment of solar rooftop. And we have tried to highlight the issues in this paper.

CHAPTER-3

Theory

Solar energy is created through sunlight. Solar modules or photovoltaic systems convert light into electrical energy during the day. It usually has a limitation of 20 to 100WP. Electricity generated in solar panels is stored in batteries for uninterrupted power in bad weather and at night. A charge controller is a device that protects the battery from electrical damage. When the battery is not charged or the module does not work properly, the charge controller warns the buyer. Solar Residential System (SRS) typically operates at a 12volt coordinate current, and this power is used in lights and other equipment through light emitting diodes (HANKINS 1993: 10) [74]. A 50WP SRS can provide uninterrupted connection for up to about five hours on 4 lights and a 15-inch TV. A solar PV system usually has solar panels, charge controllers, batteries, inverters, loads, etc. connected.

3.1 Solar Panel:

Solar panels are usually made of photovoltaic (PV) cells, which convert daylight into electrical energy.

Fig.3.1.1: Solar Panel

3.2 Charge controller:

If a battery is installed in a solar PV system then a charge controller is required. A charge controller controls the uncertain volt build-up of a solar PV system. On a bright day, solar cells can generate excess voltage, which can significantly damage the battery. The charge controller protects the battery from damage by maintaining a balance of excess voltage.

Fig. 3.2.1: Charge controller

3.3 Batteries:

Batteries are usually used to store charges. There are many types of batteries on the market, but not all are suitable for solar PV technology. Batteries made of nickel or cadmium are more commonly used. High concentration batteries like sodium, sulfur, zinc, bromine etc. are also used. But medium-term batteries made of nickel, metal have the highest cycling performance.

Iron, Chromium, Red Ox and Zinc or Manganese batteries are best for long term performance. Absorbent glass mat (MAT) batteries are also ideal for use in solar PV systems[75].

Fig. 3.3.1: Battery

3.4 Inverter:

Fig. 3.4.1: Inverter

The job of an inverter is to convert direct current (DC) to alternating current (AC). Alternating current (AC) can be converted to any frequency and voltage through the inverter, resulting in proper use of transformers, switching and control circuits. Inverters are commonly used to supply renewable energy or direct current (DC), such as alternating current (AC) power from solar panels or batteries. Electrical inverter is a high-power electronic oscillator.

Inverters are designed to convert from 12-volt current (DC) source to 115-volt alternating current (AC). This inverter generates 1.2Amps alternating current (AC) which can turn on two 60-watt lights.

3.4.1 String inverter:

Fig. 3.4.2: String Inverter

1. Beautiful to see string inverter.
2. Small and medium size PVs are commonly available at power stations.
3. User-friendly interface.
4. Its power level is 1.5 KW to 6 KW.

3.4.2 Power plant inverter:

It is usually a long size PV Transformer type and transformer-less type is designed. As if it can be used in any power station. A grid-tie inverter (GTI) is a special type of inverter used to convert direct current (DC) from renewable energy to alternating current (AC) and to be used in utility grids. The technical name of this grid-tie inverter is “grid-interactive inverter”. It is also called synchronous inverter. Grid-interactive inverters are not commonly used in standalone applications, where utilities are not commonly available.

Fig. 3.4.3: Power plant inverter

3.5 Hybrid optimization of Multiple Electric Renewable (HOMER):

Homer is a micro power optimization model that simplifies the design of power systems for a variety of applications such as off-grid and on-grid. Homer can model both single and multiple technologies and compare multiple combinations of different technologies. But due to the huge number of alternative technologies and the high cost of technology, the availability of energy resources makes it difficult to model the system. The sensitivity of Homer's system optimization and algorithm analysis makes it possible to evaluate many potential system configurations. This software was first developed in 1993 to understand trade-offs in various word production configurations of the DOE (Department of Energy). But a few years later, NREL (National Renewable Energy Limited in the United States) released the software for free to provide a growing expansion service to designers interested in renewable energy production.

CHAPTER-4

SYSTEM DESIGN

Currently about one-third of the world's population lives in poverty. About 75% of this poor living population lives in villages. Rural areas often lack energy, clean water and healthcare, as there is little incentive to increase these services as they are costly. Traditional grids in rural areas cannot be easily extended, so diesel generators are used for power generation and water extraction, which is harmful to the environment, climate and wind. Considering the technical aspects of protection from this harmful aspect, it is seen that photovoltaic solar system is a good way for the rural community. Photovoltaic systems are now modular and easily expandable. Photovoltaic systems and panel production have increased worldwide, and their market value is now declining.

4.1 Location

A photovoltaic solar home system project with 20kW power capacity is done on our permanent campus. Our permanent campus is located at Ashulia, Savar, Dhaka, Bangladesh. In this photovoltaic solar home system, we have considered a 11 kilowatts solar photovoltaic system.

