FEASIBILITY AND COST ANALYSIS FOR PHOTOVOLTAIC-BIOMASS HYBRID ENERGY SYSTEMS AT UNIVERSITY CAMPUSES IN BANGLADESH

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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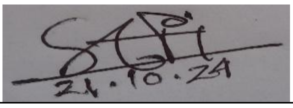
DECLARATION

I hereby declare that this project "**Feasibility and Cost Analysis for Photovoltaic-Biomass Hybrid Energy Systems at University Campuses in Bangladesh**" represents my own work which has been done 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, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

Signature of the candidates



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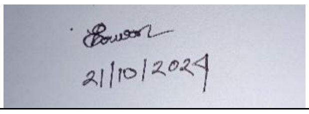

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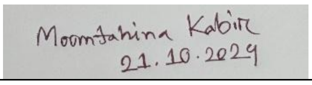

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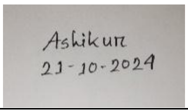

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APPROVAL

The project entitled **"Feasibility and Cost Analysis for Photovoltaic-Biomass Hybrid Energy Systems at University Campuses in Bangladesh"** submitted by **Md. Safi (203-33-1311), Shawon Chowdhury (203-33-1318), Moomtahina Kabir (203-33-1350) & Mohd. Ashikur Hasan Himel (203-33-1312)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **December, 2024.**

Signed

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Dedicated

To

Our Parents

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LIST OF ABBREVIATIONS

BAETE	Board of Accreditation for Engineering and Technical Education
PV	Photovoltaic
HRES	Hybrid Renewable Energy System
SDGs	Sustainable Development Goals
SREDA	Sustainable and Renewable Energy Development Authority
COE	Cost of Energy
NPC	Net Present Cost
LOCE	Levelized Cost of Energy
SASEC	South Asia Subregional Economic Cooperation
NASA	National Aeronautics and Space Administration
O&M	Operation and Maintenance
DAV	Data Access Viewer
IL&RRC	Landfill and Resource Recovery Center
GDP	Gross Domestic Product
VOCs	Volatile Organic Compounds
BERC	Bangladesh Energy Regulatory Commission Executive Committee
MPEMR	Ministry of Power, Energy and Mineral Resources
RE	Renewable Energy

LIST OF SYMBOLS

Symbol	*Name of the symbol*

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First of all, we want to give thanks to **Almighty Allah**. With his blessing we are able to complete our work with best effort.

We want to pay our utmost respect to our Supervisor **Nusrat Chowdhury, Assistant Professor** of the **Department of EEE, Daffodil International University** for who has given us the chance to work on an impactful idea and taken care of every issue of development of this concept. Then we would like to take this opportunity to express gratitude to our supervisor for being dedicated in supporting, motivating and guiding us throughout this project. This project can't be done without her useful advice and help. Also thank her very much for giving us the opportunity to work with this project.

We also want to convey our thankfulness to **Prof. Dr. Md. Shahid Ullah, Head** of the **Department of EEE, Daffodil International University** for his support and encouragement. Apart from that, we would like to thank our entire class fellows for sharing knowledge; information and helping us in making this project a success. To beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this Institution.

ABSTRACT

This research works presents a comprehensive study on the design and implementation of a hybrid energy system integrating solar photovoltaic (PV) and biomass technologies for sustainable energy generation at a university campus in Bangladesh. The project aims to solve the country's energy crisis and encourage the adoption of renewable energy by harnessing the untapped potential of biomass and solar energy. The research methodology includes a multidisciplinary approach, with load distribution analysis, waste measurement analysis and field visits to The Skate Ltd., a major landfill site in Jhumjhumpur, Jashore. Practical insights from this implementation enable the design and optimization of hybrid energy systems to ensure consistency by adopting appropriate methods for biomass processing in key components of the study, e.g. For economic and technical considerations including aerobic digestion and solar radiation data to be evaluated to optimize solar PV systems, including capital and operating costs, system quality and environmental assessments, the uniqueness of the project highlights biomass energy, an underutilized resource in Bangladesh. By implementing a hybrid energy system on the university campus, the project not only aims to meet the energy needs of the department but also provides valuable learning opportunities for students in renewable energy technology.

Keywords: Biomass, PV-Biomass Hybrid, HOMER Pro, Renewable Energy, Daffodil University.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The modern world is developing with diversity, invention, and transformation along with massive energy demand. Basically, energy demand indicates in regard to electrical energy, which is currently one of the undeniable portions of our daily existence. Moreover, it is truly difficult for the current world to run any single work or action without electrical energy Currently, non-renewable energy resources such as coal, natural gas, oil, and nuclear energy are used for generating electricity or electrical energy. So The world's future is in threat because of the growing need for electrical energy, which is fueled by those non-renewable resources and produces harmful emissions during manufacturing.

Utilizing environmentally friendly renewable power sources like solar PV systems, biomass, wind, and so on for the generation of electrical energy is one of the most promising perspectives in the present-day world. Contrasted with conventional fossil fuels, sustainable power sources have various advantages, like lower greenhouse gas emissions, decreased dependence on imported fuels, and more prominent energy security. However, there are several drawbacks to renewable energy sources, namely their high initial prices and inconstancy. Therefore, it is important to design and optimize hybrid energy systems that can combine different renewable energy sources and balance their strengths and weaknesses.

In Bangladesh, there has population of 170 million people and Current per capita electricity consumption in Bangladesh stands at approximately 348 kWh, which is well below the global average of 3,065 kWh [1]. Besides, per capita CO_2 emissions is about 0.51t and the rate of CO_2 emission in Bangladesh is about 6.7%which is much higher than the total energy consumption [2]. Bangladesh has several challenges in meeting its growing demand for electricity, including no age restriction, transmission and dispersion mishaps, and recurrent blackouts. It is also extremely vulnerable to the effects of ecological change, including floods, dry periods, rising ocean levels, and cyclones. Bangladesh therefore needs to implement sustainable power arrangements that will improve its ability in adjusting to environmental change, reduce its carbon footprint, and enhance its energy security.

In Bangladesh, there has almost 165 universities both public and private and among those many of the universities have a large campus area. Moreover, a large number of universities located far from the main national grid which might result in extremely high installation, transmission, distribution, and maintenance expenses. As a result it faces difficulties in providing reliable and dependable electricity to the campus. As mentioned before, those universities have a large campus area which produce a lot of waste. This garbage can be used as a biomass source for a hybrid renewable energy system. So When such situations arise, the proper utilization of renewable energy sources may offer a practical and cost-effective alternative for the development of electrical networks. By utilizing clean, renewable energy sources, they can mitigate the campus's environmental effect and greenhouse gas emissions.

The suggested hybrid energy system combines biomass with photovoltaics (PV), one of Bangladesh's wealthiest and promising renewable energy sources. PV is able to harness Bangladesh's abundant and consistent solar energy, As the average monthly solar radiation intensity remains 136.05 to 287.36W/m2 in the country [3]. For 10 h a day, average solar radiation intensity ranges from1500W/m2/day to 2750W/m2/day in Bangladesh especially in Chittagong, and Cox's Bazar regions throughout the year. In an area of 100 m2, 45MW to 83MWpower per month may be generated in the abovementioned regions. it is estimated that the total annual generation and recoverable amount of biomass in Bangladesh is about 182.22 and 108.208 million tons/year respectively [4]. The common biomass resources available in Bangladesh are agricultural crop residues, wood residues, animal waste and municipal solid waste, etc. This resources can be utilized on a larger scale for electricity generation, which are inexpensive and abundantly available in Bangladesh. A university campus, which is a typical off-grid load in Bangladesh, may receive power from the proposed hybrid energy system with a peak demand of around 25 kW and an average daily demand of about 150 kWh. The proposed hybrid system can supply electricity to meet these energy needs efficiently.

Taking into consideration the previously mentioned financial and environmental concerns, the goal of this research is to conduct a feasibility assessment of the potential and expected effect of a hybrid PV-biomass system as a potential alternative for electricity provision on university campuses in Bangladesh. The study is essentially performed employing the simulation tool referred to as Homer Pro Software. The main objective of the study is to offer a preliminary design of a hybrid PV-biomass system that may fulfill the energy requirements of the selected institution and compare its economic performance with alternative systems using cash flow and other data from software. This research looks at both the integration and adaptability of a hybrid PV-biomass system as well as its viability from a technological, economical, and environmental perspective.

1.2 Problem Statement:

Bangladesh faces major challenges in satisfying its growing power requirements, as well as limitations in its generation capacity and distribution infrastructure. The nation has seen tremendous industrial development and growth in the economy, but it still has ongoing power outages, which seriously hamper social and economic progress and lower the standard of living for its people. During peak hours, the gap between the supply and demand of power gets worse, resulting in frequent blackouts, unstable voltage, and reliability problems.

Bangladesh now uses a lot of traditional fossil fuels, especially oil and natural gas, to generate electricity. This makes the country more susceptible to changes in the price of energy worldwide and contributes to environmental degradation. The country becomes more dependent on limited resources and increasingly at risk for distractions in the energy supply due to low investment in renewable energy sources and system upgrades.

Additionally, substandard transmission and distribution infrastructure adds substantially to transmission losses and inefficiencies, which makes it more challenging to consistently supply power to consumers in both urban and rural areas. Furthermore, the higher rate of energy loss and insufficient funds adds further stress to the already vulnerable power industry and results in losses for utility distributors.

To overcome Bangladesh's demand for energy and generation dilemma, significant changes and strategic initiatives are desperately needed to consider these challenges. To achieve this, it will be necessary to update energy-saving regulations, update the transmission and distribution network, and increase funding for renewable energy sources like biomass, solar, and wind. In order to establish an atmosphere that encourages the development of sustainable energy and ensure every aspect of society have equal access to dependable energy services, collaboration between the public and private sectors, institutional capacity developing, and modifications to laws are also required. By implementing an integrated strategy involving technological innovation, regulatory frameworks, and involvement of stakeholders, Bangladesh has the ability to resolve its electrical crisis and build a flexible, equitable, and sustainable energy future.

1.3 Aims & Objectives:

The implementation of a hybrid energy system utilizing photovoltaic (PV) and biomass at a university campus is studied in this thesis, along with its financial implications. As the demand for sustainable energy solutions expands, universities are essential in leading this transformation. Through analyzing the feasibility and economics of implementing such a system on a campus, this research aims to provide insightful information that may be applied to other comparable institutions throughout the world.

Objectives:

- To review the literature on photovoltaic (PV) and biomass energy systems, particularly emphasis on operational aspects, technological components, and case studies of previous hybrid systems.
- To collect and evaluate data in order to assess the energy consumption patterns and supply demands in target university campus.
- To evaluate the potential for renewable energy in the area around the university campus, considering factors like solar radiation and biomass availability.
- To design a Photovoltaic-Biomass hybrid energy system tailored to meet the specific energy needs of the university campus, considering factors such as system sizing, configuration, and integration.
- To perform a feasibility analysis of the proposed hybrid energy system, taking into account technical feasibility, environmental impact, and potential regulatory constraints.
- To conduct a comprehensive cost analysis, including initial investment costs, operational expenses, maintenance costs, and potential revenue streams (e.g., energy savings, carbon credits) associated with the implementation of the hybrid energy system.
- To compare the economic performance of the Photovoltaic-Biomass hybrid energy system with conventional energy systems (e.g., grid-connected, fossil-fuel-based) in terms of long-term financial viability and return on investment.
- To identify potential barriers and challenges to the adoption of renewable energy technologies within the university campus context and propose strategies for mitigating these challenges.

Aims:

- The primary aim of this thesis is to evaluate the feasibility and cost-effectiveness of implementing a hybrid energy system that combines photovoltaics (PV) and biomass within a university campus setting.

- With regard to economic effectiveness and the impact on the environment, our specific goal is to figure out if this integrated system can consistently supply the energy that needs the university.
- In order to promote sustainable energy practices and reduce carbon footprint, we aim to offer recommendations and insights to stakeholders, policymakers, and university administrators about the viability and practical aspects of implementing a photovoltaic-biomass hybrid energy system on university campuses.

1.4 Brief Methodology

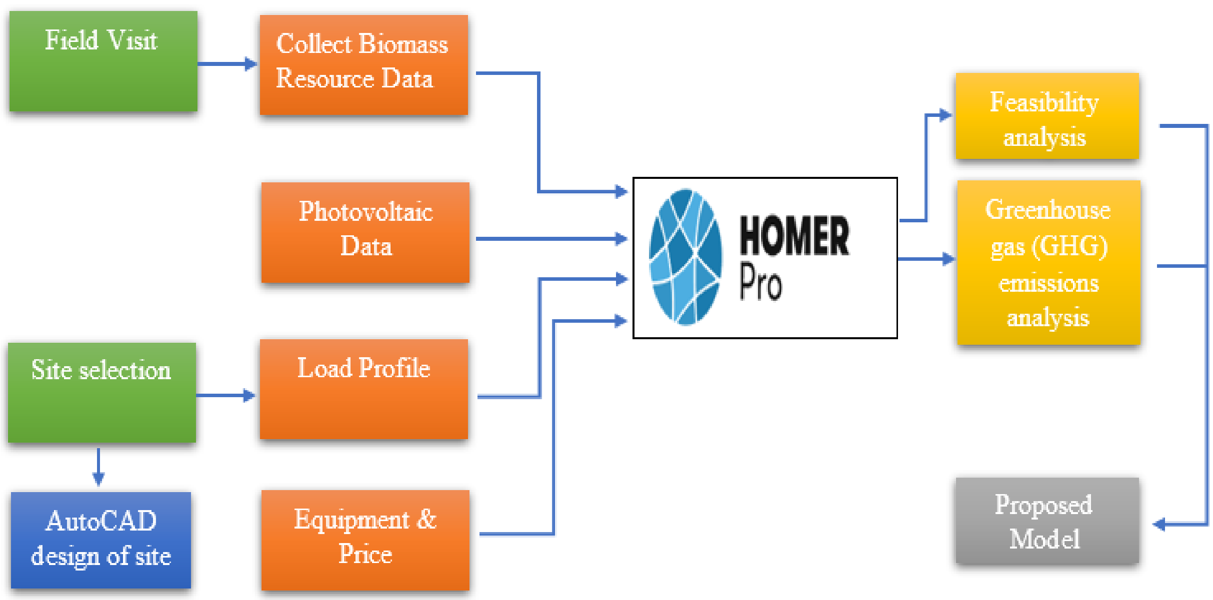


Fig. 1.1. Methodology of our study

The Fig. 1.1 illustrates a comprehensive procedure for evaluating the possibility and financial analysis of introducing a Photovoltaic-Biomass Hybrid Energy System in a university campus in Bangladesh. The process begins with a thorough on-site inspection to collect vital information about biomass resources, including their accessibility and quality. The data-collecting phase is crucial for knowing the available potential renewable energy sources for the planned system. At the same time, complete information on photovoltaic (solar) energy is gathered, including factors such as solar irradiance levels and panel efficiency. These early steps establish the foundation for making well-informed decisions during the review process. After that, a thorough and detailed site selection procedure occurs, taking into account aspects such as the geographical location and the availability of land. A design of the chosen site using AutoCAD is created to strategically arrange and configure the components of the hybrid energy system, guaranteeing efficient use of space and resources. At the same time, the site's energy consumption patterns are analyzed to create a thorough load profile, which is crucial for precisely determining the appropriate size of the energy system. Once the necessary equipment for the hybrid system has been evaluated and the corresponding expenses have been estimated, the data is entered into the HOMER Pro software. HOMER Pro performs complete feasibility and greenhouse gas emissions assessments, assessing the technical and economic feasibility while taking into account issues such as resource availability and system reliability. The analysis provides a recommended model for the Photovoltaic-Biomass Hybrid Energy System, which includes recommendations for system configuration and implementation techniques with the goal of optimizing energy efficiency and reducing the environmental effect. This complete strategy guarantees that the suggested system is both technically possible and economically viable, while also being environmentally friendly. It is in line with the broader objectives of promoting renewable energy adoption and sustainability in Bangladesh.

