Impact Analysis of Rooftop Solar Photovoltaic Systems in Academic Buildings

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Impact Analysis of Rooftop Solar Photovoltaic Systems in Academic Buildings

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Abstract. Solar energy is a non-depleting and eco-friendly source of renewable energy that is generated through the use of solar panels, which convert the energy from the sun into electricity. In the current world, we need electricity supply constantly but produced electricity cannot meet the world's demand. Even in our country, the situation is much more crucial. The government attempts to handle this situation by shedding loads, which has a detrimental impact on industrial, commercial, and educational institutions. In this paper, we provided a solution to produce renewable energy through photovoltaic solar panels that are environmentally friendly. The paper also provides the working process of solar panels, how solar panels meet load demand and reduce the cost of electricity bills, and future trends and aspects of solar energy.

Keywords: Renewable energy · Solar panel · Photovoltaic system · Green campus

1 Introduction

Energy is the key to the economy. There is a correlation between the growth rate of electricity GDP and the growth rate. Today, the number of uses of technology is gradually increasing. Smart technology is now taking over the world. As there is an increasing energy demand, there is a chance of running out of energy as we are dependent on limited sources. For this reason, renewable energy has become a very important part of our time, as the cost of energy has increased rapidly in recent years. Our earth receives a large amount of sunlight (1366 W nearly). This energy source is limitless to us and this is no-charge energy.

For this, we use a solar panel system to transform sunlight into energy. The solar cell, which is the fundamental part of a solar power system, produces energy by absorbing photons that the sun emits. The primary advantage of solar energy over other conventional

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power sources is that it can be produced using the smallest photovoltaic (PV) solar cells, allowing sunlight to be directly transformed into solar energy [1].

Solar panels are considered one of renewable energy sources because excess energy from solar panel systems can be easily stored in a battery when not used. The solar cell is the most significant component of a solar power system, which gets energy from the sun's photons and turns it into electricity [2]. As one of the renewable, CO2-free energy sources, it will have the least environmental impact on any system. On a daily basis, we receive an infinite amount of energy from the Sun. Using solar panel systems, we can generate additional energy from the Sun with relative ease. Any location where direct sunlight is available can be used to generate energy. In some systems, such as the production of power from renewable resources, fossil fuels are utilized [3].

However, as we use fossil fuels every day, the supply is decreasing. Using wind or the Sun to create power is a smart concept if we want to reduce our reliance on fossil fuels because the Sun will always shine on the Earth's surface. After converting sunlight into energy, an endless amount of sunlight remains for the future. This is what makes solar energy a renewable source of energy. Furthermore, solar energy is green since, unlike other systems, it does not emit greenhouse gases. As the need for electricity increases, people are investing more money in solar panel systems to make the panels work better and save more energy. Using certain methods, it is possible to make PV systems work better. Increasing the efficiency of solar cells, using maximum power point tracking (MPPT) control algorithms, and implementing solar tracking systems are the three main ways to get the most energy from the Sun. Solar panel systems can be made more powerful by buying more concentrated photovoltaic (CPV) cells and more efficient variants of solar panels. This saves more energy than before [4].

As the price of fossil fuels fluctuates, renewable energy is quickly gaining prominence as an energy source. The most abundant source of energy is solar energy. Furthermore, in this paper, we have discussed cost-effectiveness analysis and economics, where simulations of the results are presented and examined from a financial point of view.

2 Literature Review

In this section, we focus on existing and related work on solar photovoltaic-based power generation. To enhance our understanding of the application and sustainability of solar photovoltaic energy in the pursuit of a greener environment, we have investigated a variety of supplementary materials. In the majority of previous publications, the authors have investigated and proposed several models based on various parameters.

Islam et al. [5] address the potential effect of using solar energy to resolve the current demand for power imbalances in the world. They also state that Bangladesh's geographical location is considered to be an ideal place for the utilization of solar energy. The discussion is about 3 types of solar power technology, such as concentrated solar power (CSP) technology, grid-connected solar PV systems, and solar home systems.

Ahmed et al. [6] have presented their research on rooftop solar power generation in Bangladesh and its potential. The authors argue that Bangladesh might be one of the leading rooftop solar installation proponents. The authors of the study asserted that the rooftop solar potential in urban Bangladesh is very high. They suggested implementing the solar energy plant on the roofs of industrial and commercial buildings, residential buildings, etc. They reported that 47.2%, 30.5%, and 4.85% of Bangladesh's total energy consumption was consumed by the industrial, residential, and commercial sectors, respectively. This can be reduced by implementing solar energy on the roofs of respective structures.