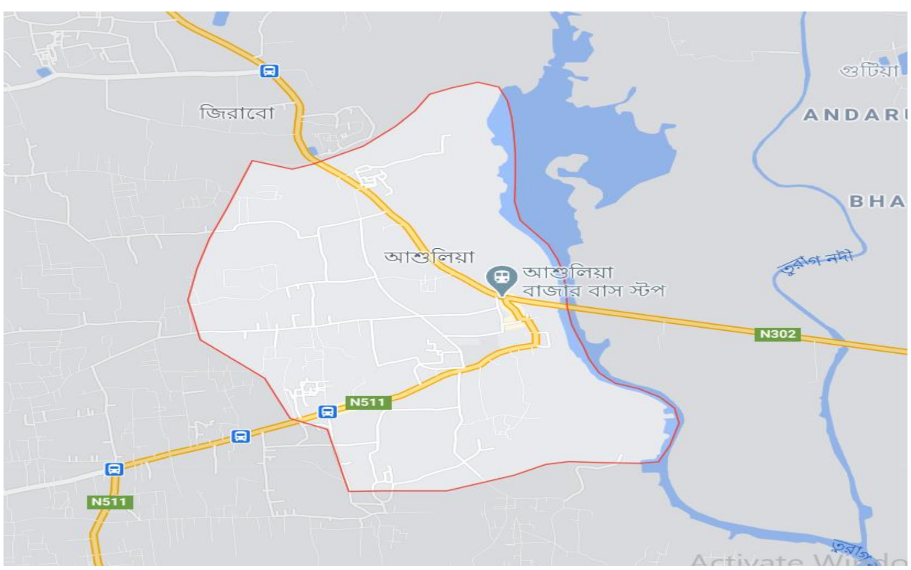


Fig. 4.1: Location Selection.

4.2 Explanation of Design:

First you need to choose a few photovoltaic modules that are connected in series and are connected to the charge controller. The charge controller regulates the voltage and current coming from the solar panel which is stored in the battery through the DC bus bar. Since solar panels cannot generate electricity at night, arrangements have to be made to store electricity. Power is stored overnight by connecting a number of battery series. This system is illustrated by a block diagram.

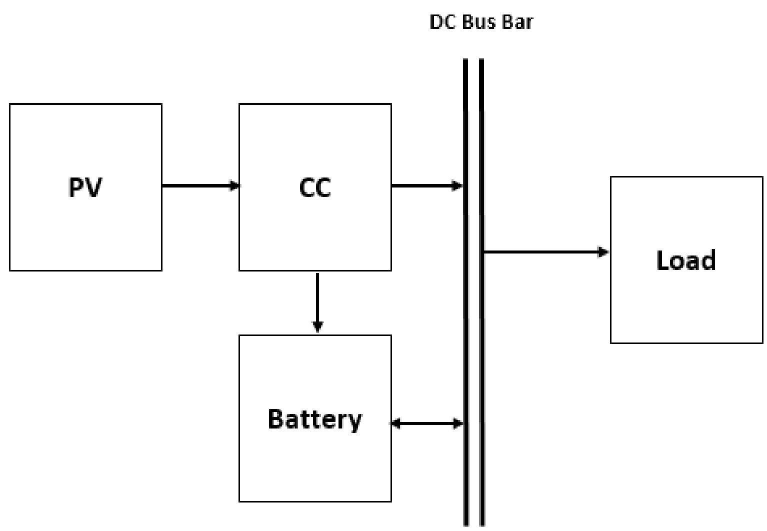


Fig. 4.1.1: Block Diagram of System Design

4.3 System design by HOMER:

Homer simplifies the generation distribution design for a variety of applications, both off-grid and on-grid. Homer's software provides insights into how much energy can be generated from a renewable grid, the cost per unit, the cost of the project, the operating hours, the durability of the system, efficiency, and maintenance costs etc.

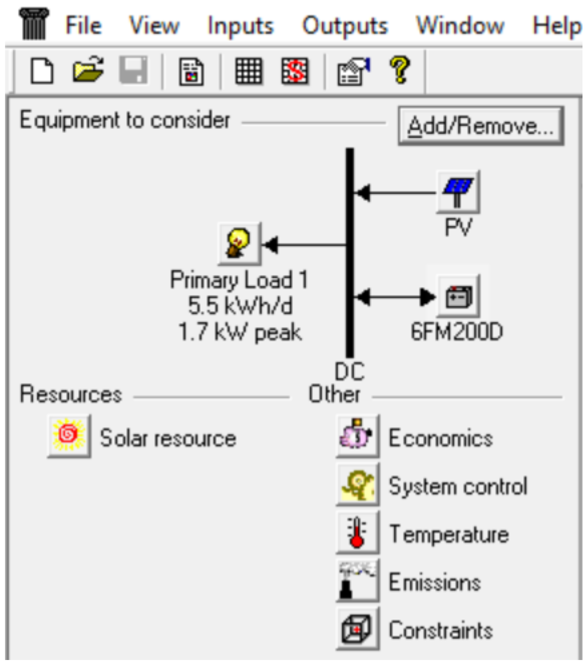


Fig. 4.2.1: System Design by HOMER

4.4 Daily Load profile:

Educational institutions generally do not require electricity 24 hours a day, seven days a week. So, the profile is usually made on an hourly basis, when the load is used. Usually in the afternoon solar panels can't do much due to lack of light. Bangladesh does not have the same solar radiation every time of the year so the same amount of electricity is not generated every day. Since Bangladesh is a conspiratorial country, the demand for electricity is not always the same. The daily load profile can generally be divided into three categories based on this power demand.

November to February

March to June

July to October

Daily Load November to February:

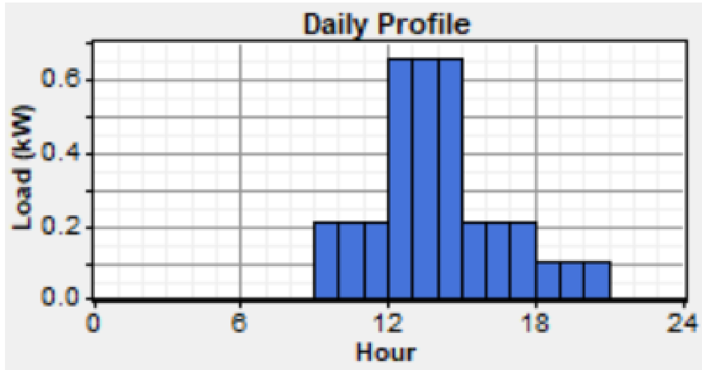


Fig. 4.3.1: Daily Load November to February

Daily Load March to June:

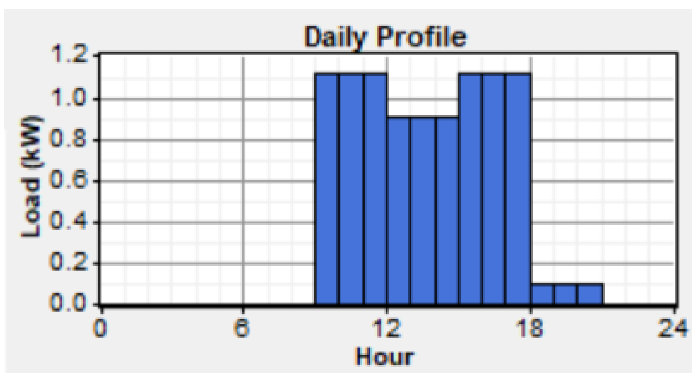


Fig. 4.3.2: Daily Load March to June

Daily Load July to October:

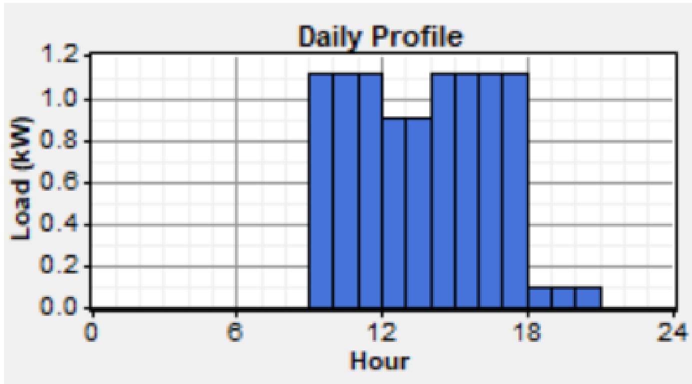


Fig. 4.3.3: Daily Load July to October

4.5 Seasonal profile:

Considering the above daily load curve is used in the monthly load curve. This monthly load curve is created using the seasonal profile where the maximum load, the minimum load, of the month is shown.

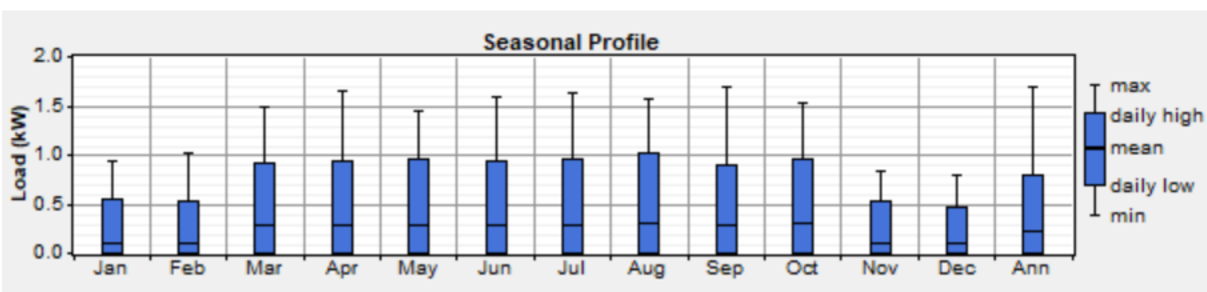


Fig. 4.4.1: Seasonal Profile

4.6 Homer Input value:

Since Homer software is an off-grid design system, we have to give some number of input values like photovoltaic, diesel generator, biomass generator, battery etc. To design an off-grid system is to give input values to everything in Homer software.

4.7 Photovoltaic Array (PV):

The lifespan of a photovoltaic array is 25 years. Here an 11-kW photovoltaic array is used with a nominal operating cell temperature of 47^{o}C.