1.5 Implementation Schedule

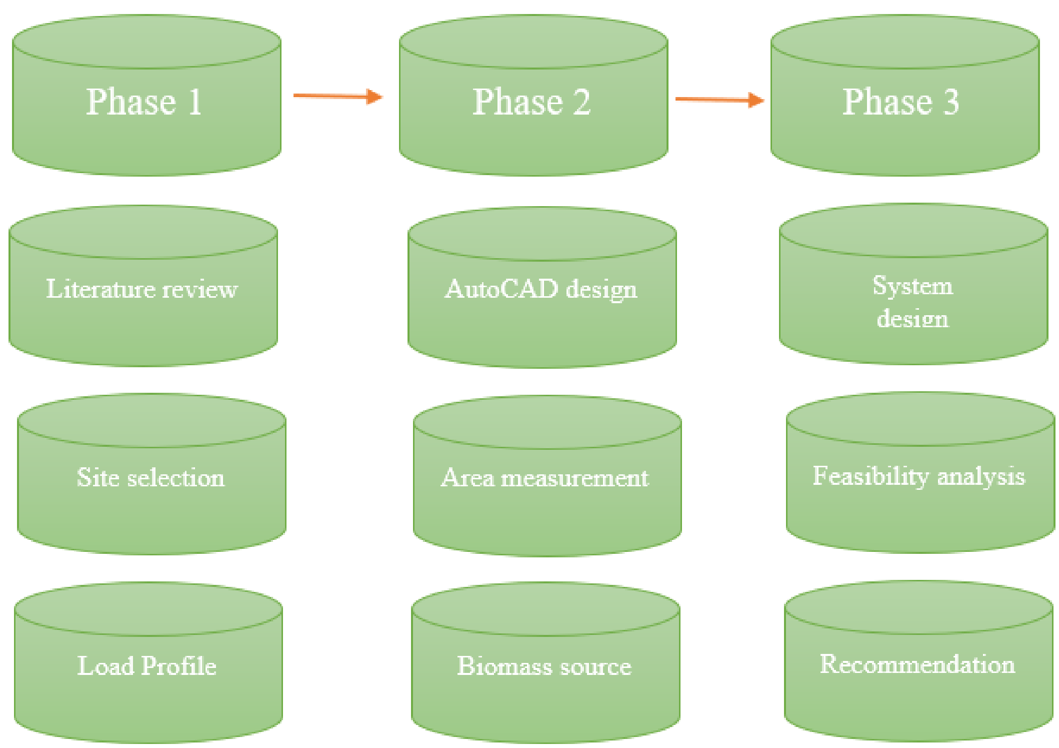


Fig. 1.2. Implementation Schedule step Block Diagram of this study

The Fig. 1.2 shows a systematic and sequential method for the execution of our study, centered around the advancement of renewable energy. The process is divided into three primary stages: Phase 1, Phase 2, and Phase 3. During Phase 1, the project begins by doing a literature review to collect current knowledge and precedents that are relevant to the project. Subsequently, important tasks such as selecting a site, analyzing the load profile, and identifying biomass sources are undertaken, all of which establish the foundation for future stages. Phase 2 includes detailed planning and design tasks, such as utilizing AutoCAD software to create layout plans and conducting area measurements to evaluate space needs. These tasks are crucial in transforming abstract concepts into practical designs. In Phase 3, the main objective is to complete the system design using the findings from the previous stages and do a thorough feasibility analysis. The conclusion of these endeavors results in the development of suggestions for the execution of the project, providing guidance to decision-makers on the most feasible course of action. In summary, the diagram illustrates a methodical and organized process that moves from the basic idea to practical suggestions, enabling efficient project management and achieving positive results.

Chapter 2

Literature Review

2.1 Introduction

The growing population is causing an increase in the daily demand for energy. One of the main factors that influence a country's economic growth and development is its energy supply, particularly it is electrical energy. Because of this, there is a growing concern about energy security. SDG7 (Sustainable Development Goals) has three main objectives: first, universal access to affordable and reliable modern energy services for all individuals, second, to increase renewable energy contribution to the global energy sector significantly and third, to accelerate progress on the global energy sector [5]. Most of the world's energy demand is met by fossil fuels. Despite the widespread use of fossil fuels, it's non-renewable natureis a major challenge. As global energy consumption increases, limited supplies of fossil fuels have become a threat. As a result, relying solely on fossil fuels is considered insufficient to meet the world's expanding energy needs in a sustainable manner. Because of this, energy insecurity is a concerning problem in the modern world. The awareness that energy instability hinders human development and overall well-being in low- and middle-income nations has grown. Even while fossil fuels provide 46% of the world's energy needs, depending only on them to produce power can have a number of negative effects [6]. In addition, using fossil fuels to produce electricity releases a lot of greenhouse gases into the atmosphere, which damages the ozone layer and contributes to acid rain and global warming. In this situation, utilizing renewable energy can be an excellent replacement for meeting global energy demand in an affordable and sustainable manner. In the world's energy consumption, the contribution of renewable energy sources is currently over 20% and will continue to increase [7]. It is a limitless and environmentally beneficial energy source that emits almost no greenhouse gas. The utilization of renewable energy sources also reduces the need for imported electricity and the fossil fuels that are required to produce electricity. In Bangladesh, the challenge of meeting the increasing electricity demand is growing due to population growth. As it is a lower-middle-income country, it is experiencing a scarcity of energy as a result of insufficient non-renewable resources and increasing consumer demand. To increase energy security, mitigate environmental impact, and improve electricity generation, the nation is utilizing renewable energy sources such as biomass, solar, hydro, wind, and tidal power. According to a report of Sustainable and Renewable Energy Development Authority (SREDA), the share of Renewable energy of the country in the total final energy consumption was 4.11% in 2023. Due to the country's geographical location, solar, biomass and biogas are the most useful among all renewable sources. The installation of large solar power plants can be difficult in Bangladesh due to the country's unavailability of land. Installing solar panels on the rooftops of residential buildings and commercial buildings is a great way to take advantage of solar energy, though. This strategy can assist in overcoming land constraints and maximizing the amount of space that is available. Another excellent renewable energy source is 'Biomass and Biogas'. Biomass is an excellent source of solar energy as it is produced from the sun. Therefore, it is necessary to manage waste properly, especially in the current environmental situation. Bioenergy is a form of green energy that emits less CO_2. Hence, with proper waste management, we can convert waste into green energy and produce electricity from it. Renewable energy sources cannot be utilized independently due to their unpredictable and unstable nature. As a result, they work best when combined as hybrid, such as solar-wind, wind-battery, or solar-biomass.

Any system that generates electricity from two or more of these types of sources is called a hybrid power system. In order to meet the energy demand, hybrid power systems are advantageous. In particular, they find widespread usage in off-grid applications

in remote areas. Considering that the aim of our study is to analyze economic viability of a Rooftop Photovoltaic-Biomass Hybrid Energy System for a university campus in Bangladesh.

2.2 Related Research

A possible way to reduce greenhouse gas emissions and conserve resources for future generations is to develop a HRES [8-12]. Many studies on renewable energy systems that use hybrid technology were found in the literature analysis. Although many studies examined hybrid renewable energy (HRES), the best systems in our region do not include these elements due to erratic wind speeds, and lack of other resources. Therefore our literature review focuses only on solar and biomass hybrid power systems.

Some of the previous studies that worked on the hybrid PV-Biomass system are summarized below.

2.2.1 Feasibility study of a biomass-solar hybrid power system

Eecan, Bahtiyar, Sertac examined an on-grid PV-biomass hybrid systems for university in Istiklal [13]. The system combines a 1,500 kW biomass generator, a 5,000 kW PV array, an inverter, and a 3,000 kW grid connection. Using animal waste from university farms as biomass feedstock, the system processes 2.45 tonnes of biomass per day using solar global radiation of 5.85 kWh/m2 in making the initial investment in the system 941.123 USD, with 0.107 USD per kWh of energy (COE), present cost (NPC). f is 18.800.000 USD Annually this model reduces the emissions of 4.554.834 kg of CO_2, 19.746 kg of SO_2 and 9.657 kg of NOx.

Another paper examined by Heyam, Christoph, Rafat, El-Khozondar which includes a hybrid grid-connected power system which generates total 118,623 kWh annually [14]. The COE is USD 0.143 per kWh. 42.4% of electricity was generated from the proposed system. Per ton biomass price was 40 USD. The system includes solar PV of 150 kW,bio generator of 75 kW, and a 50 kW converter to supply the necessary electricity.

The paper examined by Shrestha, Singh, Khanal, Maskey a hybrid energy system for the Kathmundu University Campus by utilizing solar PV, biomass, and diesel generator [15]. The system's estimated capital investment is USD 372,874 and the Levelized Cost of Energy(LCOE) is USD 0.124/kWh without using university's existing resources. And with university's existing resources, system's estimated capital investment is USD 73,060 and LOCE is 0.113/kWh.

Another study focuses on developing and configuring a PV-biomass-battery storage system, which aims to produce electricity from locally available resources efficiently [16]. From the proposed system electricity production was 33% from biomass and 4% from PV array and the solar irradiation was 6.7 kWh/m^2/day.

2.2.2 Hybrid energy system analysis for sustainable electricity solutions.

Aayush, Nasib, Ashish, and Diwakar investigated a hybrid system which combines with solar, solid waste, biomass, and diesel generators [17]. Solar PV contributes 38% of the load and 26% of the solid waste, resulting in a cost of $0.111/kWh of energy (COE) with a shared renewal ratio of 0.603.

Priyanka, Sarbjeet, and Rizwan examined a HRES for a remote area in Sonioat district of Haryana, India of which the estimated COE is USD 0.067 with an ignorable amount of greenhouse gas emission [18]. The source of biogas was cattle dung. The daily solar radiation was 5.26 $kWh/m^2/day$.

The research mainly focuses on developing and configuring a PV-biomass-battery storage system, which aims to produce electricity from locally available resources efficiently. From the proposed system electricity production was 33% from biomass and 4% from PV array and the solar irradiation was 6.7 $kWh/m^2/day$.

A different study examined the efficiency of a hybrid energy system designed to produce electricity in rural area in Kakkavayal, India [19]. It consists of solar PV, pico-hydel, biomass generator, and battery storage, including solar PV and biomass at an initial cost of Rs. 3,00,000 each, and pico-hydel costs Rs. 10,00,000, and batteries worth Rs. 75,000 square feet. The total Net Present Cost (NPC) is Rs. 24,24,836 has been invested. Notably, the energy supply is defined with solar at 3%, pico-hydel at 91%, and biomass at 6%. The study concludes that biomass-based hybrid systems offer an economically viable solution for sustainable electricity generation in the Western Ghats region of India, meeting the unique energy needs of remote areas there is a solution.

Loiy, Adnan and Ahmad investigated a hybrid PV-Wind-Biomass system where the proposed model estimated COE is USD 0.1626 [20]. The system was able to meet 93% of the campus's load demand. It was also able to save 73% of the COE than local grid tariff. The payback period was 6.584 years.

Another paper evaluated electrical power generation from human waste which is a source of biomass for Federal University Of Technology Owerri which is capable of running a 5kW biogass generator [21] .

2.3 Research Gap

Various universities in Bangladesh have already implemented rooftop solar systems. In fact, our university, Daffodil International University (DIU) already has a 24 kWh solar rooftop system. However, the concept of bioenergy production in campus areas is not very popular in Bangladesh. Even no private university in this country still couldn't implement such project. In this country waste is an alarming issue [22]. Proper waste management is a must to reduce environmental pollution. But the government alone can't manage waste from such a densely populated country very quickly unless the general public helps. So, it is very important to take initiatives on a small scale. Through our proposed model, we can bring the garbage of the campus area under proper waste management.

Many foreign universities around the world have implemented this project and have been successful. For example, The Landmark University (LU), Omu-Aran, Kwara State Nigeria produces 0.38MW of electricity from solid waste, their daily waste generation is ranged between 1655.34 kg to 1947.32 kg, with an average of 1785.4 kg [23]. Ohio State University has developed a dry anaerobic co-digestion system capable of handling 30,000 tons of organics per year and generating 7,800 megawatt hours of renewable electricity[24].

The paper also mentioned about Ateneo de Manila University's implementation of a pilot anaerobic co-digestion facility that generates 42,325 Nm^3/year biogas from 129 tons of bio-wastes produced annually. A case study has shown that if a hybrid waste-to-energy system is implemented on the campus of the University of Victoria, it could reduce 1130t CO_2 emission of yearly greenhouse gas emission [22].

So, we can not only produce electricity from bioenergy by using the waste around the campus area but also reduce CO_2 emissions. Besides, in the current world's energy crisis, biomass fuel will play a vital role in developing countries, including Bangladesh. Modern bioenergy is the biggest energy source of all renewable energies. The bioenergy could contribute 15% to global primary energy supply by 2050 [25]. The energy assessment for the year 2000 indicated that the total primary energy supply of Bangladesh amounted to 1147.80 megajoules (MGJ) of which 57% of the supply is from biomass fuel [26]. Therefore, considering the potential of solar and biomass energy in Bangladesh, our study aims to produce sustainable electrical energy from sunlight as well as waste around our university campus.

Chapter 3

System Design

3.1 Introduction

So far from our title and our analysis of the first two chapters we have already given a glimpse of what we are going to do in this research. Currently, the whole is going through a serious crisis regarding inflation, and so is Bangladesh. And the impact of inflation especially in middle-income countries like us is huge. Another problem of our country is it is a densely populated area. The shortage of power generation, rapidly growing urbanization, industrialization and population growth, causes a significant challenge to the country's progress.

Poor infrastructure and inefficient distribution networks are among the major causes of the electricity crisis in Bangladesh. Despite efforts to expand electricity generation in recent years, there remains a significant gap between supply and demand in the country. Ageing power plants, power outages and mechanical inefficiencies further increase the problem, leading to power outages and power fluctuations across the country, while lack of investment in resources maintenance and modernization prevent the reliability and instability of the electrical system.

Another critical issue which increases the electricity crisis is the heavy reliance on fossil fuels for power generation. Bangladesh mainly relies on natural gas and coal-fired power plants to meet its electricity needs, contributing to environmental degradation and carbon emissions. However, the intake of natural fuel reserves, coupled with growing international electricity costs, creates full-size challenges to the sustainability of this electricity model. Moreover, the over-reliance on fossil fuels puts the United States vulnerable to disruption of strength delivery and rising expenses, in addition to the strength crisis.

In addition, the widespread theft of energy and unpaid software bills provide significant challenges to the financial sustainability of Bangladesh's strong quarter. The ability of electrical utilities to generate money is impeded by illegal connections, meter manipulation, and sales losses resulting from unpaid bills. They are unable to invest in a capacity growth strategy that includes tighter legislation, public awareness campaigns and investments in smart grid technology, which plays a larger role in monitoring and metering.

In Bangladesh, concerted efforts to diversify the country's energy mix and promote renewable energy sources such as solar, wind and hydro are needed to solve the electricity crisis Energy by improving energy efficiency measures including reducing reliance on fossil fuels. Promoting conservation practices can help reduce and decrease electricity demand pressure on power lines.

Moreover, countries in the region can address common energy challenges and provide mutual economic benefits through the joint development of goods and services that can help alleviate the electricity crisis in Bangladesh by enhancing cooperation and cooperation with neighboring countries on cross-border energy trade and regional energy integration. In addition, investments in regional energy projects such as the South Asia Subregional Economic Cooperation (SASEC) program can enhance energy security and promote sustainable development in the region.