Podder et al. [7] have modeled a rooftop photovoltaic system (RPS) for an academic institution in Bangladesh. The authors asserted that their proposed strategy may create a moderate amount of electricity and reduce the exorbitant price of electricity. The authors built four configurations of 46, 64, 91, and 238 kW solar (PV) systems and investigated their economic, ecological, and sensitivity benefit analysis to determine that the 91 kW setup is the most optimal. Furthermore, they showed that 91 kW delivers 97% of the total PV-generated usage, while the grid delivers only 3%. In fact, the 91 kW RPS can export 26% of the surplus electricity to the grid.

Hasapis et al. [8] have installed large-scale solar electricity production systems (PV) on university campuses in an effort to achieve energy independence. They created a model that first calculates power usage with a real-time metering system and then collects solar irradiation data to evaluate solar potential. If the prospect is high, a PV system design is proposed based on the identification of suitable regions. Researchers then select the right technology for electrical design, such as photovoltaic module, inverter, mounting structure, and layout. Furthermore, they demonstrated that a 2 MWp on-grid solar power plant can supply 1899 MWh of yearly power, which meets 47% of campus consumption, saves 1234 tons of CO_2, and has a projected cash flow of 4.2 years with only an LCOE of 11 cents per kilowatt hour.

Paudel et al. [9] have examined the techno-economic and ecological impact of a 1 MW rooftop solar photovoltaic installation on a college campus using PVsyst. The authors anticipate that the plant will generate approximately 1660 MWh of sustainable AC power per year, of which 95% can be sent to the grid. The repayment period for this solar photovoltaic project was predicted to be 8.4 years.

Baitule et al. [10] demonstrated the viability of creating an academic campus powered entirely by solar photovoltaics. In the study, the study illustrates that a 5-MW solar photovoltaic system can generate 8000 MWh of power annually while reducing its carbon footprint by 173,318 tons annually.

Chakraborty et al. [11] presented their solar photovoltaic technical mapping strategy for the green campus initiative. The authors analyzed the performance of nine commercially available solar panels and concluded that "a-Si" is the best in terms of power losses, land requirement, PR, CUF, YF, and cost. Furthermore, they demonstrated that the total energy produced by solar photovoltaic technology is approximately 8 MWh/day, which supplies 40% of the campus's net energy demand/day. They also claimed that the use of solar photovoltaic energy could reduce electricity costs by approximately 27.4% of the current annual energy bill.

Barua et al. [12] investigate the feasibility report and the relationship between a rooftop solar photovoltaic system. When the project area is provided with PVsyst and the software, the model is carried out with NASA surface meteorological data through the geographic project location coordinator. The PVsyst software was used to simulate the results. The simulation results show that using a solar photovoltaic system to generate power could save 42 tonnes of CO_2. The work in [13–22] shows good contributions and guidelines.

To construct this proposed methodology, the above-mentioned research publications were surveyed. In this paper, we have done a feasibility study to implement solar photovoltaic panels on East West University's (EWU's) rooftop.

3 Methods and Materials

At East West University, there is a huge amount of electricity consumed on a daily basis. The amount becomes massive when it comes to a monthly estimation. To reduce this huge power consumption, we propose a model where we produce renewable energy by implementing solar panels. We will use the roof of the university to set up our model. It will convert electricity usage to solar energy, which will help the authorities cut the electricity bill.

In this section, we provide a detailed explanation and reasoning for our research.

3.1 Data Collection

Here is a picture (Fig. 1) of the roof of East West University and a list of how many buildings there are and where they are. Usable areas are shown in Table 1.

Due to the presence of an air conditioning compressor, the area on the eastern side of the rooftop has been rendered inaccessible and unusable. As a result, the eastern section of the rooftop is blocked off and it is not possible to use it for any purpose.

3.2 Flow Diagram

First, all data sets necessary for the research are collected and verified by the executive engineer of Bangladesh Electric Company of Bangladesh Ltd. (PGCB). Then we calculate and compare the university load demand and the power derivation from the implemented solar panel. The steps taken are given in Fig. 2.