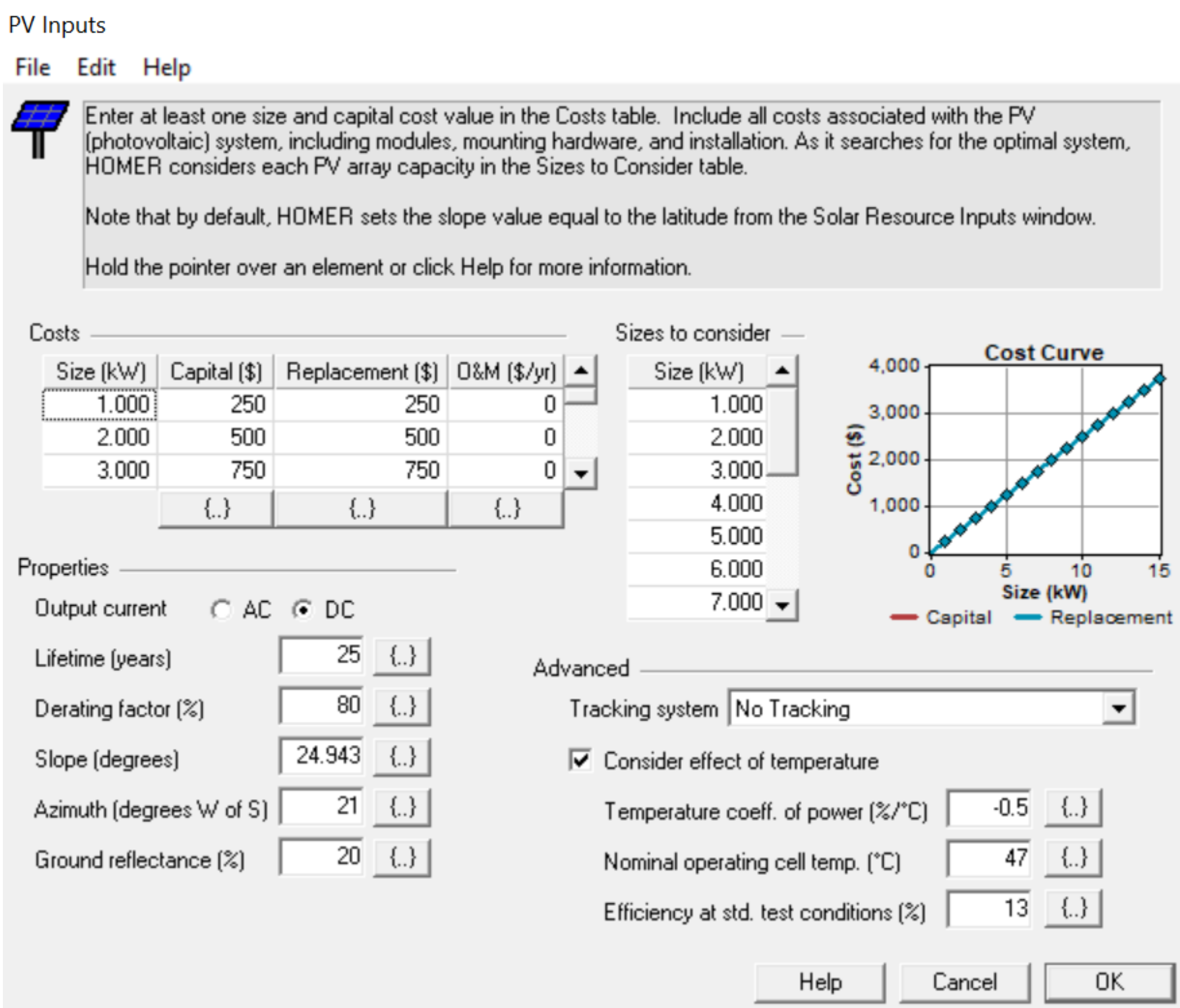


Fig. 4.6.1: Photovoltaic Array

4.8 Battery:

12 voltage Vision FM 200 D type battery is used, With a capacity of 200Ah, lifetime 917 kWh. Here five batteries are used where the maintenance cost of each battery is .10$. And replacement cost 1000.