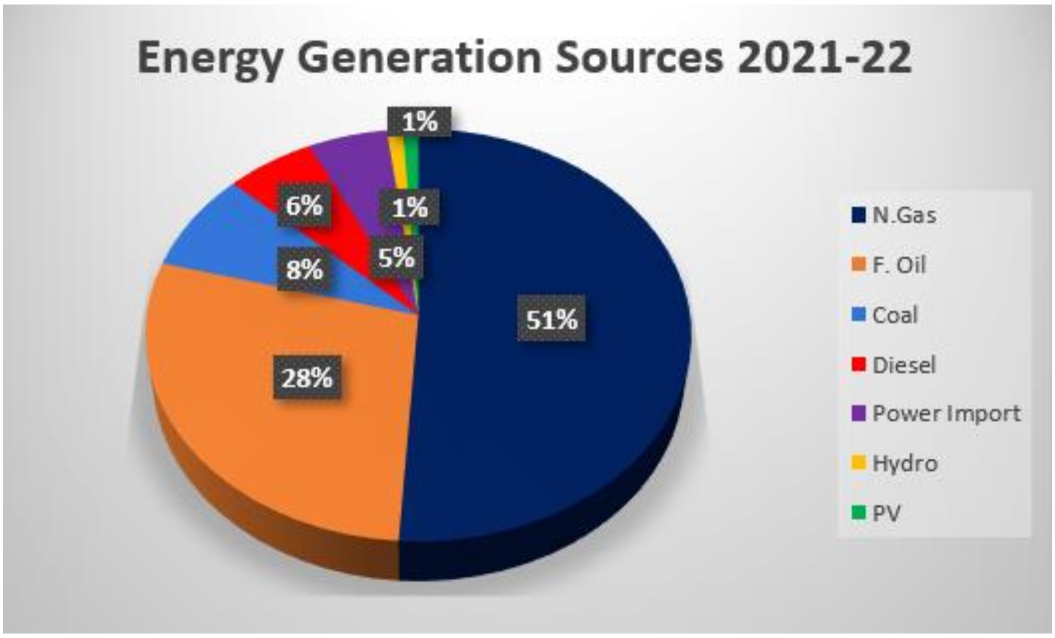


Fig 3.1. Bangladesh's Energy Production 2021-22

The pie chart shows the distribution of electricity production in Bangladesh from various sources in 2021-22 [27]. Notably, natural gas often comes in first place with 51% in total. Auxiliary furnace oil comes in second place, accounting for 28% of the arena's energy. On the other hand, renewable energy resources, consisting of solar photovoltaics (PV) and hydropower, account for a decreased portion of the general electricity generation by 1% each.

This static highlights how heavily the state relies upon conventional fossil fuels, in particular furnace oil and natural gasoline, to deliver its energy needs. Highlights the addition of renewable strength to the nation's strength blend at the same time as giving it little attention.

3.2 Motive of Our Project

Our motive for proposing a solar PV and biomass hybrid model at our university campus is to address the ongoing energy crisis in Bangladesh by helping to realize sustainability Our vision in developing a hybrid model of solar PV and biomass in our university campus is to solve the ongoing energy crisis in Bangladesh by helping to achieve the United Nations Sustainable Development Goals (SDGs) fulfilment. By developing renewable energy and reducing carbon emissions, the strategy is in line with SDG 7: Affordable Clean Energy and SDG 13: Climate Action Through a hybrid strategy that includes solar energy (PV) and biomass energy together, we rely on for our university campuses Let's aim for sustainable energy generation. The solar PV unit harnesses the region's abundant sunlight to generate clean electricity, while the biomass power unit uses fossil fuels such as agricultural waste, ensuring a sustainable energy source at night and during cloudy periods.

Our hybrid model not only supports the energy needs of the campus but also serves as a demonstration project for the environment, demonstrating how renewable energy can be integrated more fully into existing infrastructure. This task can inspire other organizations and administrations to undertake similar techniques and achieve successful development in the direction of SDG 7 and SDG 13. In addition, our initiative contributes to SDG four: Better Education, using imparting a fantastic knowledge of the environment for students and researchers interested in modern power and sustainability. Our objective is to strengthen leaders' upcoming strategic ideas to further enhance the season and the sport via this practical session. Our ultimate goal is to build a reliable and sustainable energy system on our university campus combining biomass and sunlight electricity. This integrated strategy to help achieve the SDGs promotes a sustainable future for both our university and the network.

3.3 Floor Design

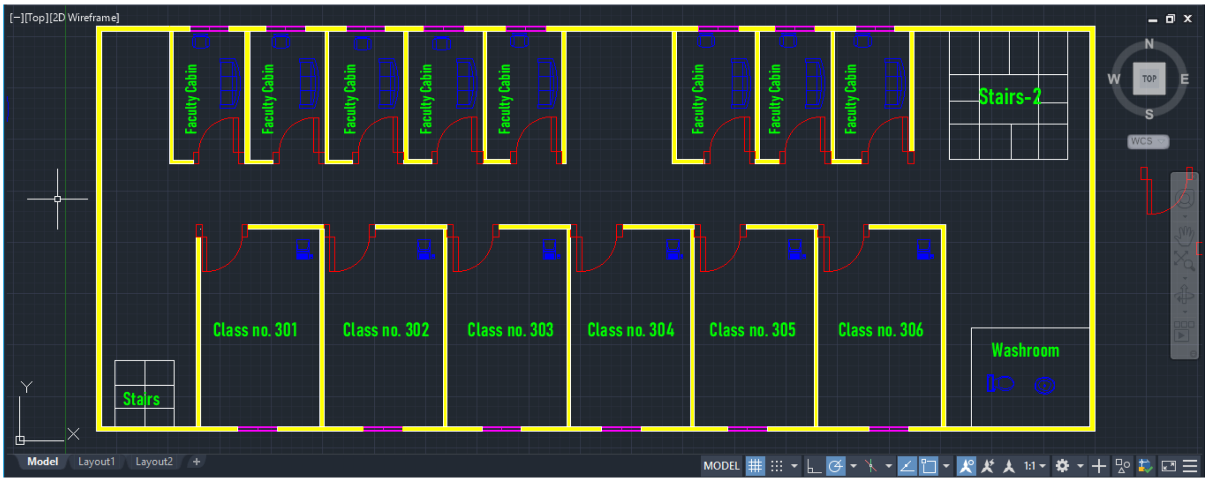


Fig 3.2. Floor design of Engineering Complex

The proposed hybrid energy system consisting of solar PV and biomass is planned and implemented based on the floor plan of the Engineering Complex (EEE Building), DIU building. We have produced a main floor plan in Fig 3.2 that shows the building's structure and layout and gives a clear picture of the area and its elements. We used applications like AutoCAD to try this.

This layout consists of certain architectural and technical drawings displaying the classrooms, the faculty rooms and the washroom spaces of the building. We can understand energy desires and consumption patterns of the exclusive constructing additives considering every area is correctly measured and categorized to represent its real proportions.

We can become aware of capability locations for sun panel installations at the roof or façade, in addition to the finest locations for the setup of biomass electricity systems, including boilers or storage gadgets, by carefully analyzing the ground layout. The ground layout additionally dictates the first-rate methods to distribute the energy generated by the hybrid gadget for the duration of the shape.

3.4 Load Distribution

Room Type	Load Type	Wattage	Quantity	Total Wattage
Classroom	LED Tube	20W	10	1090W
	Fan	80W	8	
	PC	250W	1	
Lab Rooms	LED Tube	20W	10	1290W/1590W
	Fan	80W	8	
	PC	250W	1	
	Extra	200W	-	
	Extra*	500W	-	
Control Systems	LED Tube	20W	10	2040W
	Fan	80W	8	
	PC	250W	4	
	Extra	200W	-	
DSP & Simulation Lab	LED Tube	20W	10	7450W
	Fan	80W	8	
	PC	250W	26	
	Extra	200W	-	
EEE Office	LED Tube	20W	8	1890W
	Fan	80W	6	
	PC	250W	5	
1^{st} Floor's Office Room	LED Tube	20W	6	1110W
	Fan	80W	3	
	PC	250W	3	
Renewable Lab	LED Tube	20W	10	1890W
	Fan	80W	8	
	PC	250W	1	
	Heavy Machine	800W	-	
Faculty Cabin	LED Tube	20W	2	370W
	Fan	80W	1	
	PC	250W	1	

Table 3.1: Room Based Load Consumption

Approximate Peak Time=8h (8 AM to 4 PM)				
Floor Type	Room Type	Wattage	Running Hour	Total Load
Ground Floor	Control Lab	2040W	4h	8160Wh
	Lab Class×2	1290W×3	4h	15480Wh
	Lab Class*×3	1590W×3	4h	19080Wh
	Extra For Night Light	500W	-	500Wh
Sub-Total of Ground Floor=38.06kWh				
1st Floor	DSP Lab	7450W	4h	29800Wh
	Simulation Lab	7450W	4h	29800Wh
	Lab Class×3	1290W×3	4h	15480Wh
	Office Room×3	1110W×3	8h	26640Wh
	Extra	500W	-	500Wh
Sub-Total of 1st Floor=102.22kWh				
2nd Floor	Classroom×6	1090W×6	8h	52,320Wh
	Faculty Cabin×12	370W×12	8h	35,520Wh
	Extra	200W	-	200Wh
Sub-Total of 2nd Floor=88.02kWh				
3rd Floor	Classroom×6	1090W×6	8h	52,320Wh
	Faculty Cabin×12	370W×12	8h	35,520Wh
	EEE Office	1890W	8h	15,120Wh
	Extra	200W	-	200Wh
Sub-Total of 3rd Floor=103.26kWh				
4th Floor	Renewable Lab	1890W	4h	7560Wh
	Extra	200W	-	200Wh
Sub-Total of 4th Floor=7.76kWh				
So, in total=339.94kWh per day				
Monthly= (339.34×26) kW=8822.84kWh. Nearly 9000kWh or 9000 units.				

Table 3.2. Monthly load profile of Engineering Complex.

Tables 3.1 & 3.2 above give the load of EEE building of DIU. The four-story building uses about 340 units of electricity per day, which translates to about 9000 units per month. The first and third floors have the highest daily usage, at 102.22 and 103.26 kWh, respectively. These figures show the variation in energy consumption in different areas of the building.

The load profile mustn't include the capacity consumed by air conditioners, as they will not be powered by renewable sources. This exclusion may affect total energy consumption and must be considered when designing a hybrid energy system. However, the load pattern provides valuable insights for designing and targeting effective renewable energy solutions for a building.

3.5 Survey about Waste Measurement

Name	Organic waste (kg)
YKSG Hall -1	50
YKSG Hall -2	40
RSG Hall	35
Green Garden	25
Food Court	5
Other food shops	5
Total	**160**

Table 3.3. Organic waste data from inside campus survey

We measure the quantity of organic garbage produced both on and off campus throughout our study. The findings show a significant daily production of organic waste, of 424kg. This comprises around 160 kilograms gathered from the university, including residence halls and an extra 264kg from other sources, such as surrounding hotels.

The records highlight the large availability of natural waste that can be applied as a resource for our hybrid strength gadget. By changing this waste into energy through the biomass era, we will make contributions to sustainable waste management even by assisting our renewable strength dreams.

Name of Hotels/Restaurants	Organic waste (kg)
Downtown	20
Roster King	15
Ma Hotel	5
Hotel Magura	20
Master food	10
Ma-Babar down	5
Tangail Hotel	5
Brahmanbaria Hotel	8
Uttarbongo Hotel	20
Tong-ghor Restaurant	10
Elite Garden	15
Astobanzon	8
Jam Jam Hotel	7
Kutumbari	6
Alhamdulillah Biriani	3
Daruchini	8
Vai Hotel	3
Food Point	3
Shariatpur Hotel	10
Hazi Biriani House	3
Pizza Bahadur	2
Ma Biriani	3
Allium	3
Juice bar	2
Food Village	15
Dewan Hotel	20
Dhaka Hotel	20
Chandpur Hotel	10
AFC	5
Total	**264**

Table 3.4. Organic waste data from outside campus survey

By adopting a targeted program, we can increase the resilience and long-term capacity of our campus community and consistently maintain our sustainable renewable energy sources with their increased efficiency.

Fig 3.3. During waste data collection survey in hotels around the campus area

In addition, we have photos of our group in action that we used to record our survey. These images provide concrete evidence of our methodology and the possible scope of the task. These images offer a visual testament to the thoroughness of our research process and the extent of the organic waste resource available to us. Overall, the study confirms that adding biomass strength to our campus's renewable power strategy is feasible.

The findings underscore the practical and effectiveness of integrating biomass energy production into our campus's renewable power strategy. This technique can offer a reliable supply of clean energy and even simultaneously address the demanding situations of waste control. By transforming organic waste into a usable shape of electricity, we make contributions to environmental conservation and energy self-sufficiency.

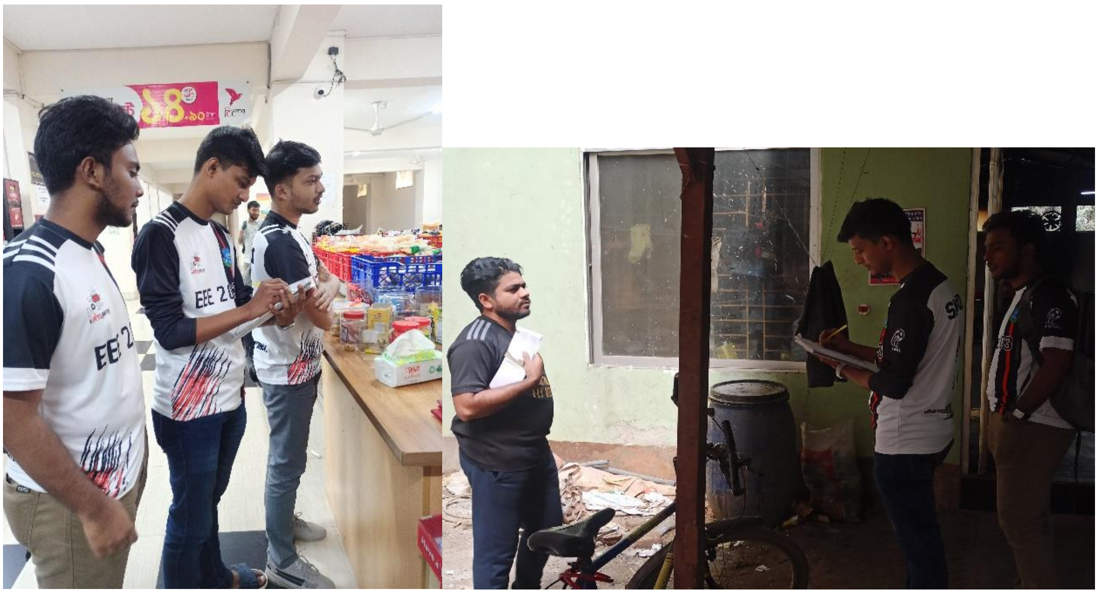


Fig 3.4. Waste data collection survey from the residential hall of the campus

3.6 Field Visit

During our field trip to Bangladesh's largest waste disposal facility, The Skate Ltd (Sewage Treatment Plant) in Jhumjhumpur, Jashore, we gained valuable insights into the usage and challenges of waste management in the country. The technology features both aerobic and anaerobic degradation processes, allowing us to gain a comprehensive understanding of the pollutant cleanup process. Although the unit is primarily focused on aerobic biogas production, it uses 25 tons of waste daily, up from the 50 to 60 tonnes available.

Fig 3.5. From "The Skate Integrated Landfill and Resource Recovery Center"

The plant has a capital cost of Rs 23 crore, indicating the huge investment required to set up such a facility. According to the plant manager, the success of the sewage treatment plant largely depends on government support, stressing the need for public-private partnerships to ensure sustainable waste management.

Our visit highlighted the critical role of waste management and management in protecting the environment and paving the way for a sustainable future. Operating the plant not only avoids the negative impact of unmanaged waste on the environment but also enables renewable energy through the production of biogas picture taken during our visit means our team interacts with factory workers and operators, as well as waste management systems.

Fig 3.6. During our monitoring at the treatment plant.

Photographs from our field trip at The Skate Limited provide an account of our experience, showing first-hand interaction with the equipment and methods employed in the production and consumption of manure. We were able to gain important insights into the complexity of large-scale waste production and its potential impact on local economies and the environment through direct observation.