3.3 Working Process of Solar Panel

A solar panel is made up of photovoltaic cells that are responsible for collecting sunlight. Solar energy is converted to direct current when photovoltaic cells are exposed to daylight. Through the use of inverter technology, DC energy stored in PV cells can be transformed into AC electricity. The net metering process is how energy is transferred and used as the source of electricity for your home electronics. Once you have solar panels and an inverter set up, this is how solar energy will benefit you.

3.4 Peak Hour for Sun

The time between sunrise and sunset is not when the sun is at its strongest. They directly refer to the amount of solar insolation that a specific location would experience during a specific period of time when the sun is at its most intense. In Fig. 3, an hour is considered

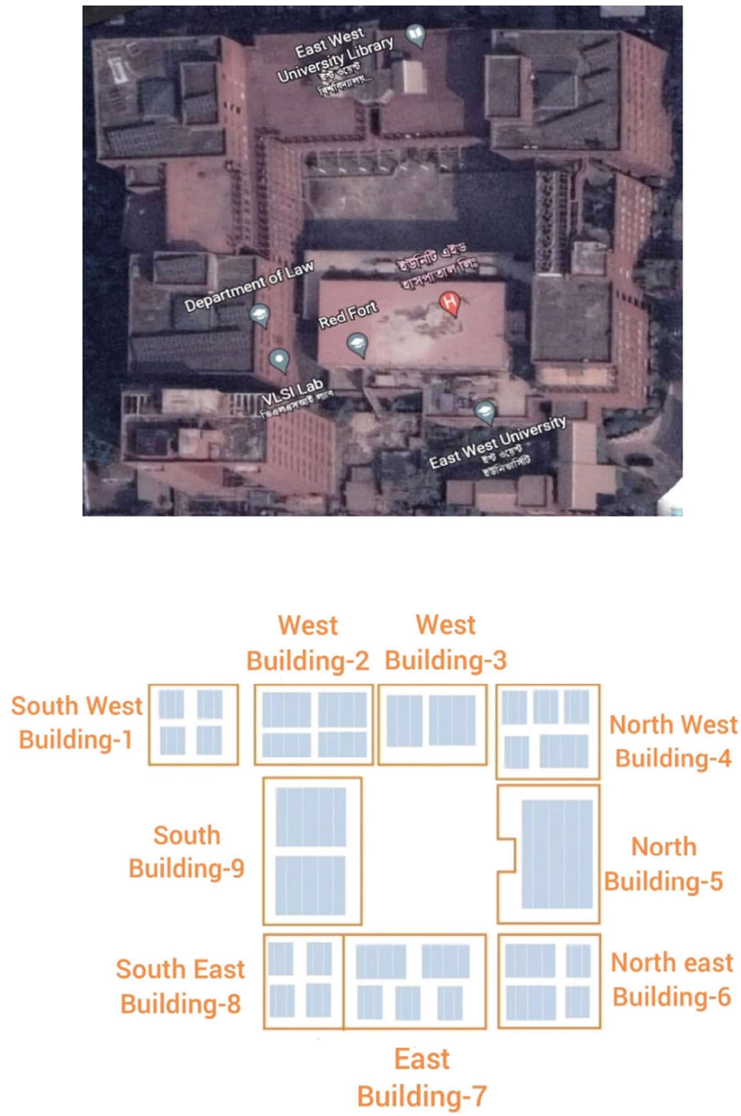

Fig. 1. EWU rooftop design.

a peak sun hour when the amount of solar irradiance (or sunlight) averages 1000 (W) of energy per square meter (roughly 10.5 feet) [23]. Early mornings and late afternoons are approximately to have less than 500 W/m^2 of sunlight. In contrast, under optimum conditions midday on a bright, sunny day it is possible to receive more than 1000–1100 W/m^2. Despite the fact that solar panels receive an average of 7 h of daylight each day, the average peak solar hours are often between 5 and 6 which varies from region to region. At solar noon, when the sun is at its highest in the sky, solar radiation peaks.

Table 1. Measuring the usable area.