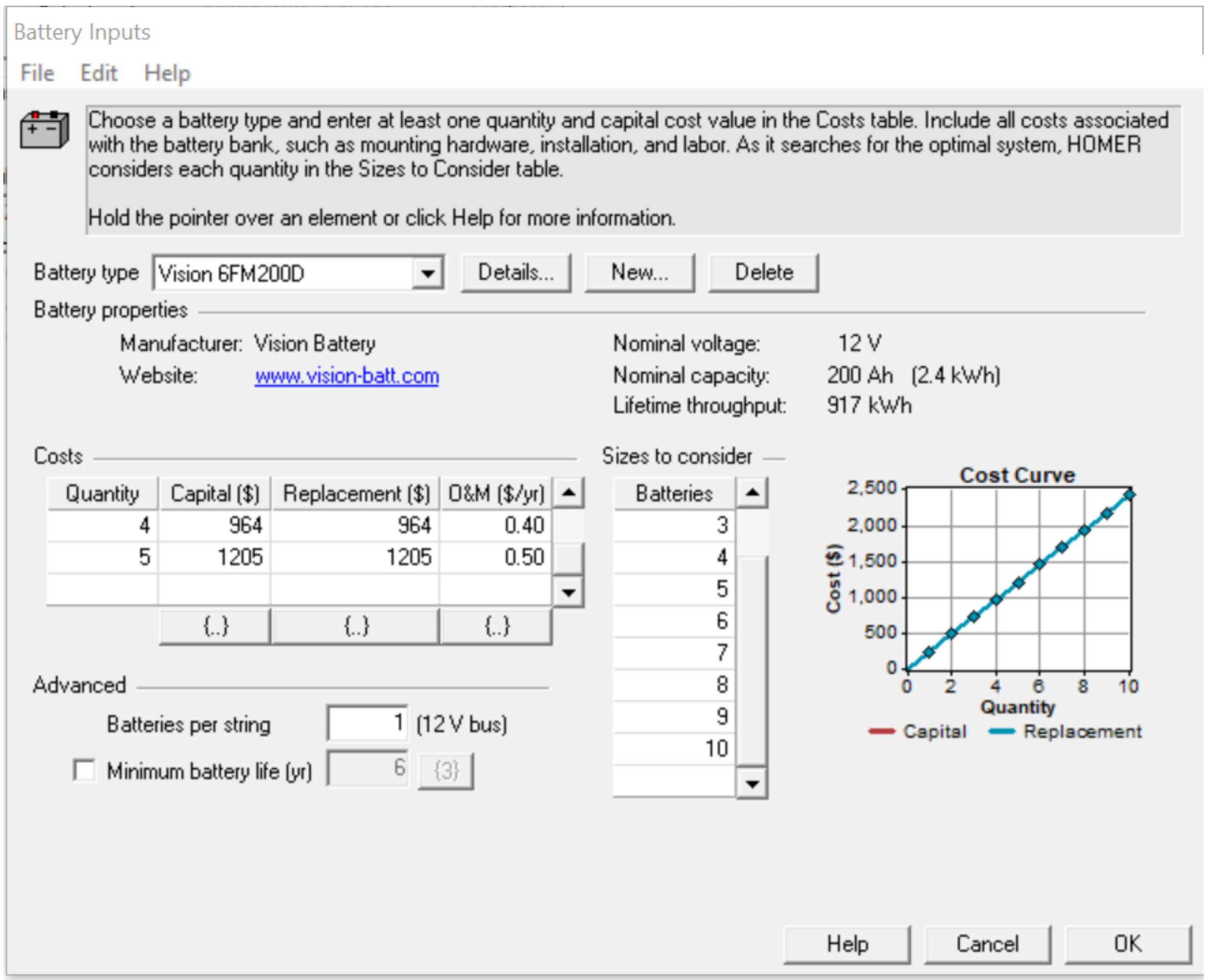
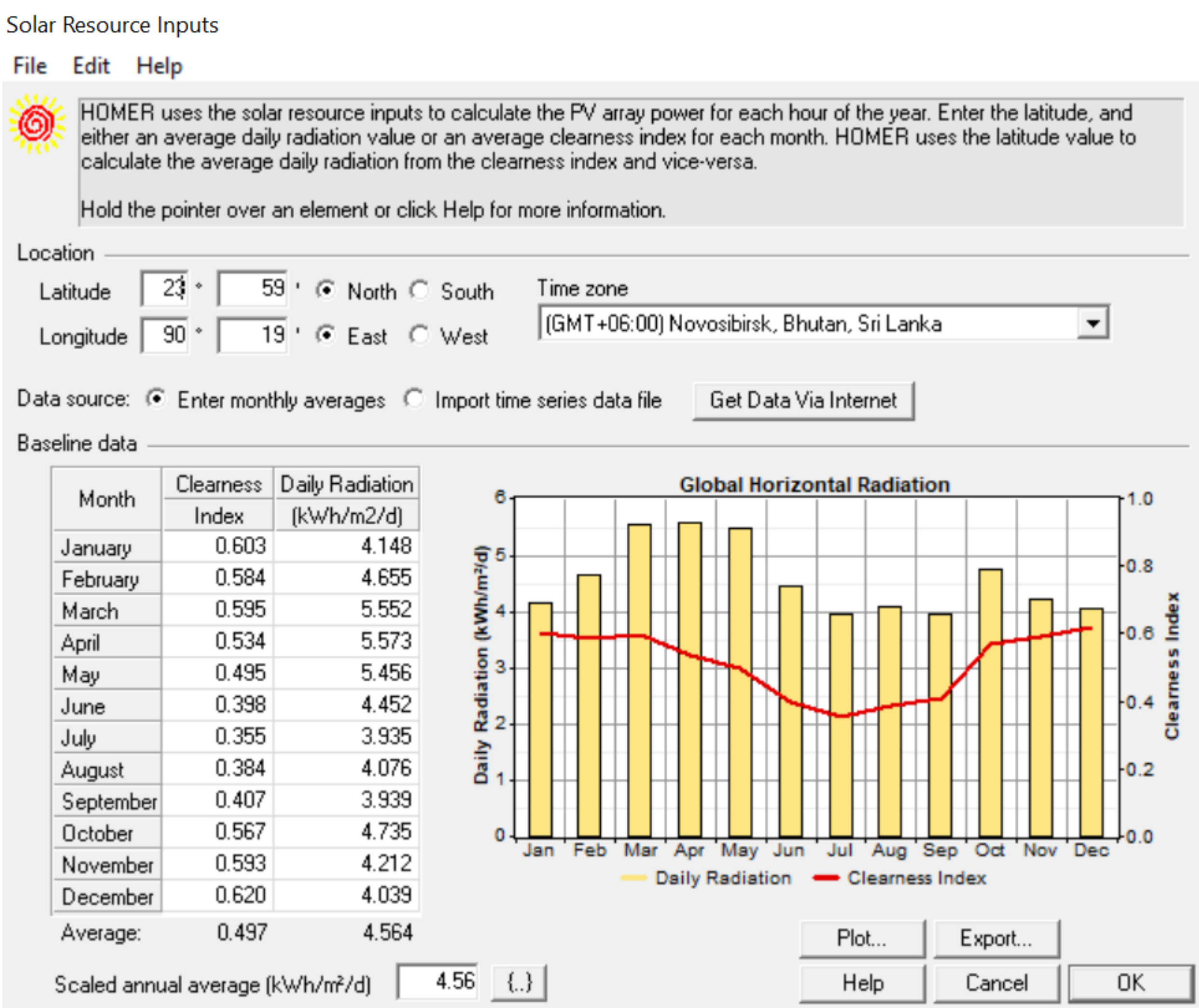


Fig. 4.7.1: Battery details

4.9 Solar resource:



Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.603	4.148
February	0.584	4.655
March	0.595	5.552
April	0.534	5.573
May	0.495	5.456
June	0.398	4.452
July	0.355	3.935
August	0.384	4.076
September	0.407	3.939
October	0.567	4.735
November	0.593	4.212
December	0.620	4.039
Average:	0.497	4.564

Fig. 4.8.1: Solar Resource

4.10 Economics:

Lifetime of the project is 25 years; annual interest is 6%. The fixed capital cost of the system is 700$ and the maintenance cost is 120$.