Furthermore, our tour gave us a better knowledge of the plant's operating difficulties as well as the creative solutions used to maximize productivity and reduce environmental effects. This information is crucial to improving our study since it enables us to approach our thesis with a thorough understanding of practical pollution control strategies and the challenges they face.

Details of “The Skate Ltd (Waste Treatment Plant)”	
➢ Stating Year	April, 2023
➢ Waste Collection per day	50/60 Ton
➢ Usable waste per Day	25 Ton
➢ Average electricity generates per day	Still under observation
➢ Generator Capacity	1MW // 1000m^3 gas
➢ Biogas Production Method	Aerobic
➢ Per Unit Cost	-
➢ Capital Cost	23 Crore
➢ Maintenance Cost	2 Crore
➢ Project lifetime	20 years
➢ Project Area	12.5 Acres

Table 3.5. Collected data from our field visit which is validated by the manager of the plant

In conclusion, our field visit to The Skate Ltd. at the Jhumjhumpur, Jashore provided a strong foundation for our research, broadened our understanding of important wastewater treatment processes, and increased our appreciation for the critical role of sustainable practice in ensuring a healthy future. This fact reinforces the accuracy of our budget by focusing on the accuracy of current pollution strategies and their implementation.

3.7 Selected Waste Processing Method

Our field trip to “The Skate Waste” provided a great opportunity to observe the production and the challenges of large-scale waste management. We were able to use this prior knowledge to identify potential barriers and variables that could affect the establishment and efficiency of biomass energy systems.

We have decided to use an anaerobic processing strategy for our suggested biomass model based on our knowledge of various processing techniques and our research. The method “The Skate Waste” uses to turn organic waste into compost and biogas is effective in producing these two useful products.

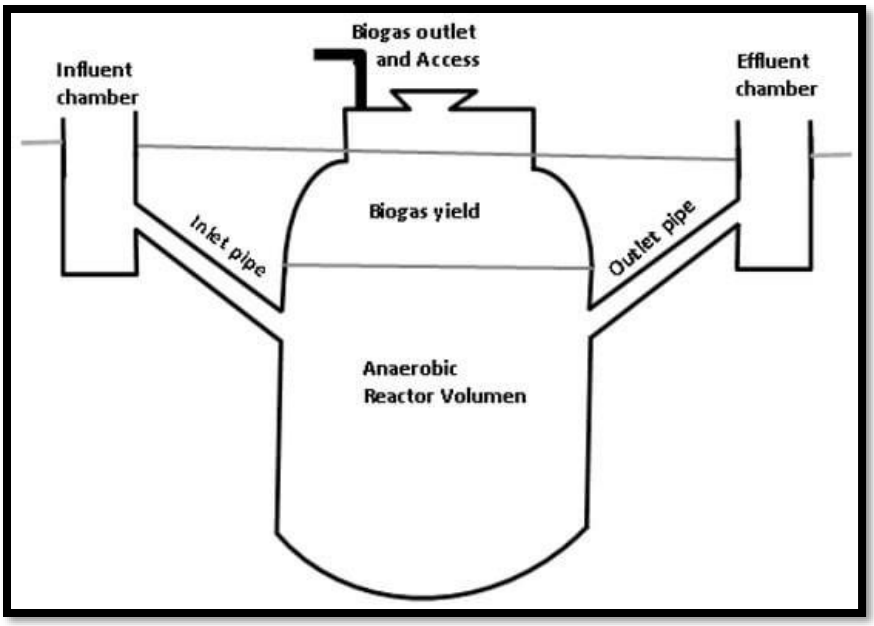


Fig 3.7. Aerobic Processing method [29]

Because the anaerobic process does not require oxygen to break down organic compounds, it reduces emissions of methane, a potent greenhouse gas. The decision is consistent with our commitment to use biomass to generate electricity in a sustainable manner and with minimal adverse effects on the environment.

Anaerobic approaches make sense for our university's needs since they are thought to be simpler to implement and sustain than anaerobic ones. Moreover, this waste biodegrades quickly, which facilitates the effective production of biomass and energy.

The anaerobic processing strategy has several technological advantages that make it a good fit with our proposed biomass model. Organic waste may decompose more rapidly and effectively due to the activity of non-oxygen dependent bacteria, which speeds up the conversion of waste. Microbial activity is maximized via temperature control, which is made feasible by the exothermic nature of the process. Furthermore, this method’s effective smell control makes it more appropriate for an on-campus setting. High-quality compost for improving soil is one of the useful products of aerobic processing, and the biogas produced may be recovered and utilized as a sustainable energy source. Furthermore, the manner can be altered to accommodate new traits in web page inspection and decontamination practices. Our target of the use of renewable strength sources and sustainable waste control is aided through these benefits.

In summary, our subject observations provided us with a realistic understanding that informed our choice of aerobic processing methods for our counselled biomass model. To gain our sustainability desires, this has allowed us to effectively transform natural waste into strength in addition to creative and powerful materials which have a lower environmental impact.

The use of anaerobic processing is consistent with our overall mission to support the circular economy and encourage environmentally responsible practices. In this way, we can demonstrate how waste can be better managed and turned into a valuable asset, ultimately benefiting the university and the community.

3.8 Design Specifications

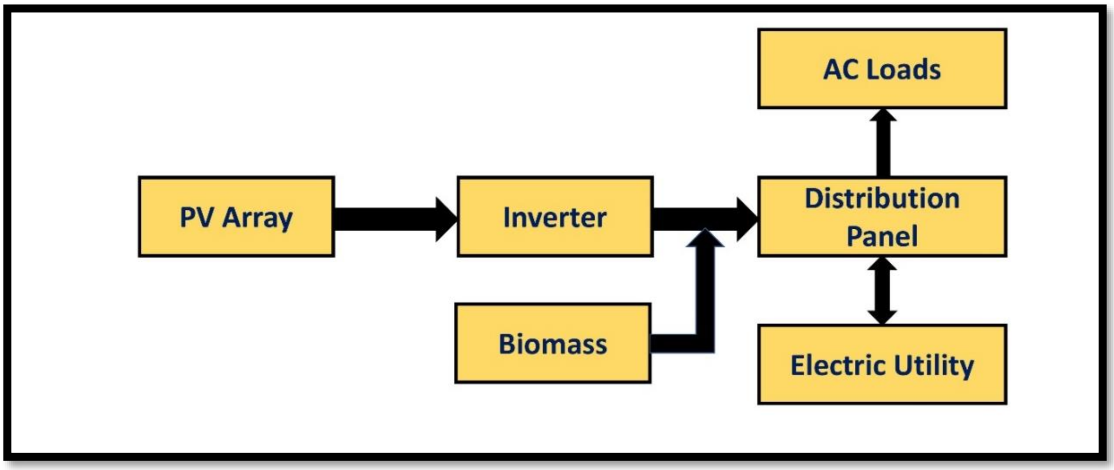


Fig 3.8. Diagram of grid-connected solar PV and biomass hybrid system

We are undertaking a project to develop and compare different hybrid energy models for the Engineering Complex building, starting with a 20-kWh load from laboratories during peak hours. Initially, we will assess two hybrid models—on-grid and off-grid solar PV and biomass combinations—and compare them with the existing diesel generator system.

Grid-connected hybrid models of solar photovoltaic and biomass energy efficiency integrate renewable energy into the energy system, providing continuous and uninterrupted power. Another force for grid sustainability is economic efficiency increased as the demand for renewable energy exceeds the supply that can be recharged into the system. By decreasing reliance on traditional fossil fuels and enhancing total energy conservation, this strategy contributes to the diversification of the energy mix.

In addition, the on-grid initiative provides an opportunity to contribute to the renewable energy supply of the national grid, which supports the broader objectives of environmental sustainability with advanced systems with proper monitoring and control, this model can provide more efficient and effective energy flow and support universities and larger communities in. The grid approach can also enable participation in grid balancing operations, providing additional cost savings and revenue streams.

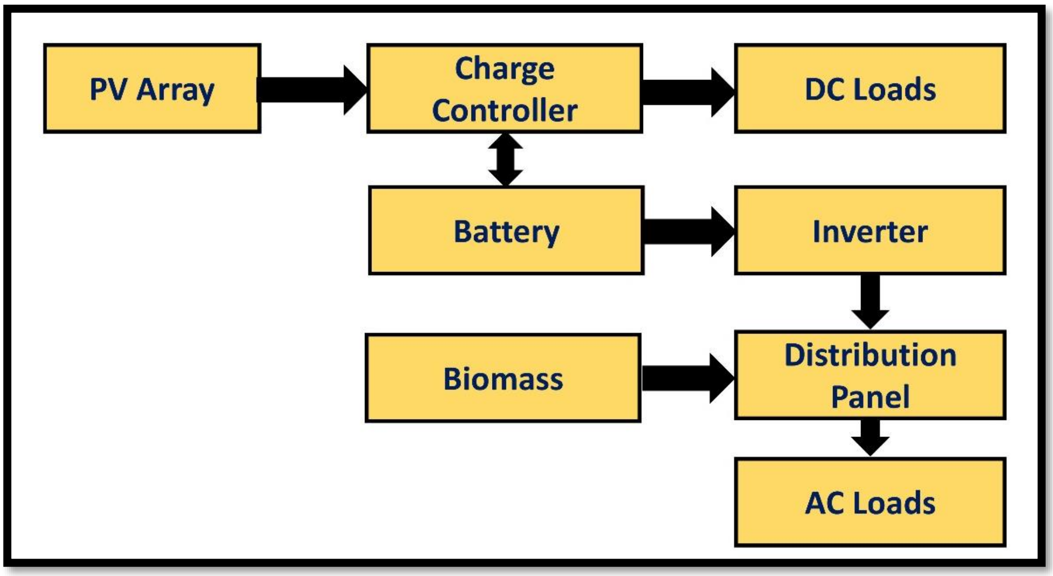


Fig 3.9. Diagram of off-grid solar PV and biomass hybrid system

By contrast, the off-grid hybrid approach of solar photovoltaics and biomass ensures power delivery in distant or remote places without relying on the grid. Although this paradigm provides resilience and energy self-sufficiency, maintaining a steady supply of energy necessitates careful management of storage and backup options.

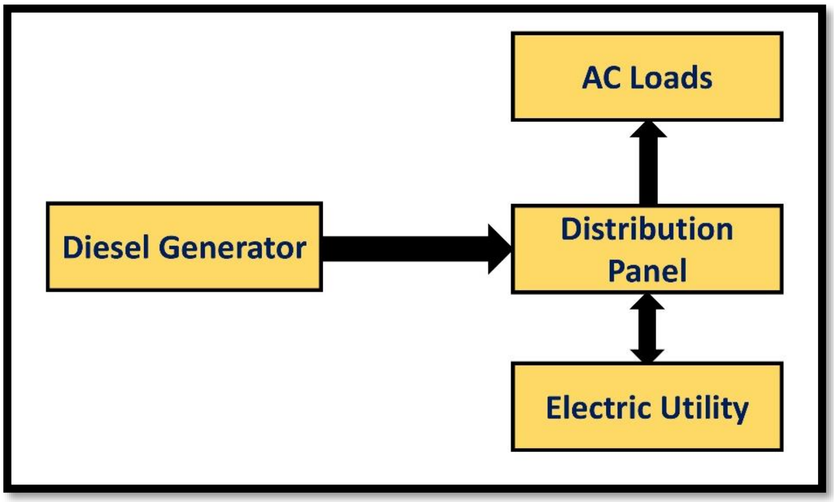


Fig 3.10: Diagram of currently running diesel generator system

Finally, the current diesel generator system operates as a conventional energy source but incurs high operating costs and environmental problems due to emissions. Through operations, costs create and compare the environmental impacts of each model. Our model aims to identify optimal energy solutions.

3.9 Simulation Setup

For our simulation, we will be using HOMER software, a powerful tool designed for modelling and optimizing hybrid energy systems. The software offers a user-friendly interface for entering various parameters such as load profiles, renewable resources data and system costs. By running simulations in HOMER, we can assess and compare the feasibility and efficiency of each energy model in meeting the 20-kWh laboratory load during peak hours.

3.9.1 Solar PV

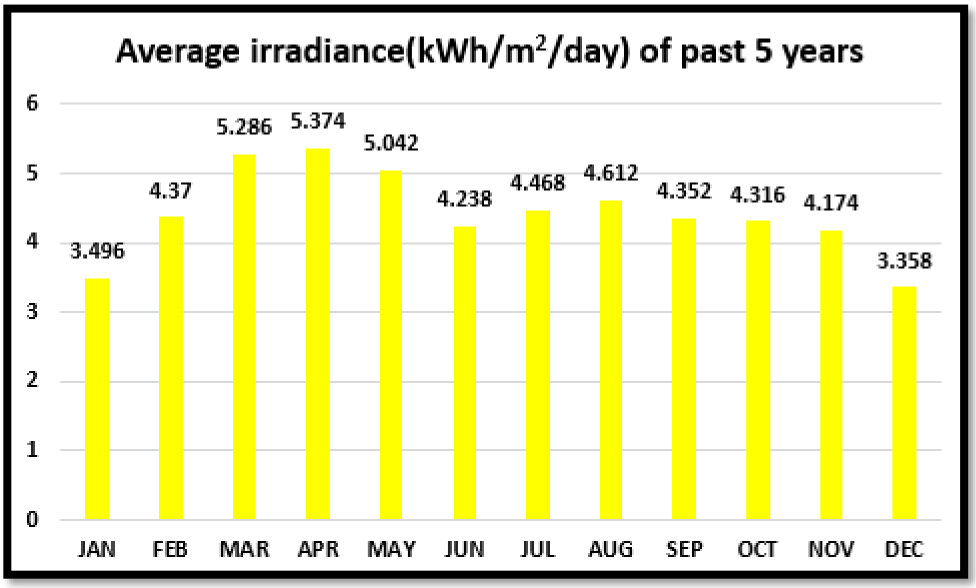


Fig 3.11. Solar irradiance average for the past 5 years

With our campus's latitude (23°87′) and longitude (90°32′), we utilized the NASA Power database to get estimations of the associated solar radiation [28]. This dependable source provides data averages and satellite weather for the years 2018 through 2022. Because the bar graph displays the quantity of average sunshine in each month, we can choose the weather and the times of day when the sun is out most. This information is crucial to properly design our solar PV system and deliver the highest level of electricity.

We chose the 'REC Solar 325' solar panel for our project, which has an efficiency of 13% and a rated output of 13kW. The total cost of the panels is approximately BDT 38,392.41. This strategy is consistent with our commitment to using reliable and cost-effective solar PV systems to generate large amounts of energy and support our sustainability goals.

3.9.2 Converter

The "Fronius USA Primo Fronius 8.2" converter is the one we have selected to convert the DC current produced by the solar PV system into AAC current. With a nominal voltage of 240V and an efficiency of 97%, this inverter ensures effective energy conversion and interoperability with conventional electrical systems. The cost based on capacity will be 164,538.9 BDT for 8KW, 54,846.3 BDT for 3kW and 21,938.52 BDT for 1kW. The main component of our solar

PV system is this converter, which transfers electricity efficiently and can be transported by relying on it.

3.9.3 Biogas Generator

To add to our proposed system, we will use a biogas-fired generator rated at 1 kW. This generator costs around 43,877 BDT and has a minimum load factor of 25%, making it a stable and efficient operation. Biogas generators provide a reliable source of energy by converting naturally occurring waste into usable energy. It supports our hybrid energy system, especially during periods of low sunlight or high energy demand.

3.9.4 Grid

We have included a cost of 6.5 BDT per unit of grid power for our hybrid energy system. Furthermore, surplus power produced may be sold back to the grid at a cost of 10 BDT per unit under the net-metering scheme.

3.9.5 Battery

To store extra energy for later use, we selected a 1kW lead-acid battery with a nominal voltage of 12V and a capacity of 1kWh. Furthermore, the battery can hold 83.4 Ah at its highest capacity, thus our hybrid energy system will have a fortune of storage. At about BDT 16,453.89, the battery is a reasonable goal for a power garage.