Rooftop index	Position	Area (m^2)	Usable percent (%)	Usable area (m^2)
1	South-West	377	70	264
2	West	520	80	416
3	West	351	70	246
4	North-West	550	70	385
5	North	882	30	265
6	North-East	570	90	513
7	East	288	0	0
8	South-East	240	90	216
9	South	580	30	174
Total usable area				2479

In our work field, East West University is situated in Dhaka, which is located in the Bangladesh region. Therefore, the peak hour of the Sun in this region is given below in Fig. 4:

The average peak hours of sunlight in the annual year are 7 h. The solar path of the university area is presented in Fig. 5 which is imported from the Global Solar Atlas website. The average produced energy can be calculated using Eq. (1). The peak hours of sunlight on a daily basis are presented in Table 2.

$$\text{Average Produced Energy} = \frac{Max\ Peak\ Hours\ \% * Max\ Peak\ Hours\ of\ Sunlight * Produced\ Solar\ Energy}{Average\ Peak\ Hours\ of\ Sunlight} \quad (1)$$

3.5 Cost of Solar Setup

The installation of solar panels in Bangladesh is a great step toward mitigating catastrophic issues such as climate change. Given the current power situation in Bangladesh, it is also preferable to produce one's own electricity at home. What is great about solar panels is that they don't cost much money to install and do not need to be maintained. On-demand rooftop or exterior solar panels are placed, with standard batteries installed for use when the sun goes down. A charge controller is included to ensure that the battery is not overloaded and therefore cannot damage itself. As soon as the battery is fully charged, the controller will stop sending power from the PV array to the storage device. We are using a photovoltaic solar panel in our model.

To produce 1-W energy from the solar panel will cost 75 BDT. So, producing 244 kW energy from the solar panel will cost 18300000 BDT (Table 3).

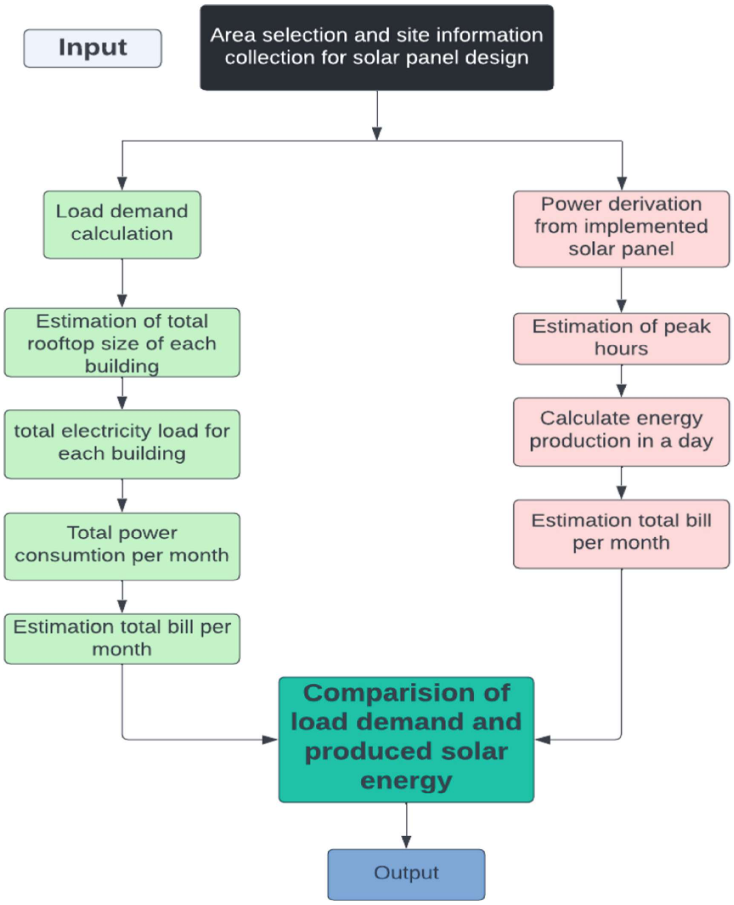

Fig. 2. Work process flow diagram.

4 Results and Discussion

In this section, we will compare and discuss the result of our proposed model and the university's cost of load demand. We also show how beneficial our model is. Additionally, we will analyze the marginal profit of our model. In the initial period, we will experience a negative figure because of our model, but in long term, it will offer a huge amount of profit throughout our model.

The total usable roof size of each building is 2479 m^2 (0.61 acres). Land availability is one of the greatest obstacles to the establishment of renewable energy projects on a utility-scale in Bangladesh. Wind or solar farms require a substantial amount of land (based on the solar irradiation of Bangladesh, approximately 2.5–4.0 acres of land are needed for 1 MW of solar energy) [24].