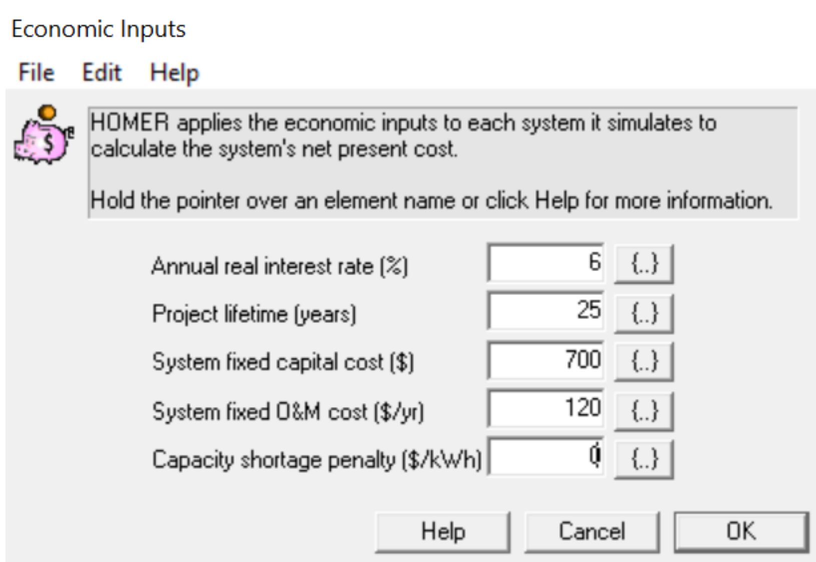


Fig. 4.9.1: Economics details

CHAPTER 5

CALCULATION

5.1 Load Definition:

Here are all the classrooms in a unit of Daffodil International University's EEE department, where 30 LED lights, 30 DC fans are considered. Since the load profile is divided into 3 parts, the operating time of the light and the fan is different. Needless to say, the operating time of the 14 lights of the year is a total of 3 hours/day from 6 pm to 9 pm. So, from November to February the operating time of 30 lights is 9 hours/day, and the operating time of 15 fans is 3 hours/day. The power of each light is 7W, and the power of DC fan is 30W. So, the amount of daily total load is 3.534KWh. It is described in Table.

Loads	Power Ratings[W]	No. of Pieces	Operating hours/day
LED light	7	30	9
LED light	7	14	3
Fan	30	15	3

Table-5.1.1: load definition-1

From March to June the operating time of thirty lights is 6 hours/day and the operating time of 30 DC fans is 9 hours/day and. So, the amount of daily load is 9.654KWh. It is described in Table.

Loads	Power Ratings[W]	No. of Pieces	Operating hours/day
LED Light	7	30	6
LED Light	7	14	3
Fan	30	30	9

Table-5.1.2: load definition-2

The operating time of 30 lights from July to October is 7 hours/day, and the operating time of 30 DC fans is 9 hours/day so the daily load is 9.864KWh. It is described in Table.

Loads	Power Ratings[W]	No. of Pieces	Operating hours/day
LED Light	7	30	7
LED Light	7	14	3
Fan	30	30	9

Table-5.1.3: load definition-3

From the equation bellow, the energy per day E_d can be determined.

$$E_d = \frac{\sum_{k=1}^{N} A_k P_k Q_k}{1000} \text{ (kWh)}$$

Where,

k=index of each type of load like fan, light etc.

$A_{k=}$numbers of hours k^{th}device type used per day

$Q_{k=}$device number of k^{th}type

$P_{k=}$power of k^{th} device type.

5.2 Daily load Profile:

Observing the seasonal profile shows that, the maximum value of daily load is 9.864KWh, which is required from July to October. At this time about 187.968 KWh load is required per month. Also 77.75 KWh load is required from November to February and 178.068 KWh load is required from March to June.

5.3 Size Consideration of PV Array:

The lifetime of a photovoltaic system is 25 years. The cost of PV system per kilowatt 250$.Complete PV system installation cost 700$, operation and maintenance cost 120$.From the bellow equation, we can find PV generation capacity.

$$PV_{capcity} = \frac{E_d}{I_d \times d} \text{ (kW)}$$

Where,

I_d=number of avg. hours sun shine.

d=de-rating factor, which defines the effect of efficiency and solar generation changes through day.

In Bangladesh, I_d and d values are 5h and 80% respectively.

5.4 Battery Size:

Batteries are usually used to supply electricity at night or in bad weather. Here 12-volt 200Ah battery is used. Whose lifetime is 6 years. The installation, replacement and operation, and maintenance costs of this battery are 241$, 241$ and 0.1 $/year respectively.

5.5 Charge controller:

The charge controller is identical to the voltage regulator. Charge controllers usually protect the battery. The voltage and current generated from the solar panel are stored in the battery through a charge controller. Charge controllers are usually 16 to 20-volts and cost 70$.

5.6 Solar Radiation:

Through HOMER software, for solar radiation, the value of solar radiation is taken from the NASA website. Our solar panel installation locations are 23^o 59' north latitude and 90^o19' east longitude.

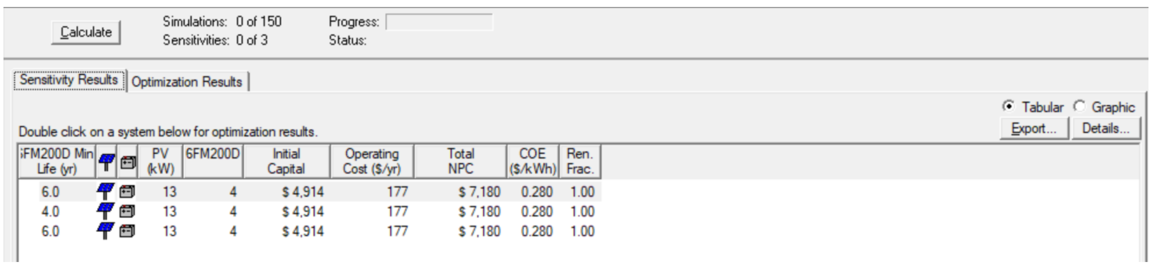
CHAPTER 6

Result and Discussion

In this solar system, the solar panels are installed on the roof. This system has no grid connection. The power supply starts shortly after the solar system is switched on, and the battery is charged as a backup so that there is no problem with the power supply at night and in bad weather. The charge controller protects the battery from being fully discharged and from overcharging.