3.10 Summary

Our project involves creating a hybrid power plant that combines grid power, biomass and solar power to meet our university's electrical needs. The combination of so many parts is shown in the schematics, which provide a clear visual depiction of the project's design and function ability.

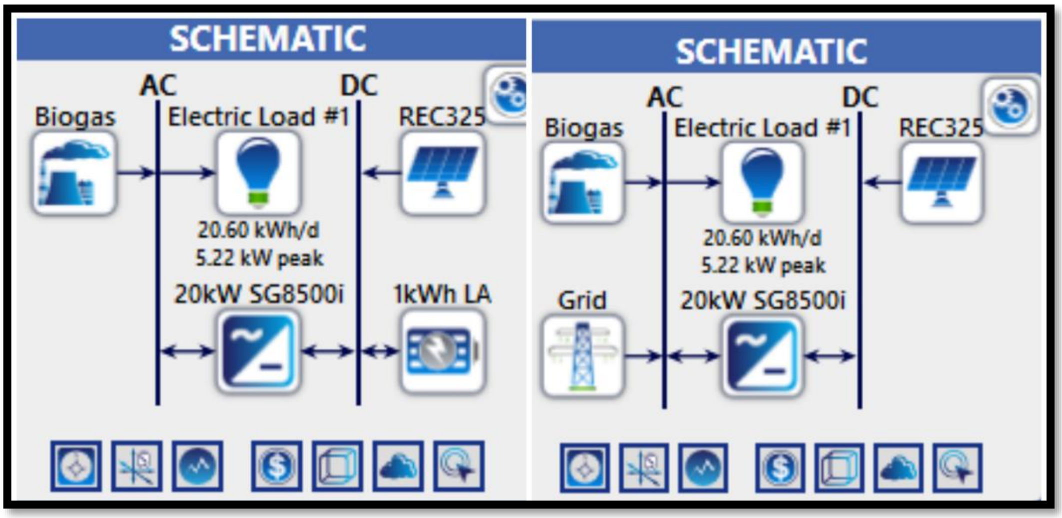


Fig 3.12. Schematics of On-grid and Off-Grid Hybrid Powerplant of Proposed Model

Our multi-faceted approach involves developing a distribution system, conducting surveys to assess waste levels, and visiting Bangladesh’s largest landfill, The Skate Ltd, in Jhumjhumpur, Jashore. During our visit, we gained insight into the aerobic manure system, which we chose for its environmental benefits and alignment with our project objectives. Choosing this option allows us to turn waste into more energy, making it both sustainable and efficient.

Chapter 4

Results and Discussion

4.1 Introduction

The results of our examination and analysis of the records gathered for our investigation are presented in this chapter. The Purpose of this chapter is to provide an overview of our suggested power tool's overall performance, emphasizing important aspects like prices, efficiency and energy usage. We want to know the greatest structure for our classroom energy demands as we assess the outcomes of our simulations and comparisons.

The evaluation consists of the contrast of on-grid and off-grid solar PV and biomass hybrid models with the presently ongoing diesel generator device. In addition, we show the impact of renewable energy implementation in terms of our proposed power solutions but additionally discuss power enhancements and pointers for destiny implementations.

Our analysis takes into account the maintenance and performance of each sample, providing a comprehensive assessment of its fitness and durability. We look at the economic benefits of each option and estimate potential savings from the use of renewable energy and the costs of installation, operation and maintenance.

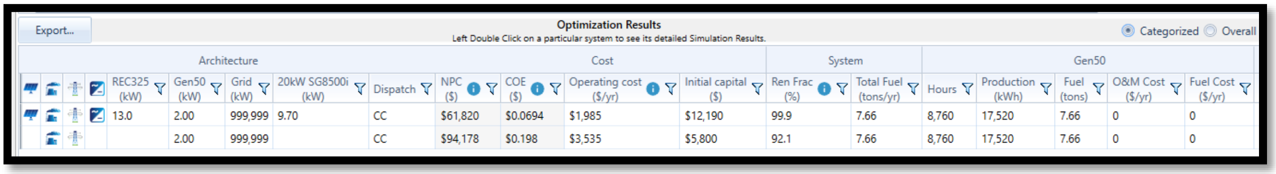
Through a careful examination of the results, we goal to contribute valuable expertise to the sector of renewable energy structures and manual selection-making for comparable tasks. The findings and dialogue will shape the idea for our conclusions and similar studies' directions.

Furthermore, bankruptcy must contend with all industry-wide obstacles, such as disparities in integrated energy systems' actual and projected total performance. By tackling these problems, we hope to provide our comprehensive viewpoint and offer useful solutions that will enhance the development and application of hybrid energy systems in homogenous energy efficiency.

In conclusion, our analysis expands the scope of all industrial performance and past economic endeavours to include broader social interest, environmental stewardship, resilience, and equity concerns. By addressing these multidimensional considerations, we want to optimize the development and capacity of hybrid power systems that currently make it, not the most flexible operation but put people and the planet first again has been developed.

4.2 Observations

4.2.1 On-Grid Hybrid Model



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Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Categorized Overall

Architecture					Cost				System		Gen50				
REC325 (kW)	Gen50 (kW)	Grid (kW)	20kW SG8500i (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (tons/yr)	Hours	Production (kWh)	Fuel (tons)	O&M Cost ($/yr)	Fuel Cost ($/yr)
13.0	2.00	999,999	9.70	CC	$61,820	$0.0694	$1,985	$12,190	99.9	7.66	8,760	17,520	7.66	0	0
	2.00	999,999		CC	$94,178	$0.198	$3,535	$5,800	92.1	7.66	8,760	17,520	7.66	0	0

Fig 4.1. Different optimizations results for on-grid model

In Fig 4.1, which shows the optimization results for the on-grid hybrid model, we chose the top choice because of its limited performance. This option offers a high renewable fraction of 99.9%, indicating all energy can be generated from renewable energy sources. Also, it has a low unit cost of 7.57 BDT, making it an affordable option. The combination of high innovation and low unit cost makes this approach viable and sustainable for our business. It represents a complex balance of environmental and economic benefits that aligns with our commitment to address renewable energy on campus. This approach reflects our commitment to efficient and cost-effective operation of our energy systems.

4.2.1.a Cost Summary

Component	Capital	Replacement	O&M	Salvage	Total
Fronius USA Fronius Primo 8.2 (240V)	201,834.38	201,834.38	-	67,277.76	336,391.01
Biogas Generator	87,754.08	1,228,557.12	-	35,101.63	1,281,209.57
Grid	-	-	6,924,532.95	-	6,924,532.95
Other	548,463	-	10,969,260	-	11,517,723
REC Solar 325	499,101.33	-	71,300.19	-	570,401.52
System	1,337,152.79	1,430,391.5	4,116,027.24	102,379.39	6,781,191.05

Table 4.1. Cost summary of on-grid hybrid model

(**All the values have been considered in BDT currency)

Table 4.1 gives a cost outline for the on-grid hybrid version and describes the economic planning required for the device. The overall fee of the gadget is visualized at BDT 67 lakh, with a capital expenditure of BDT 13.3 lakh. This preliminary investment involves the purchase and installation of strength connectors. Energy connections must be purchased and installed as part of this initial outlay. The system's 25-year operating and maintenance costs exceed BDT 4.1 million. These costs include routine maintenance, repairs, and spare parts to ensure the system operates smoothly and reliably over time. While operation and maintenance are expensive, the long-term benefits of using a newer high-quality material and lower energy costs can offset those costs. Considering the total cost of the system, we can assess the financial viability and sustainability of the on-grid hybrid model at the university.

4.2.1.b Solar PV Output

Rated Capacity	13.0kW	Total production	18,771kW
Capital Cost	498,165.85 BDT	Maintenance Cost	2,846.66 BDT
Specific Yield	1,439 kWh/kW	LOCE	1.22 BDT/kWh
PV Penetration	29%		

Table 4.2. PV output details for the proposed on-grid hybrid model.

Table 4.2 indicates the output information of our sample solar PV and offers the economic and production situations of the machine. The capital cost of the solar PV unit is approximately 5 million BDT, which covers the acquisition and set up of the solar panels.

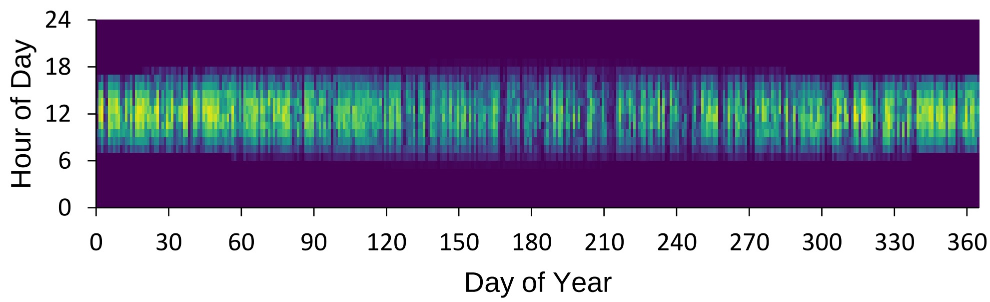


Fig 4.2. PV power output

Over time, the device proves to be free with a minimum protection value of BDT 2,846.6 per year. This maintenance cost ensures that the solar PV remains green and reliable. This major event supports the energy needs of the university and encourages the use of clean, renewable energy. Electricity cost unit or standardization cost of electricity (LOCE) is very low at only 1.22 BDT, indicating that solar energy is feasible. This low LOCE indicates the economic advantage of solar implementation, provides a good return on investment and supports our sustainability objectives.

4.2.1.c Biogas Generator

Capacity	2.00kW	Hours of operation	8,760 hours/yr
Generator Fuel	Biogas	Fixed Generation Cost	BDT 5.84/hr
Capital Cost	87,589.60 BDT	Total Production	17,520 kWh
Fuel Consumption	7.66 tons/yr		

Table 4.3. Biogas Generator details

Table 4.3 provides an overview of the biogas output of our model and sheds light on the associated costs and energy output of the biogas system. The purchase of necessary machinery and infrastructure includes a capital expenditure of approximately BDT 88,000 for the biogas segment.

The fuel source for the system is biogas. The anticipated annual fuel consumption rate of 7.66 tons emphasizes how much fuel the biogas generator needs in order to run efficiently.

Even with these fuel needs, the biogas system can generate 17,520 kWh of power each year. This initiative allows the combination of renewable electricity and contributes considerably to meeting the strength call for on campus. The biogas gadget affords a sustainable manner to supply power by means of converting organic waste into easy strength. This facilitates waste control and reduces greenhouse fuel emissions, which furthers our environmental and sustainability ambitions.

4.2.1.d Total Electrical Summary

Production	**kWh/yr**	**%**
REC Solar 325	18,711	51.6
Biogas Generator	17,520	48.3
Grid	38.2	0.105
Total	36,270	100

Table 4.4. Total Electrical Summary of on-grid hybrid model

Table 4.4 presents a total electricity precis of the on-grid hybrid version, showcasing the contribution from both solar and biogas assets. From solar electricity, we are generating 18,711kWh of power annually, which constitutes 51.6% of the whole strength manufacturing inside the version. In addition, biogas energy production contributes 17,520 kWh per year, making up 48.3% of the total output. This close balance between solar and biogas sources indicates an effective diversification of renewable energy inputs.

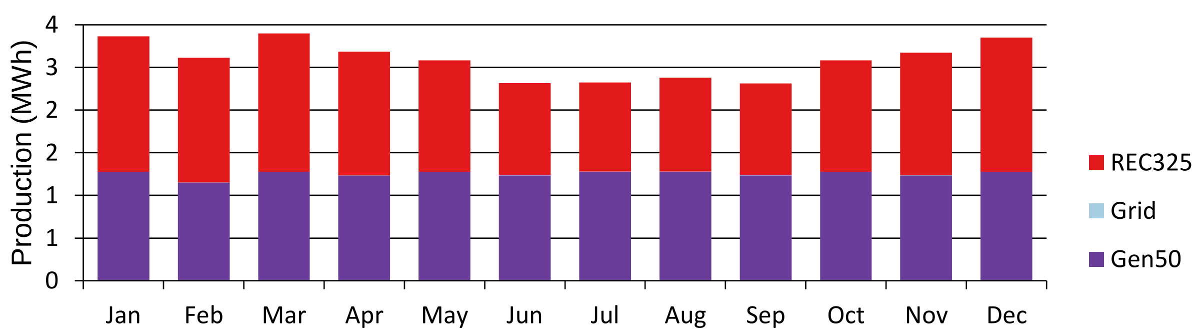


Fig 4.3. Month-wise electric production of the model

The nearly equal distribution of solar and biogas production increases the overall reliability and robustness of the hybrid model. The overall flexibility and reliability of the hybrid model can be enhanced by synchronizing the biogas supply with the solar energy supply. With both functions, the system is able to consistently turn on power throughout peak time and various weather conditions. Our goal of maximize renewable energy and improve the integrity of the power grid is consistent with this circular approach.

4.2.1.e Emission

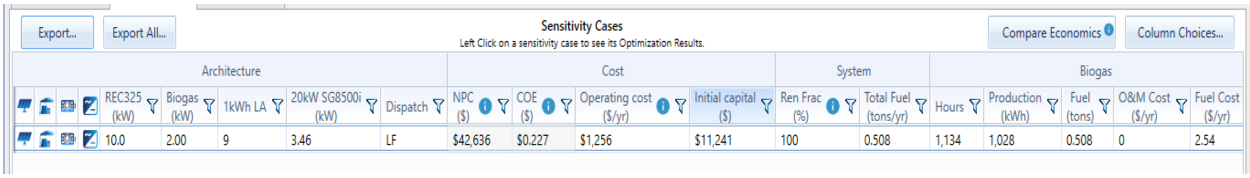
Quantity	**Value**	**Units**
Carbon Dioxide	25.4	Kg/yr
Carbon Monoxide	0.125	Kg/yr
Unburned Hydrocarbons	0.00551	Kg/yr
Particular Matter	0.000751	Kg/yr
Sulfur Dioxide	0.105	Kg/yr
Nitrogen Oxide	0.169	Kg/yr

Table 4.5. Gas emission list

Table 4.5 affords an outline of the list of greenhouse fuel emissions for the hybrid model on the grid. The version emits 25kg of CO_2 in keeping with 12 months, which is notably low in comparison to conventional fossil fuels. Other greenhouse gasoline emissions including carbon monoxide, sulfur dioxide and others are under 1%, indicating that the model is based on easy, sustainable resources of energy. This small quantity of emissions demonstrates the effectiveness of the version in decreasing the environmental footprints and contributing to transparency.

This approach facilitates climate change mitigation efforts and is consistent with our sustainability goals as it minimizes greenhouse gas emissions as there is greater interest in reducing carbon emissions, thus making sustainable capacity decisions that are environmentally friendly.

4.2.2 Off-Grid Hybrid Model



Export... | Export All...

Sensitivity Cases

Left Click on a sensitivity case to see its Optimization Results.

Compare Economics | Column Choices...

Architecture									Cost				System		Biogas				
				REC325 (kW)	Biogas (kW)	1kWh LA	20kW SG8500i (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (tons/yr)	Hours	Production (kWh)	Fuel (tons)	O&M Cost ($/yr)	Fuel Cost ($/yr)
				10.0	2.00	9	3.46	LF	$42,636	$0.227	$1,256	$11,241	100	0.508	1,134	1,028	0.508	0	2.54

Fig 4.4. Optimization results for off-grid model

The off-grid model's optimization findings are shown in Fig 4.4. The fact that this study's progress findings are 100% renewable suggests that the system only uses renewable energy sources to produce power. Despite the high renewable resources, the cost per unit of 25 BDT means that this off-grid model is expensive compared to alternative energy options. This cost can be impacted by the importance of requiring advanced storage or backup solutions to provide continuous off-grid electricity systems.