1 MW of energy was produced using 2.5 acres of land. Using 0.61 acres of land, the amount of energy that will be produced is 0.244 MW $<$ 244kWh.

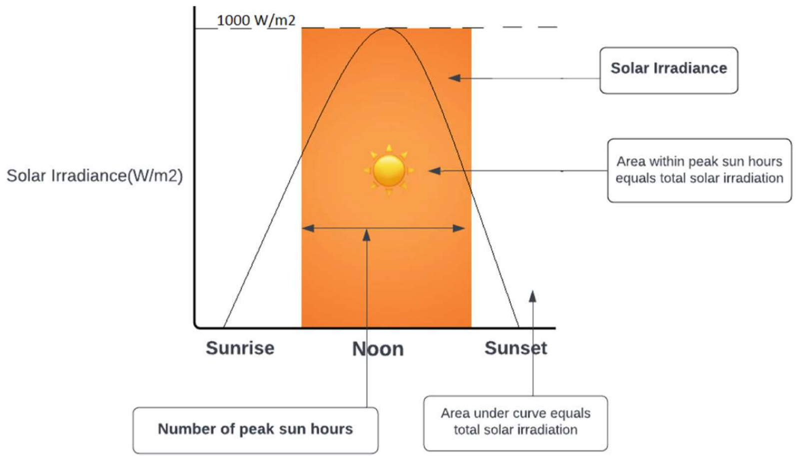

Fig. 3. Total solar irradiation over the day.

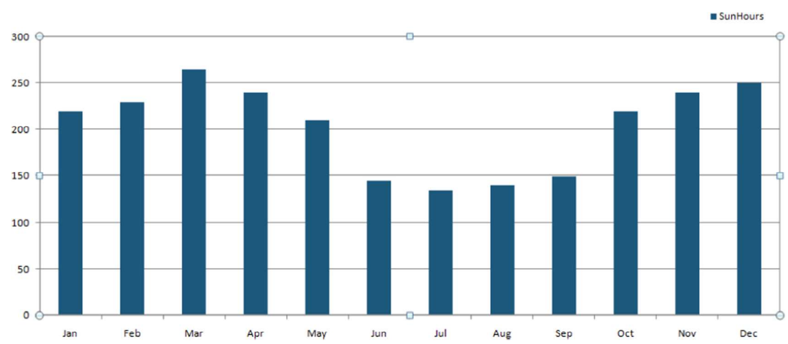

Fig. 4. Peak hours of sunlight throughout the year.

In our region, the maximum peak hour of sunlight is 5 h and the average peak hour of sunlight is 7 h (Table 2). The maximum peak hour provides sunlight of about 80%. Our proposed solar panel will produce 244 kW per hour. From Eq. (1), we get an average produced energy of 139.43–140 kWh. Therefore, our proposed solar panel will produce 140 kWh.

Here, in this (Table 4), we show the load demand calculation of our institution.

As our model works only in daylight, we will not store any amount of energy in the battery because cutting off the cost of the battery. Therefore, we will compare our solar energy with the off-peak energy consumption.

In off-peak hours, the energy consumption is 266.67 units 267units.