Homer Software designed the complete solar home system, where the maximum load per day was 9.864 kWh, and the full load per hour was 1.11 kWh.

6.1 Optimized Result:



6FM200D Min Life (yr)			PV (kW)	6FM200D	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
6.0			13	4	$ 4,914	177	$ 7,180	0.280	1.00
4.0			13	4	$ 4,914	177	$ 7,180	0.280	1.00
6.0			13	4	$ 4,914	177	$ 7,180	0.280	1.00

Figure 6.1.1: optimize result from HOMER.

We've got an optimized result after the entire system has been managed by Homer Software. An analysis by Homer Software shows that the 13 kW photovoltaic panel requires four 6FM200D batteries, each 200Ah and 12 V. The results are based on the minimum LCOE and SHS operating.

$$LCOE = \frac{(AnC - Cs)}{WT}$$

The following equation is used to calculate LCOE.

Where, LCOE=0.280$/kWh (23.76 tk/kWh).

In this complete system, 13 kW solar panels are installed in the parallel form so that there is no shortage of power in the system's load. Four 6FM200D batteries are connected in series so that there is no problem in load demand, and the bag is connected at night or in bad weather.

6.2 Overall Result:

Overall, the results analysis shows that the whole system is 13 kW. This complete system uses four Vision 6FM200D batteries. The entire system costs 7180$ to install, the cost per kilowatt of electricity is about .280$, and the operating cost is $177 / year. The system capital costs 3250$ for solar panels, 964$ for batteries, 700$ for other capital costs, and total capital cost 4914$. Capital cost are shown in Table:

Component	**Capital Cost($)**
PV	3250
Vision 6FM200D	964
Other	700
System	4914

Table 6.2.1: System Capital cost

There is an annual cost to maintain the entire system, such as yearly capital cost for solar panels 254$, annual capital cost 75$ for batteries, and other annual capital costs 55$, total annual capital cost 384$. The annual capital cost is shown in Table:

Component	**Capital cost($)**
PV	254
Vision 6FM200D	75
Other	55
System	384

Table 6.2.2: System annual cost

The system generates about 16998 kilowatts of electricity per year. The maximum power generation capacity of this system is from October to April. But only 2003 kilowatts of electricity are used. The system generates 13 kW, mean output 1.94 kW, daily mean output 46.6 kW, and about 16998 kWh of electricity per year. This system has string size 1, strings in parallel 4, batteries 4, and bus voltage 12 v. The system's nominal capacity is 9.60 KWh, Usable nominal capacity 5.76KWh, Autonomy 25.2 hr. Lifetime throughput 3668KWh, Battery wear cost .294 $/KWh, and average energy cost 0.00 W/KWh.

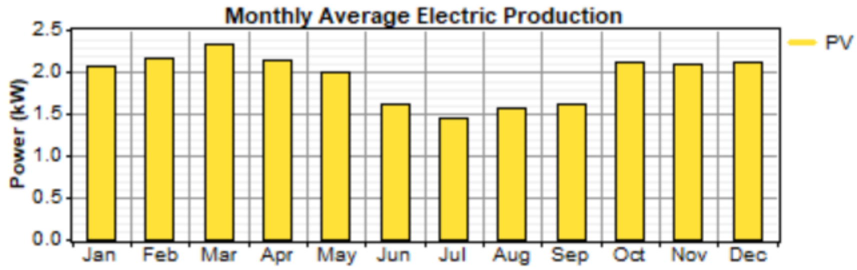


Fig. 6.2.1: Monthly Avg. electric production.

6.3 Cost Analysis:

If the system was connected to the grid, users would have to pay an average of about 464.16 units of electricity per month. Where the price of electricity per unit 0.071$. And after 25 years a total of 9925$ had to pay the electricity bill. And the total cost of installing this complete solar home system is 7180$, we can profit 2745$ from this project. It is possible to reduce the electricity bill about 109.8$ per year by installing solar home system. Calculations can be made using payback period equations.

$$Payback\ Period = \frac{C_{pv}}{E_d \times C_{unit} \times 365}\ (yr)$$

Where,

C_{pv}=total cost of rooftop solar system

C_{Cunit}=cost of per unit energy

After about 18 years, its initial cost will be recovered. This means that the payback period of the system is about 18 years. If the rooftop solar home system user gets 40% support from the

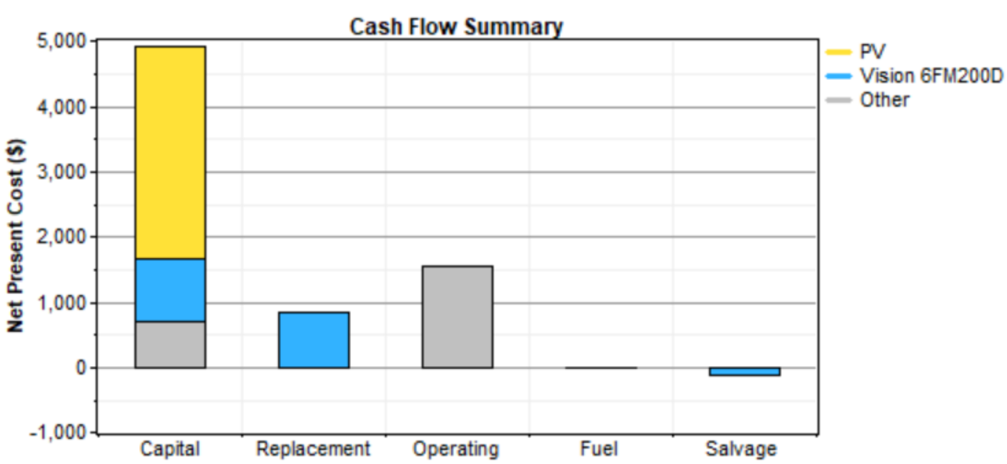


Figure 6.3.1: Cash flow summary for SHS.

government, its payback period will be much less than the current payback period. And users will be able to save their money. In an SHS, 80% of the total cost is battery-based because of its short lifespan. Below is a picture of the price. The cost summary above shows that most of the capital cost is for solar panels. The replacement cost is higher for the short life of the battery. The specific model of the battery is 6FM200D. The longer the life span of PV solar panels, the greater the benefits of solar systems. Below is the annual cash flow chart.