4.2.2.a Cost Summary

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Fronius USA Fronius Primo 8.2 (240V)	64,721.05	64,721.05	-	-	21,873.32	107,868.78
Biogas Generator	87,589.6	87,589.6	-	6,950.23	9,634.86	172,494.58
Battery	147,807.45	591,229.8	49,269.15	-	123,172.88	665,133.53
Other	574,435	-	2,737,175	-	-	3,284,610
REC Solar 325	383,204.5	-	54,743.5		-	437,948
System	1,230,757.6	743,540.45	2,841,187.65	6,950.23	154,381.05	4,668,054.89

Table 4.6. Cost summary of off-grid hybrid model

Table 4.6 offers an outline of prices for the intra-grid hybrid version and gives insight into the financial funding required for the gadget. The overall cost of the off-grid device is predicted at

BDT 4.6 million, which incorporates capital expenditure for the acquisition and set up of the system. The cost over the 25-year life of the machine is expected at more than BDT 2.8 million. These ongoing charges encompass protection and different prices essential to keep the system running and prolonged-lived.

While the full price of the off-grid hybrid model is sizable, it should be weighed in opposition to the benefits of a 100% renewable energy gadget that operates independently from the grid. This version presents electricity self-sufficiency and resilience, even though the long-term value-effectiveness may be stimulated by the way of the higher operational and preservation fees

4.2.2.b Solar PV Output

Rated Capacity	10.0kW	Total production	14,393kW
Capital Cost	383,204.5 BDT	Maintenance Cost	2,189.74 BDT
Specific Yield	1,439 kWh/kW	LOCE	1.22 BDT/kWh
PV Penetration	191%		

Table 4.7. PV output details for the proposed off-grid hybrid model.

Table 4.7 affords the sun PV output information of our off-grid hybrid version, focusing on the cost and production aspects of the machine. The capital value for the solar PV aspect is approximately 38.3 lakh BDT, which incorporates the investment in solar panels and associated installation.

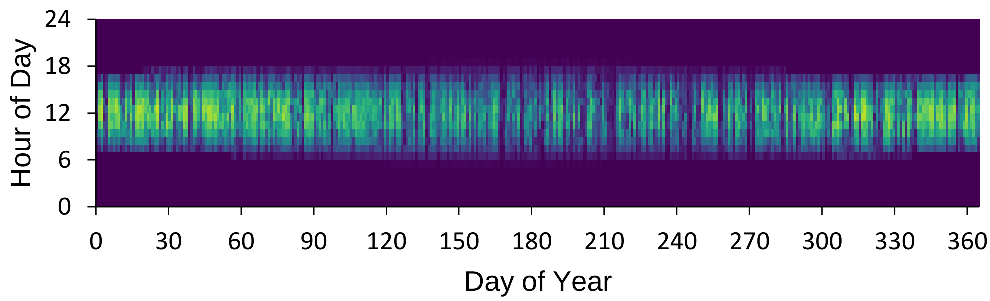


Fig 4.5. PV power output for off-grid

The device’s long-term cost-effectiveness is aided by its exceptionally cheap yearly renovation price of 2,090 BDT. This upgrade guarantees that the solar PV device remains untrained and dependable for the duration of its life. An estimated 14,393 kWh of power will be generated by the device per year, which accounts for a large amount of the off-grid version’s electrical source. Without a doubt, solar PV’s normal price of strength (LOCE) is extremely cheap, comparable to 1.22 BDT. If taxation is equitable and sustainable, solar photovoltaic devices have the performance and affordability to support an off-grid hybrid type of power delivery. This is our promise that operating value efficiencies will be maintained while steady, renewable power is produced.

4.2.2.c Biogas Generator

Capacity	2.00kW	Hours of operation	1,134 hours/yr
Generator Fuel	Biogas	Fixed Generation Cost	BDT 5.84/hr
Capital Cost	87,589.60 BDT	Total Production	1,028 kWh/yr
Fuel Consumption	0.508 tons/yr		

Table 4.8. Biogas Generator details

Table 4.8 shows the biogas production data for our off-grid hybrid model and highlights the costs and energy production associated with the biogas segment. The total cost of the biogas system is estimated at which is 88,000, which includes equipment purchase and necessary infrastructure construction. The biogas generator uses biogas as fuel. Fuel consumption is relatively low, 0.508 tons per year, keeping fuel costs reasonable. Despite which is very low compared to the other energy sources.

Even though the biogas component only adds a little amount of electricity to the system as a whole, it is crucial for supplying energy at times when there is less sunshine. Given its modest energy output, biogas would be more suitable for use as a backup power source in the off-grid hybrid model than as the main source.

4.2.2.d Battery

Rated Capacity	9.01kWh	Expected Life	6.00 yr
Annual Throughout	76.4kWh/yr	Capital Costs	BDT 147,805.47
Maintenance Cost	BDT 1,970.77/yr	Losses	17.1kWh/yr
Autonomy	6.30 hr		

Table 4.9. Storage details of off-grid model

Table 4.9 presents the info on the battery used in the off-grid hybrid version. The battery device has a capital value of approximately 148,000 BDT, representing a huge investment in power garages for the venture. This fee covers the acquisition and installation of the batteries for the gadget. The battery provides 6.3 hours of freedom, providing a reliable backup power source for a period of time even if the renewable energy period is low or calls are high. This freedom provides a continuous supply of electricity through for to fulfil the wishes of the laborer.

A battery tool has an estimated life of six years, which is the amount of time the battery is supposed to lose before failing. The garage answer adds to the off-grid hybrid model's balance and ease, even though battery choice may be important after this. All things considered, the battery gadget performs an essential function in keeping a balance between distribution and getting in touch, which complements the strength plant's dependability and performance.

4.2.2.e Total Electrical Summary

Production	**kWh/yr**	**%**
REC Solar 325	14,933	93.3
Biogas Generator	1,028	6.67
Total	15,421	0.105

Table 4.10. Total Electrical Summary of the off-grid hybrid model

Table 4.10 indicates the capability of the solar and biomass assets and the overall cumulative power of the non-grid hybrid version is given. The plant produces 14,393 kWh of strength from solar electricity, that's 93. Energy production all 3 in the pattern. In addition, the biogas plant produces

1028 kWh per year, which accounts for 6.67% of total production. Although the contribution of biogas is relatively small compared to solar energy, it plays a supporting role in supplementing the energy distribution at a time when solar time may be insufficient.

This classification emphasizes the version's strong reliance on solar electricity, which is predicted because of the highly innovative off-grid hybrid machine. A small but significant amount of money from biogas makes it easy to diversify energy resources to tune the reliability of devices. The off-grid hybrid model's emphasis on solar energy demonstrates its alignment with our sustainability goals and commitment to maximizing the use of clean, renewable sources. The balance between solar and biogas supports consistent power delivery and aligns with the model's overall design objectives.

4.2.2.f Emission

Quantity	Value	Units
Carbon Dioxide	0.08	Kg/yr
Carbon Monoxide	0.083	Kg/yr
Unburned Hydrocarbons	0.000366	Kg/yr
Particular Matter	0.00005	Kg/yr
Sulfur Dioxide	0	Kg/yr
Nitrogen Oxide	0.0078	Kg/yr

Table 4.11. Gas emission list for off-grid hybrid model

Table 4.11 presents the list of gas emissions in the off-grid hybrid model, indicating that the system emits almost no gas per year. These results indicate that our following sustainability objectives, the model operates with minimum environmental impact. This improvement highlights the potential of the model to have an environmentally friendly energy solution, contributing to cleaner air and reduced carbon footprint.

4.2.3 Currently On-going Diesel Generator

Export... Optimization Results
Left Double Click on a particular system to see its detailed Simulation Results.
Categorized Overall

Architecture					Cost				System		Biogas				
REC325 (kW)	Biogas (kW)	1kWh LA	20kW SG8500i (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (tons/yr)	Hours	Production (kWh)	Fuel (tons)	O&M Cost ($/yr)	Fuel Cost ($/yr)
10.0	2.00	9	3.46	LF	$42,636	$0.227	$1,256	$11,241	100	0.508	1,134	1,028	0.508	0	2.54

Fig 4.6. Optimization results for the generator model

Fig 4.6 suggests the optimization outcomes for the cutting-edge diesel generator model, which discovered a fee according to a unit of seven.34 BDT. This value reflects the cost of producing electricity through the use of diesel fuel, which is a non-renewable resource. While the value according to the unit is relatively aggressive, the diesel generator version poses environmental worries because of emissions and its dependence on fossil fuels and the reason consequences in a conventional diesel generator might not meet lengthy-term sustainability objectives. However, the version serves as a benchmark for evaluating new renewable electricity solutions and affords perception into ability areas of improvement.

4.2.3.a Cost Summary

Component	Capital	O&M	Fuel	Salvage	Total
Diesel Generator	43,794.8	-	17,182.89	39,269.7	21,707.99
Grid	-	1,232,303.56	-	-	1,232,303.56
Other	109,487	27,371.25	-	-	136,858.75
System	153,281.8	1,259,675.31	17,182.89	39,269.7	1,390,870.29

Table 4.12. Cost summary of the currently running diesel generator model

Table 4.12 suggests the cost summary for the modern diesel generator model, with total system expenses of approximately BDT 1.4 million, including BDT 1.2 million for the acquisition and set up of the generator Life Although diesel turbines provide a competitive preliminary investment even though the continuing operating fees and environmental impact highlight the importance of considering alternative routes emphasizes permanence.

4.2.3.b Emission

Quantity	**Value**	**Units**
Carbon Dioxide	4,759	Kg/yr
Carbon Monoxide	0.103	Kg/yr
Unburned Hydrocarbons	0.00452	Kg/yr
Particular Matter	0.000615	Kg/yr
Sulfur Dioxide	20.6	Kg/yr
Nitrogen Oxide	10.2	Kg/yr

Table 4.13. Gas emission list of the currently running diesel generator model

The list of gas emissions for the diesel generator kind that is presently in use is displayed in Table 4.13, which highlights the large environmental implications. A great amount of CO_2 is produced by the use of the machine every twelve months—4,759 kilograms—which contributes to greenhouse gasoline emissions and climate trade. Furthermore, the version emits 10 kg of nitrogen dioxide and 20 kg of carbon dioxide yearly, endangering both public fitness and air satisfaction. These alarming emissions tiers emphasize how urgently clean, renewable power sources need to be switched to reduce pollution and store the surroundings.

4.3 Discussions

In evaluating the on-grid, off-grid, and currently strolling diesel generator fashions, every choice gives first-rate benefits and annoying conditions. The off-grid hybrid version, even as environmentally pleasant with a 100% renewable thing, contains a great consistent with-unit fee of 25 BDT, making it much less costly for good-sized implementation. In contrast, the current diesel generator model in flight offers a constant reduction worth 7.34 BDT, but an excess greenhouse gas emission of 4,759 kg of CO_2 per year the hearing and specific radiation hazards raise severe environmental issues in comparison, on-grid hybrid versions may be the most balanced opportunity, with ongoing co-unit costs permanent and the lowest greenhouse fuel emissions in Round 7 BDT This model effectively integrates renewable energy with the electricity grid and delivers reliable, cost-effective and sustainable electricity. Thus, in line with environmental and economic objectives, the on-grid model appears as the gold standard alternative for most of these models.

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

We maintained specific task, schedule and milestone from the vary beginning of our project.

Task 1: Literature review on current photovoltaic-biomass hybrid energy System in university campus.

Schedule: 4 weeks (week 1-4).

Milestone: To find out the cost, process, technology and drawbacks of the existing systems.

Task 2: Select a university and specific place.

Schedule: 2 weeks (week 5-6).

Milestone: Specify a university and a specific building of the university from which we can collect the load profile and waste data. Based on this, we will design the model for HOMER Pro.

Task 3: Load profile making.

Schedule: 2 weeks (week 7-8)

Milestone: Making the load profile of our selected building at the university campus, from which we can use load input in our simulation.

Task 4: AutoCAD design of site

Schedule: 2 weeks (week 8-10).

Milestone: Complete AutoCAD design of the selected site, including placement of different lab, classrooms and any other relevant infrastructure.

Task 5: Required area measurement

Schedule: 2 weeks (week 10-12).

Milestone: Measure the required area for installing photovoltaic panels and biomass facilities on the selected site. Ensure accuracy for efficient utilization of space.

Task 6: Biomass source Selection

Schedule: 3 weeks (week 12-15).

Milestone: Research and select an appropriate biomass source for the hybrid energy system. Consider factors such as availability, sustainability, cost, and compatibility with the selected site and technology.

Task 7: Field visit & System design

Schedule: 4 weeks (week 15-19).

Milestone: Conduct a field visit to the selected running biomass project to gather necessary data and assess the site conditions. Based on the collected data, finalize the design of the hybrid energy system using HOMER Pro.

Task 8: Feasibility analysis

Schedule: 2 weeks (week 19-21).

Milestone: Conduct a comprehensive feasibility analysis of the proposed hybrid energy system by evaluating technical, economic, and environmental aspects to determine the viability of the project.

Task 9: Recommendation

Schedule: 1 weeks (week 22).

Milestone: Compile all findings and recommendations into our report and recommendations to stakeholders based on the results of the feasibility analysis and other relevant factors.

5.2 Resources and Cost Management

The title of our study clearly indicate that we are using PV and biomass in our proposed hybrid system. For the PV resource, we take the data from the NASA Data Access View, which gives us the latest data on irradiance, clarity index, active radiation, etc.

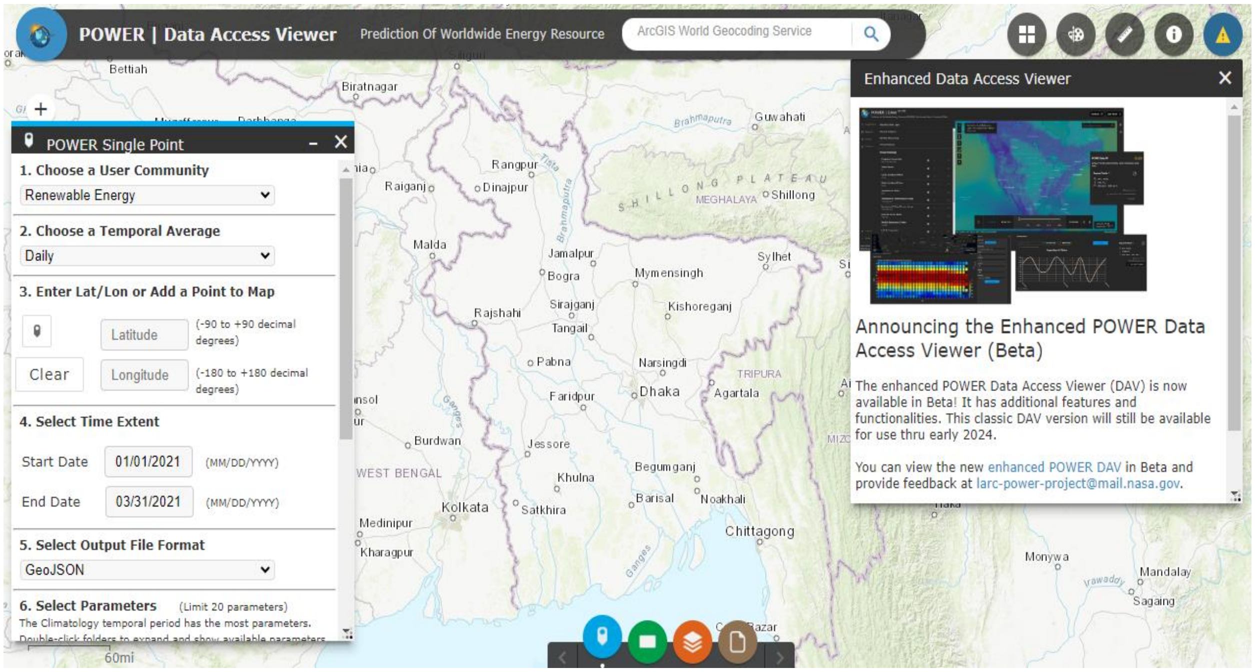


Fig. 5.1. NASA Data Access Viewer (DAV) [28]

The NASA Data Access Viewer (DAV) [28] is a user-friendly interface created to simplify access to NASA's extensive repository of Earth science data. The platform functions as a centralized hub where researchers, scientists, educators, and the general public can access, investigate, and download data sets produced by NASA's Earth monitoring satellites and projects. The DAV offers a simplified and user-friendly browsing experience, enabling users to search for data based on instrument, mission, keyword, geographic region, or temporal range. Users can explore metadata, utilize interactive tools and maps to visualize data and access a range of data formats that fit their analysis requirements. In addition, the DAV provides sophisticated functionalities like as data sub setting, reformatting, and modification, allowing users to customize datasets according to their research needs. The NASA Data Access View is an essential tool for furthering Earth's scientific research, increasing collaboration, and facilitating data-driven decision-making to address global concerns. It offers a broad data catalog and a user-friendly interface.