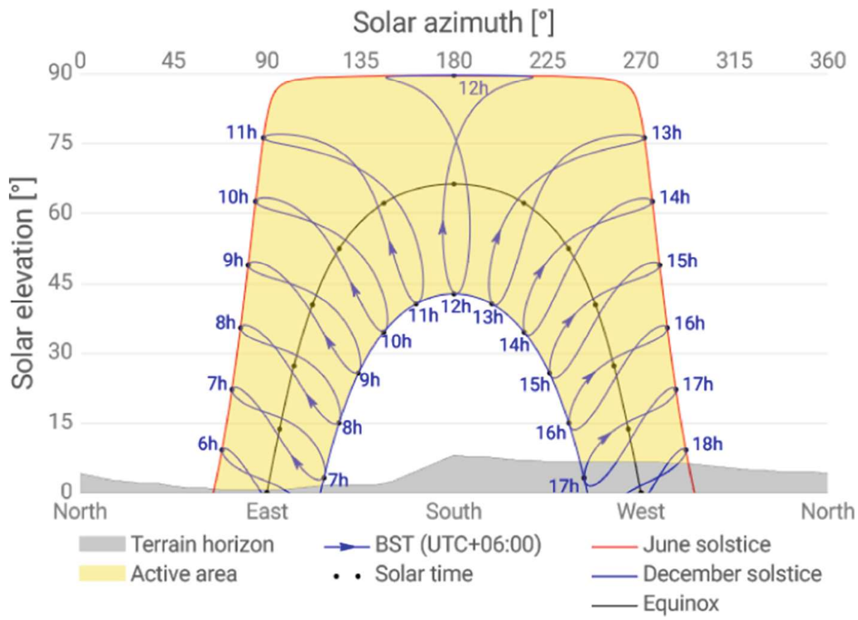

Fig. 5. Solar path of the university area.

Table 2. Average peak hour in a day.

Month	Peak hours of sunlight (daily)
January	7.1
February	8.2
March	8.5
April	8
May	6.8
June	7
July	4.7
August	4.5
September	5
October	7.1
November	8
December	8.1

Here, in (Table 5), we show the cost of the load demand of our institution.

From Tables 2 and 4, we see that the monthly energy charge (off-peak) is 192,000 units. The monthly unit cost is 1,461,120 BDT. The cost per unit is 7.61 BDT.

Table 3. Approximate setup cost.

Component name	Total cost (BDT)
Solar panels	7,564,000
Inverter	5,073,000
Mounting system	4,002,320
Installation	1,660,680
Total cost	18,300,000

Table 4. Load demand of EWU.

Load demand	Variation	Monthly (unit)	Daily (unit)	Per hour (unit)
	Total	264000	8800	366.67
	Off-peak	192000	6400	266.67
	Peak	72000	2400	100

Table 5. Electricity cost of the EWU.

Cost	Variation	Monthly (BDT)	Per unit (BDT)
	Total	2,221,440	8.41
	Off-peak	1,461,120	7.61
	Peak	760,320	10.56

The university consumes 267 units and our model is producing 140 units, which is 52.43% of the consumed energy. So, 766,065 BDT will be saved from the university electricity bill per month. To adjust this set-up cost, we need approximately 2 years. The lifetime of the PV panel used is 25 years. Therefore, our proposed model will save 17,619,495 BDT in its lifetime (Fig. 6).

The overall rooftop area is 4 358 m^2, and we are allowed to utilize 2479 m^2, or 56.89% of the total area, due to other circumstances. If we could utilize the entire roof, we could generate more energy, which could be used to replace the demand for power during the day. It could be more sustainable and efficient for the university.

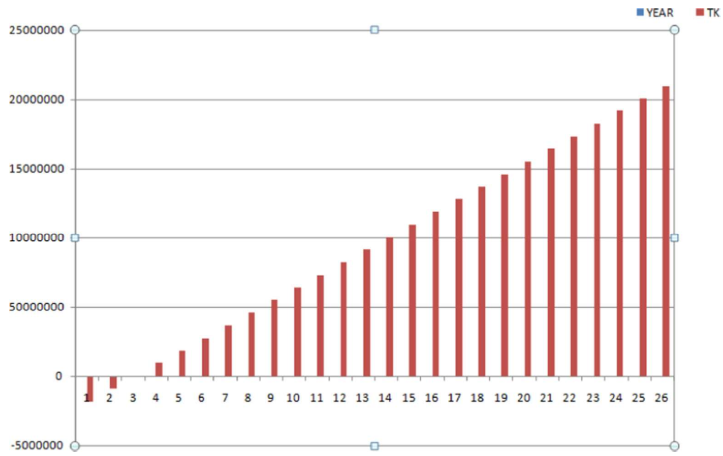

Fig. 6. Cash flow over 25 years.

5 Conclusion

The article illustrates a feasibility study of the implementation in an academic building in Dhaka, Bangladesh, to become self-sufficient, reduce the huge cost of electricity, and create a greener environment. Bangladesh is facing a fuel scarcity for electricity generation and due to the world's limited fuel supply, the entire planet may soon suffer the same problem. It is high time that the world should focus on producing renewable energy to overcome the issue. As a result, we chose solar photovoltaic cells to generate solar energy as a secondary source of energy. The advantage of our proposed system is (1) less dependence on grid supplies, (2) less carbon emission, and (3) building a green energy infrastructure.

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