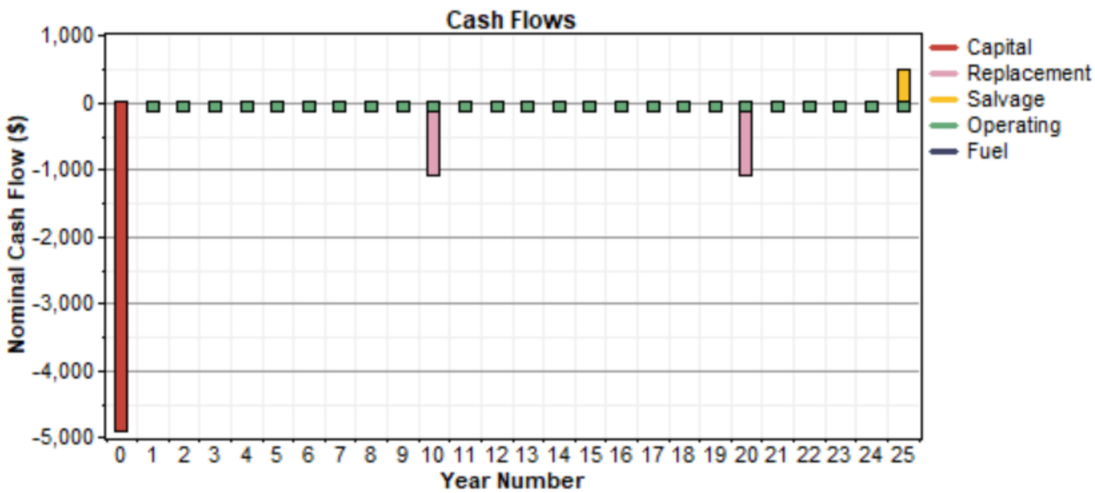


Figure 6.3.2: Annual cash flow chart.

6.4 Environmental Impacts:

Fossil fuels are the main source of power generation in Bangladesh. And these fossil fuels emit carbon dioxide into the atmosphere. Therefore, it can be said that for power generation in Bangladesh, a large amount of carbon is constantly being emitted into the environment, which is having an adverse effect on the environment.

If the efficiency of a power plant is 34%, and coal is used as fuel, 1kg of carbon dioxide is emitted into the environment for every 1 kilowatt of electricity generated. This shows that if we use 5605.92 kwh of electricity per year from the national grid, it will emit 5.605 tons of carbon dioxide per year and 140.148 tons of carbon dioxide in 25 years. Natural gas power plants generate 0.549 kg of carbon dioxide to generate 1 kilowatt of electricity [76]. This stands at 76.941 tons of carbon emitted in 25 years.

Grid Emission Factor (GEF) of Bangladesh is 0.67-ton carbon dioxide per MWh, according to the Government of Bangladesh, Ministry of Environment [77]. This amounts to 93.899 tons of carbon dioxide emissions in 25 years.

Our proposed solar system does not produce any carbon dioxide. Therefore, it is possible to reduce the amount of carbon dioxide in the environment by increasing its use. So we can say that, the proposed solar system is not only economically affordable, but also plays a very helpful role in reducing the amount of carbon dioxide in the environment. There is a table for environmental impact:

For Grid			
	Electricity Produce(KW)	**Carbone Emission(Ton)**	**Year**
Coal	140148	140.148	25
Natural Gas	140148	76.94	25
According Ministry of Environment	140148	93.899	25
For Solar PV			
	Electricity Produce(KW)	**Carbone Emission(Ton)**	**Year**
	424950	0.00	25

Table 6.4.1: Environmental impact for grid and solar PV.

CHAPTER 7

Conclusions

Most of the energy needed to meet world energy demand comes from fossil fuels. Bangladesh is no exception. Most of the national power generation in Bangladesh also comes from fossil fuel-based power plants, highly cost-effective. Even burning fossil fuels to generate electricity will increase the pressure on natural resources such as coal, gas, oil, etc. and negatively impact the environment.

On the other hand, the production of electricity from solar energy reduces the pressure on fossil fuels, lowers production costs, and has no adverse effects on the environment. And because of the easy availability of solar energy in our country, it makes electricity generation easier. Our study shows that the cost of electricity generated in this system is low. The price per unit of electricity falls to .280 $, and its maintenance cost is also low so that the desired power can be obtained continuously from this system for 25 consecutive years. This will reduce costs and reduce the demand for electricity on the national grid and reduce the amount of carbon dioxide in the atmosphere. Like other countries globally, Bangladesh is leaning towards renewable energy sources, and solar energy can play an essential role as a source of renewable energy. Through its proper use, it is possible to take the country's economy forward.

It is impossible to get 100% output from any system, so the efficiency of every component used in the system to generate electricity from solar energy needs to be increased, continuous research needs to be done on it, the initial investment cost of solar system needs to be reduced.

In conclusion, solar power can play a valuable and complementary role in meeting the power demand of Bangladesh's economic sectors, above all, to keep the country's economy afloat.

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