The block diagram in Fig. 5.2 shows the waste management system and biomass resource of our study. It includes four primary sources. Campus waste, hall waste, hotel waste, and residential waste. Every element represents a potential source of waste within the campus environment. These sources are interrelated and together contribute to the overall waste generation for our suggested hybrid model. The arrows show the flow of waste originating from individual sources towards the

“Total Waste” output, representing the collective waste produced by all sources together. This diagram likely represents several kinds of waste produced on the university campus. It is important to understand how waste is generated to develop effective waste management strategies. This data is necessary for doing a feasibility and cost study for the hybrid energy system.

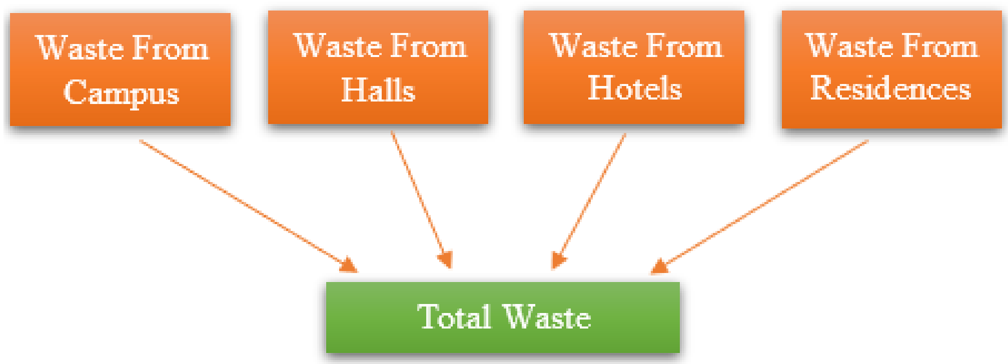


Fig. 5.2. Biomass resource (waste) collection

In our study, we proposed the photovoltaic-biomass hybrid model based on our field visit, campus resources, and HOMER Pro software simulation output. So, for this study, our main cost was the field visit at the Skate Integrated Landfill and Resource Recovery Center (IL&RRC), Jashore, which was 5000 BDT.

5.3 Lesson Learned

While doing this, we learned several important lessons through the research and analysis process.

Lesson 1: Detailed Data Collection and Analysis

The main lesson learned was the significance of efficient data gathering and examination. Gathering accurate information on variables such as energy usage, resource accessibility, technical capability, and environmental issues is crucial for conducting a thorough feasibility analysis and determining the resulting costs. This involves examining past energy usage statistics, investigating possible sources of biomass, and studying the technical details of solar systems. Through a detailed analysis of these concerns, the study can offer specific insights into the practicality and financial advantages of introducing a hybrid energy system on the university campus.

Lesson 2: Technological Adaptation and Innovation

The study highlighted the necessity of adopting and developing new technologies to close the gap between theoretical possibility and real-world use. It is essential to include progress in photovoltaic and biomass technologies, while taking into account specific variables and limitations of the site, in order to create a customized hybrid energy system that optimizes efficiency and sustainability. Furthermore, keeping up to date with developing trends and advances in renewable energy improves the project's significance and long-term sustainability.

Topic 3: Study of Regulations and Policy Concerns

Effectively understanding regulatory frameworks and policy landscapes is critical for the successful execution of a renewable energy project. Gaining a comprehensive understanding of local regulations, motives, and regulatory processes, as well as being able to forecast possible policy changes or market dynamics, is crucial for accurately evaluating the feasibility and cost outcomes. Furthermore, promoting supportive policies and establishing collaborations with appropriate government agencies may encourage the efficient implementation and promotion of the hybrid energy system.

Lesson 4: Holistic Assessment and Risk Management

Performing a comprehensive evaluation while taking proactive measures to control risks is essential in order to tackle potential difficulties and uncertainties that are inherent in complicated projects. By identifying risks associated with the integration of technology, market volatility, funding, and operational logistics, it becomes possible to execute measures to minimize the negative impact on project objectives and investments. In addition, taking into account the socio-economic effects, impacts on the environment, and community involvement promotes an in-depth understanding of the project's sustainability and long-term viability.

CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Social and Global Impact

The transition to energy efficiency has become essential to combat climate change and ensure energy security. This study examines the potential economic, social and international consequences of implementing such a system. It specifically investigates the influence on infrastructure development, energy generation and consumption patterns, employment opportunities, contribution to GDP, enhancements in quality of life, and global effects. The aim of this research initiative is to offer insights into sustainable energy solutions for educational institutions and beyond by combining solar photovoltaic technology with biomass energy.

6.1.1 Impact on Infrastructure

The integration of a photovoltaic-biomass hybrid system requires significant updates to existing infrastructure. Universities adopting this system will need to invest in both solar panel installations and biomass processing facilities, which may include land acquisition or modification of existing areas to accommodate these facilities. This development can encourage improvements in local infrastructure, such as improved electrical grids and increased transportation routes for the delivery of biomass materials, which are necessary for the continued operation of biomass nb energy systems. Infrastructure improvements will not only support the energy system but can also lead to increased capabilities in handling emergency power supplies, increasing campus resilience to power outages or local energy supply issues. Additionally, the development of such infrastructure can serve as a living laboratory for engineering and environmental studies, providing learning experiences that are directly linked to real-world applications in renewable energy.

6.1.2 Impact on Energy Generation and Consumption

Implementing a hybrid energy system would significantly change the way universities generate and use energy. By generating energy on site, the university can significantly reduce its reliance on external energy sources, usually fossil fuels. This reduction in energy imports reduces the campus' carbon footprint and is consistent with broader environmental goals.

Economically, the predictability in energy costs achieved through such systems enables better financial planning and potential cost savings in the long term. Furthermore, the surplus energy generated during low-demand periods could potentially be sold back to the grid, creating an additional revenue stream for the institution.

The university might be able to attain net-zero energy status, in which the entire quantity of energy used by the campus annually is almost equal to the amount of renewable energy produced on the site, due to the localized production of energy through solar and biomass. Such energy providing independence guarantees consistency in the cost of energy and protects against unpredictable energy prices in the global market.

6.1.3 Impact on Employment Creation

The installation, maintenance, and operation of a photovoltaic-biomass system can create numerous employment opportunities. Initially, there would be a surge in jobs related to the construction and installation of the system. Long-term employment effects would arise from the need for ongoing maintenance of solar panels, energy management, and the handling and processing of biomass materials.

Moreover, by incorporating this hybrid system, universities can also uphold academic employment by creating new research positions and teaching opportunities that focus on sustainable energy technologies, environmental policy, and related fields. These roles not only contribute to direct employment but also help prepare students for future careers in rapidly increase green industries.

6.1.4 Impact of Contribution to GDP

The economic impact of the adoption of such alternative energy systems can also be seen through their contribution to gross domestic product (GDP). Investment in renewable energy technologies is recognized as a potential stimulator of economic growth. Direct investment in renewable energy contributes to GDP through manufacturing, construction and industrial sectors. Indirectly, the implementation of such policies can reduce university energy costs, freeing up institutional funds for other uses that can contribute to economic activity, such as educational activity expanding diversity, improving campus facilities, and increasing recruitment.

Investment in renewable energy system mitigates the risk of energy price fluctuations and provides long-term economic stability by addressing geopolitical concerns associated with fossil fuel dependence. A stable energy supply promotes corporate expansion and investment, accelerates GDP growth, and supports general economic growth. The adoption of innovative energy solutions drives technological advancement and improves the competitiveness of the university and the surrounding community. Research and development in renewable energy technologies generates intellectual property, creates jobs and boosts economic growth, and increases GDP.

6.1.5 Influence on Quality of Life

Installing a sustainable energy system on campus can greatly enhance the campus environment by mitigating air pollution caused by coal combustion. It improves the standard of life on campus and was a way for students to learn about and appreciate sustainable practices. Furthermore, reducing energy expenses might result in decreased tuition fees or increased funding for student services, so enhancing the overall quality of education. The presence of a cutting-edge renewable energy system can also enhance the institutional reputation.

Additionally, Educational enhancements through new learning opportunities in renewable energy sectors prepare students better for modern workforce demands, increasing their employability and career prospects in fast-growing green industries. This educational impact, in turn, enhances personal and professional development, improving overall life satisfaction and well-being for the campus community.

6.1.6 Educational and Awareness Implications

This system provides practical, hands-on learning opportunities for students, especially those studying environmental science, engineering and sustainability. Integrating the ongoing activities of energy systems into the curriculum allows students to analyze data, monitor results, and propose changes, thus providing them with practical learning and understanding on it in terms of renewable energy systems. Practical understanding can also be enhanced. By adopting an interdisciplinary method, students can also constructively utilize theoretical standards in practical scenarios, even as additionally enhancing their problem-solving abilities, critical thinking skills and project management capabilities. Practical experience enhances student involvement, prepares them for a profession within the environmentally pleasant industry, and enhances their overall knowledge and understanding of sustainable technology.

6.1.7 Reduction of Carbon Emissions

One of the primary global effects of implementing a photovoltaic-biomass hybrid electricity system is the reduction of carbon emissions. The university campus may notably decrease its carbon footprint with the aid of switching from traditional fossil fuel-based energy system era to apply renewable energy sources. As it reduces dependence on non-renewable energy sources and decreases carbon emissions, So The implementation of a hybrid power system is in keeping with worldwide desires for sustainability, together with the Sustainable Development Goals of the United Nations and the Paris Agreement. This flow now not simplest facilitates to mitigate the effects of climate change but additionally establishes the university as a pioneer in worldwide projects to promote sustainability.

6.1.8 Global Energy Transition and Sustainable Development Goals

The evaluation to renewable energy is a key aspect of reaching the Sustainable Development Goals (SDGs) mentioned through the United Nations. By sporting out studies on the feasibility and cost analysis of a photovoltaic-biomass hybrid power system, the thesis paper straight away contributes to SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). Furthermore, the studies aligns with broader efforts to transition towards a more sustainable and equitable strength system globally.

6.1.9 Enhancing Global Knowledge and Technology Exchange

The development and optimization of hybrid energy systems can foster collaboration across borders, involving international researchers, policymakers, and industry leaders. This global exchange of knowledge and technology amplifies the impact of the original research, contributing to a more sustainable and interconnected world.

The feasibility and cost analysis of a photovoltaic-biomass hybrid energy system in a university campus setting is more than an academic exercise. It is a example of broader impacts, enveloping economic benefits through infrastructure development and energy savings, societal improvements through enhanced quality of life and educational advancements, and global contributions to sustainability and international cooperation. This thesis not only underscores the substantial benefits of integrating renewable energy systems into daily operations but also serves as a catalyst for broader, scalable change toward sustainable global energy solutions.

6.2 Environmental and Ethical Issues

As the assumption of renewable energy technologies along with photovoltaic (PV) and biomass systems continues to gain momentum, it's essential to look at the environmental and ethical implications associated with their implementation, particularly in projects like the implementation of a hybrid energy system within university campuses.

6.2.1 Environmental Sustainability

6.2.1.a Resource Utilization and Environmental Impact

While PV and biomass systems are taken into consideration as renewable energy resources, their implementation calls for careful consideration of resource utilization and environmental impact. During the manufacturing and installation process, waste is produced in addition to the use of resources and energy. Similarly, improper control of biomass electricity manufacturing should result in deforestation or unsustainable harvesting strategies. Therefore, it is essential to evaluate the lifecycle environmental effects of those structures, such as aid extraction, manufacturing, operation, and decommissioning, to ensure their overall sustainability.

6.2.1.b Land Use and Ecosystem Impact

The deployment of a hybrid energy system may additionally raise worries associated with land use and environment effect. Solar panels require significant land area for installation, that can battle with modern land uses like farming or herbal areas. Additionally, biomass feedstock production might also involve land conversion or monoculture farming practices, probably leading to habitat loss, biodiversity decline, and soil degradation. Proper website choice and land management techniques are important to minimize those environmental impacts and ensure the conservation of natural ecosystems.

6.2.1.c Aesthetics and Landscape Integration

The visual impact of renewable energy infrastructure on the aesthetics of the surroundings is another critical consideration. The installation of PV panels and biomass facilities might also regulate the visual panorama of university campuses, doubtlessly affecting the scenic beauty and cultural significance of the surroundings. Therefore, efforts have to be made to combine renewable energy systems harmoniously into the campus surroundings via thoughtful layout, landscaping, and architectural issues. Engaging stakeholders, including students, faculty, and local communities, in the decision-making process can assist address aesthetic worries and ensure the maintenance of the campus's visual enchantment.

6.2.2 Ethical Considerations and Responsibilities

6.2.2.a Equity and Access to Benefits

Ethical considerations related to equity and access to benefits must be taken into consideration in renewable energy initiatives. While the implementation of a hybrid energy system can also yield environmental and economic blessings, it is crucial to ensure these benefits are also shared equally amongst all stakeholders. This consists of thinking about the needs and interests of marginalized or inclined groups, in addition to addressing capability disparities in get right of entry to to renewable energy sources and possibilities for participation in decision-making strategies. Upholding principles of social justice and inclusivity is crucial to promoting ethical consequences and fostering community empowerment.

Furthermore, Ethical considerations rise up in accomplishing a cost-benefit analysis of the proposed energy system. It's important to correctly evaluate the financial implications for the university, along with initial funding costs, operational expenses, and capacity financial savings over the years. Decision-makers have to ensure that the project represents a accountable use of financial resources.

6.2.2.b Transparency and Accountability

Transparency and accountability are fundamental ethical principles that should have guide proper planning, implementation of this planning, and operation of renewable energy. Stakeholders have the right to acknowledge information about the environmental and social impacts of the project, as well as opportunities for participation and also have right to give meaningful feedback. Thus, practitioners and university officials have a responsibility to provide transparent and accurate information, conduct successful impact assessments, and establish mechanisms for accountability and complaint resolution. By promoting openness and accountability, ethical standards can be upheld, and trust between project advocates and stakeholders can be maintained.

6.2.2.c Long-Term Sustainability and Intergenerational Equity

The concept of long-term sustainability and intergenerational equity is one of moral principal of renewable energy projects. As environmental stewards, the present generation has a moral responsibility to ensure that their actions do not compromise the well-being of future generations so decisions regarding the consumption of PV-biomass hybrid energy systems should role is guided by the principles of sustainability, resilience and intergenerational equity It also includes measures to reduce uncertainty and prioritize the interests of future generations to fulfill ethical obligations and support a legacy of sustainability.

The Feasibility and cost analysis of photovoltaic-biomass hybrid energy systems on university campuses requires careful examination of environmental and ethical considerations Ethical responsibilities must be integrated at all stages of project development and execution. By addressing these issues thoughtfully and responsibly, renewable energy projects can contribute to both environmental sustainability and ethical decision-making, thereby fostering a more equitable and sustainable future for all.

6.3 Utilization of Existing Standards or Codes

Application of existing standards and regulations is essential to ensure hybrid energy system efficiency, safety and reliability. These policies, which combine renewable energy with large-scale storage technologies, play a key role in addressing energy challenges and achieving sustainable development. The standards govern many areas, including design, design, operation, maintenance, grid connection, safety, emissions, and compliance. Compliance with this standard facilitates seamless integration into the power system, reduces environmental impact, and ensures compliance with regulatory requirements. Overall, standards compliance is essential for the successful implementation and widespread adoption of hybrid energy systems, contributing to the transition to a more sustainable energy future. Here are some codes for implementing renewable energy systems.

6.3.1. Design and Integration Standards

The design and integration of components in a hybrid energy system ensure compatibility and efficiency. These may include standards for photovoltaic (PV) modules, wind turbines, biomass generators, energy storage systems, inverters, and grid interconnection devices.

6.3.2. Installation and Installation Guidelines

This provides guidelines for the installation, commissioning, and testing of hybrid power systems. They cover site inspections, equipment installation practices, electrical and mechanical safety measures, and provision of services to mitigate risk and ensure system reliability.

6.3.3. Performance Standards and Maintenance Practices

This refers to performance practices and maintenance procedures throughout the life cycle of an integrated energy system. System monitoring, control, performance evaluation, preventive maintenance, and troubleshooting procedures are covered to ensure optimal system performance and extend equipment life.

6.3.4. Grid Connectivity Regulations

This governs the grid connections of hybrid energy systems, ensuring compliance with regulatory requirements and grid compatibility. Issues such as voltage regulation, power quality, and grid stability are addressed to facilitate seamless integration of the electricity grid.

6.3.5. Safety Standards and Emergency Programs

It establishes safety procedures and emergency procedures for hybrid power systems, addressing hazards associated with electrical, mechanical, and chemical components. Emphasis is placed on worker safety, equipment protection, and mitigation strategies to prevent accidents and ensure a safe work environment.

6.3.6. Environmental and emission standards

This include environmental and emission regulations for hybrid energy systems, especially for biomass and other technologies depending on temperature. Emission limits for air pollutants such as particulate matter, nitrogen oxides (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) are defined to make environmental impacts small and ensure compliance with regulatory standards.

6.3.7. Certification and Compliance Requirements

Certification and compliance with industry-specific regulations and certification programs include certifications of equipment performance, product quality, environmental management, and occupational health and safety to demonstrate compliance with industry standards and regulatory requirements. Additionally excess energy generators intending to sell electricity from a generating station are required 5 MW or more in order to obtain power generation license from Bangladesh Energy Regulatory Commission Executive Committee (BERC).

6.3.8 Tax Approval and "Green Energy" Projects

BERC, in consultation with the MPEMR/SEDA Department of Power, was responsible for approving energy tariffs for 5-capacity renewable energy projects MW or above, in accordance with the BERC Regulations 2003.

Hybrid energy systems can only be built, set up, run, and maintained correctly by following particular standards and regulations that are based on industry best practices. This is why we should all do our part to switch to renewable energy sources; doing so will help ensure a greener energy future.

6.4 Other Concerns

By adopting renewable energy (RE) sources and aligning with the global shift towards cleaner energy, Bangladesh has the potential to attain sustainable development. Nevertheless, the nation must overcome various obstacles, encompassing financial, technological, and regulatory aspects.

6.4.1 Financial Challenges

Renewable energy (RE) projects face significant financing hurdles, stemming from their sophistication, unpredictability, and associated risks. Convincing financial institutions to support RE projects proves difficult due to the uncertainty of new technologies and long payback periods. Also, the initial capital requirement is a barrier for entrepreneurs, especially when there are cheaper alternatives. Geographical issues and changes in the availability of renewable resources further complicate project development, adding complexity to economic analysis.

6.4.2 Technical Limitations

The development of RE solutions is hampered by technical limitations. Poor reliability of the electricity supply, coupled with uncertainty in technological progress, impedes the sustainable development of the industry. The limited knowledge in effective RE practices and tools compounds the sectors' development challenges. Additionally, poorly trained workers create safety concerns and delays in energy production, limiting investor interest and confidence in the project.

6.4.3 Policy and Regulatory barriers

Existing policies lack firmness and comprehensiveness, creating investor uncertainty. Conflicts of interest between investors and government aid distribution objectives undermine business development. A fragmented and inconsistent regulatory framework, coupled with a lack of technical expertise, hinders investment and governance. Top-down policy formulation fails to adequately involve relevant stakeholders, hindering business growth and development.

6.4.4 Legal and Regulatory Concerns

Despite legal support, practical implementation of regulations, such as provisions in tax credits, remains limited. New incentives and regulatory reforms are needed to stimulate RE investment and ease stakeholder burdens.

6.4.5 Lack of Awareness

There is a lack of community involvement and awareness about sustainable energy policy, especially in rural areas. Enhancing public awareness and participation mechanisms is crucial for adoption of RE and effective policy implementation. Solution: Comprehensive policy review and reform is needed to prioritize RE investment and address regulatory gaps. Reallocating support from conventional to renewable energy sources can stimulate industry growth. Strengthening institutional arrangements and strengthening cooperation between the public and private sectors is essential to overcome financial and technical barriers. Increased public awareness and participation programs are needed to generate support for RE programs and promote sustainable energy policy.

To effectively address these challenges, a comprehensive strategic plan must be developed in partnership with government, industry, and the public. This initiative will enable Bangladesh to make its renewable energy more efficient while also achieving its strategic sustainable development goals.

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The aim of the study was to evaluate the effectiveness and financial feasibility of introducing a photovoltaic-biomass hybrid energy system on a university campus in Bangladesh through an in-depth assessment of its performance and costs. By conducting a full evaluation of both on-grid and off-grid hybrid models, along with the existing diesel generator system, several significant conclusions were drawn.

First and foremost, the on-grid hybrid model showed significant potential as a sustainable and economically viable energy option. This model provides a balanced solution to meet energy needs while minimizing harm to the environment, with a renewable component of 99.9% and a comparatively cheap unit cost of 7.57 BDT. The combination of solar photovoltaic (PV) and biogas generation has demonstrated its efficacy in fulfilling dependable power while also mitigating greenhouse gas emissions. In addition, the comprehensive cost analysis highlighted the initial capital investment and continuous maintenance expenses necessary for the on-grid hybrid system, offering useful information for financial forecasting and decision-making.

On the other hand, the off-grid hybrid concept, while entirely reliant on renewable energy sources, faced difficulties due to its higher per-unit costs (25 BDT) and the requirement for sophisticated storage systems. Although the off-grid concept provides energy self-sufficiency and resilience, its long-term cost-effectiveness may be affected by increased operational and maintenance costs. However, it continues to be a feasible choice for areas with limited or limited access to the power grid.

Moreover, the comparison with the diesel generator system that is currently in use highlighted the environmental and economic benefits of renewable energy sources. Although the diesel generator model had a lower cost per unit (7.34 BDT), it had notable greenhouse gas emissions and posed environmental risks, highlighting the need to shift to greener energy sources soon.

Ultimately, the on-grid hybrid model appeared to be the most favorable choice for the university campus, as it provided a balanced blend of dependability, sustainability, and cost efficiency. Through the utilization of solar photovoltaic (PV) and biogas generation technologies, the campus can decrease its dependence on fossil fuels, mitigate carbon emissions, and actively participate in environmental conservation initiatives. The results of this study offer important knowledge for policymakers, energy strategists, and individuals participating in renewable energy initiatives, facilitating well-informed decision-making and encouraging the implementation of sustainable energy solutions in similar contexts. In addition, future research may prioritize the further optimization of hybrid energy systems, technology developments, and government actions to speed up the shift towards a more environmentally friendly and sustainable energy future.

7.2 New Skills and Experiences Learned

During the analysis of feasibility and cost of a PV-Biomass hybrid energy system on a university campus in Bangladesh, we gained new skills and experiences that were crucial for the success of the thesis project. These insights will be valuable for future initiatives in renewable energy and sustainability initiatives.

Real-time data collection from field: real-time data collection provides instantaneous access to current information on ongoing processes and events. This immediate data facilitates rapid decision-making and intervention when required. By gathering data in real-time, the data collected is more precise and accurate, as it accurately represents the current situation in the field. Accuracy is essential in order to make well-informed decisions and reach dependable conclusions.

Advanced energy system analysis: the thesis topic focused on conducting a thorough analysis and evaluation of renewable energy systems, with a particular focus on hybrid configurations that combine photovoltaic and biomass technologies. During this procedure, an in-depth knowledge of energy system modeling, performance analysis, and feasibility assessment was established. This involved evaluating variables such as the availability of resources, the potential for energy production, the economic feasibility, and the impact on the environment.

Technological integration: the process of combining several renewable energy technologies, such as PV panels and biomass generators, necessitated a comprehensive comprehension of their specifications, functions, and operating characteristics. Gaining proficiency in properly incorporating these technologies into a hybrid energy system improved our understanding of integrating renewable energy and optimizing the system.

Economic evaluation and financial modeling: encompass the process of doing a comprehensive cost study. This involves creating financial models, evaluating the capital expenditures and operational costs, and determining the return on investment for the proposed hybrid energy system. This expertise offered valuable knowledge on financial modeling methodologies, cost-benefit analysis, and risk assessment specifically in relation to renewable energy projects.

Environmental impact assessment: the evaluation of the environmental impact of the proposed hybrid energy system included the assessment of elements such as greenhouse gas emissions, air quality, and resource depletion. Gaining an in-depth awareness of the environmental impacts associated with energy systems is essential for making well-informed decisions and promoting long-term sustainability.

Project management and research abilities: effective project management abilities were necessary for managing a complex research project, such as conducting a feasibility and cost analysis of a energy system. This included establishing project objectives, assigning money, following schedules, and coordinating research initiatives. In addition, the act of completing literature reviews, gathering data, and analyzing outcomes improved research abilities and proficiency in research methods.

Interdisciplinary collaboration: engaging with specialists from other fields, such as engineering, environmental science, and economics, was crucial for carrying out a thorough investigation. Participating in interdisciplinary collaboration facilitated the development of teamwork, communication skills, and the capacity to include multiple points of view in the research process.

Problem-solving and decision-making: these are necessary abilities when dealing with the obstacles and uncertainties that come with renewable energy initiatives. These projects require critical thinking and the ability to make informed decisions. An essential part of overcoming obstacles and accomplishing project objectives was the identification of potential barriers, the evaluation of different solutions, and the making of informed judgments.

The photovoltaic-biomass hybrid energy system's feasibility and cost analysis offered significant opportunities to gain expertise in renewable energy technology, economic analysis, environmental evaluation, project management, and interdisciplinary collaboration. These abilities will play a crucial role in tackling future difficulties and facilitating the transition to sustainable energy in Bangladesh and other regions.

7.3 Future Recommendations

There are some scopes of future development in our proposed hybrid model and also we have some recommendation for future projects related renewable energy.

Enhanced Biomass Monitoring and Control: Implement modern sensor technologies to improve the monitoring and control of biomass in the Photovoltaic-Biomass Hybrid Energy System. By combining sensors to measure biomass feedstock quality, moisture content, and combustion efficiency, it is possible to enhance energy production and maximize resource utilization.

Smart Grid Integration: Investigate possibilities for combining the hybrid energy system with smart grid technology to facilitate two-way energy transfer, demand response, and support grid stability. Integrating smart grid technology can improve energy management, optimize grid operations, and maximize the value of renewable energy supplies.

Optimizing Hybrid Systems: Engage in additional research and analysis to enhance the performance and efficiency of the Photovoltaic-Biomass Hybrid Energy System. These activities may involve doing sensitivity studies, investigating different system configurations, and adjusting operating parameters to maximize energy production and reduce expenses.

Community Engagement and Stakeholder Collaboration: Involve university students, professors, staff, and local communities in renewable energy initiatives and decision-making processes. Promote cooperation with governmental entities, energy utilities, and industry stakeholders to advance sustainable energy practices and foster joint efforts toward achieving a low-carbon future.

Capacity Building and Knowledge Sharing: Allocate resources towards capacity-building efforts and knowledge exchange programs to enhance the abilities of local communities and promote technical proficiency in renewable energy technology. Offer training programs, workshops, and educational resources to improve knowledge, abilities, and involvement in renewable energy efforts.

Policy Advocacy and Institutional Support: Engage in policy advocacy and provide institutional support to encourage broad adoption of sustainable energy technology in Bangladesh by advocating for favorable policies, regulations, and incentives. Engage in cooperation with government agencies, policymakers, and industry players to establish an ideal environment for the implementation and financing of renewable energy.

Research and Development: Distribute funds towards investing in research and development (R&D) to foster innovation and technological developments in renewable energy systems. Allocate resources into research projects, pilot demonstrations, and technology transfer programs in order to speed up the shift towards a sustainable energy future.

Continuous Monitoring and Evaluation: Implement a systematic methodology to continuously monitor, evaluate, and assess the performance of the Photovoltaic-Biomass Hybrid Energy System. Consistently evaluate the performance of the system, identify areas that need enhancement, and apply necessary actions to ensure the ongoing effectiveness and viability of the renewable energy project.

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APPENDIX A
TURNITIN CHECK REPORT

203-33-1318

ORIGINALITY REPORT

17%	15%	11%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dspace.daffodilvarsity.edu.bd:8080 Internet Source	4%
2	Submitted to Daffodil International University Student Paper	1%
3	www.mdpi.com Internet Source	1%
4	"Affordable and Clean Energy", Springer Science and Business Media LLC, 2021 Publication	1%
5	Md Al-Amin, Mehedi Hassan, Imran Khan. "Unveiling mega-prosumers for sustainable electricity generation in a developing country with techno-economic and emission analysis", Journal of Cleaner Production, 2024 Publication	<1%
6	Submitted to University of Greenwich Student Paper	<1%
7	elibrary.tucl.edu.np Internet Source	<1%

APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Complex Engineering Problems (P) Solving		
	Attributes	**Explanation**
P1	Depth of knowledge required	In this study we need very deep knowledge in renewable energy field, about its applications, implementation and much more efficiency on simulation software named HOMER PRO and RETScreen.
P2	Range of conflicting requirements	Here assuming load vs real-time load will be the most conflicting things. Because there is a shortage of such data analysis in Bangladesh. But assuming load is mandatory for our research.
P3	Depth of analysis required	Since we want to work with hybrid powerplant model, if we want to get realistic data output from it then we need a lot of deep real time data analysis. We also need to do real-time load analysis of the reference university campus.
P4	Familiarity of issues	We have studied a lot on this topic but there will be some issues in implementation surely. Such as engaging all kinds of data, loads, field survey information together properly.
P5	Extent of applicable codes	We will do our simulation in HOMER PRO and RETScreen software, approximate floor design in AutoCAD and the data analysis will be done in MS Excel so there isn't necessity of codes here.
P6	Extent of stakeholder involvement and conflicting requirements	In Bangladesh government controls all types of powerplant so there isn't much scope for stakeholders
P7	Interdependence	We want the proposed hybrid powerplant as a solution for load shedding problems in a university campus or as backup while generator will under maintenance. And this problem of load shedding is the key problem for any educational institute's minor and major problems because we are totally helpless without electricity in 2023.

Complex Engineering Activity (A) Solving		
	Attributes	**Explanation**
A1	Range of resources	Here we will use NASA Power Database as our key data resource which is directly give us real-time data from satellite. And for load assuming we will use electricity bill of our reference university campus.
A2	Level of interaction	Actually, this project is a complete interaction of solar PV, bio-mass and diesel generator. To make this realistic model, we have to interact with many things such as data, loads and costs.
A3	Innovation	Hybrid renewable powerplant including biomass is a breakthrough innovation in the era of typical solar PV in our country.
A4	Consequences of society and environment	This project has several benefits like reducing greenhouse gas emissions and enhancing energy security. However, it can also lead to land use and habitat disruption, resource scarcity, and other environmental and social challenges. Effective planning and regulation are crucial to maximize benefits and minimize negative impacts.
A5	Familiarity	The study involves addressing challenges like resource variability, integrating multiple technologies, energy storage, grid integration, environmental considerations, regulatory compliance, and cost-benefit analysis. Engineers need expertise in various disciplines to tackle these complex issues effectively.