TECHNO-ECONOMIC ANALYSIS OF GRID CONNECTED SOLAR PV AND BIOGAS BASED ELECTRICITY GENERATION FOR DAIRY FARM 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.

Submitted by
Md. Mehedi Hasan 191-33-837
Syduzzaman 191-33-930

Supervised by
Ms. Nusrat Chowdhury
Assistant Professor
Department of Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Faculty of Engineering
DAFFODIL INTERNATIONAL UNIVERSITY

JULY, 2023

DECLARATION

I hereby declare that this project "**Techno-economic analysis of grid connected Solar PV and Biogas based Electricity Generation for dairy Farm 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

Mehedi

____

Name: Md. Mehedi Hasan
ID: 191-33-837

Syduzzaman

____

Name: Syduzzaman
ID: 191-33-930

APPROVAL

The project entitled **“Techno-economic analysis of grid connected Solar PV and Biogas based Electricity Generation for dairy Farm in Bangladesh”** submitted by **Md. Mehedi Hasan (191-33-837) & Syduzzaman (191-33-930)** 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 **July, 2023.**

Signed

____

Ms. Nusrat Chowdhury
Assistant Professor
Department of Electrical and Electronic Engineering
Faculty of Engineering
Daffodil International University

Dedicated

To

Our

Parents

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

PV	Photovoltaic
Agro	Agronomy or Agriculture
kg	Kilogram
W	watt
KW	Kilowatt
kWh	kilowatt hour
m^2	square meter
yr	Year
NPC	Net Present Cost
AC	Alternating current
DC	Direct current
HOMER	Hybrid Optimization of Multiple Energy Resources
N2	Nitrogen
CH4	Methane
H2	Hydrogen
CO2	Carbon Dioxide
O2	Oxygen
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
NEC	National Electric Code
BNBC	Bangladesh National Building Code
etc	Et cetera

LIST OF SYMBOLS

Symbol	*Name of the symbol*
$	Dollar
%	Percentage

ACKNOWLEDGEMENT

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 his useful advice and help. Also thank him very much for giving us the opportunity to work with this project.

We also want to convey our thankfulness to **Professor Dr. Md Shahid Ullah, Department 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 study conducts a techno-economic analysis of grid-connected solar photovoltaic (PV) and biogas-based electricity generation for Amin Mohammad Group Agro Ltd., a dairy farm that is located at Ashulia Model Town-2, Khagan, Savar, Dhaka (23° 52' 57" N, 90° 18' 47" E). The objective is to assess the feasibility and economic viability of integrating these renewable energy sources to meet the Amin Mohammad Group Agro Ltd. farm's electricity demand. We analyzed optimization results for solar radiation of 4.66 kWh/m^2/day, biomass resource of 5.91 tonnes/day, and load demand of 1,186 kWh/day. We used 180 KW of PV, a 40 KW biogas generator, and a 180 KW converter with a utility grid connection by net metering. The simulated cost of electricity is $0.052/kWh, with a net present cost of $285,669 and an operating cost of $9,344/yr. The system will consume 936 tonnes of biomass per year to supply electricity. HOMER software is employed for modeling and simulating various scenarios, considering solar irradiance, biogas production, system components, and economic parameters. Results demonstrate that a hybrid system of grid-connected solar PV and biogas generation can effectively fulfill the Amin Mohammad Group Agro Ltd. farm's electricity needs, reducing grid dependency and greenhouse gas emissions. The study highlights the importance of using HOMER software for techno-economic analysis, providing insights into the viability and economic benefits of grid-connected solar PV and biogas-based electricity generation for dairy farms in Bangladesh, contributing to sustainable energy solutions in the agricultural sector.

Keywords: PV, HOMER, biogas, W, KW, kWh etc.

CHAPTER 1
INTRODUCTION

1.1 Background

In Bangladesh, dairy farming plays a crucial role in the agricultural sector, providing a significant source of livelihood and nutrition. However, dairy farms face challenges in meeting their energy requirements, particularly for milk processing, cooling, and lighting. The reliance on traditional grid-based electricity is often limited by issues of reliability, availability, and affordability. To address these challenges, alternative energy solutions such as solar photovoltaic (PV) and biogas-based electricity generation have gained attention.

Solar photovoltaic (PV) technology offers a viable answer by making use of the plentiful sunlight Bangladesh has to produce clean, renewable electricity.[1] In contrast, biogas technology creates biogas, a mixture of methane and carbon dioxide that may be utilized as a fuel for energy generation, using organic waste like cow dung from dairy farms.[2]

Integrating grid-connected solar PV and biogas-based electricity generation systems in dairy farms can lead to several benefits. Firstly, it can enhance the energy self-sufficiency of dairy farms, reducing their reliance on conventional grid electricity and fossil fuels. Secondly, it can improve the environmental sustainability of dairy farming by reducing greenhouse gas emissions associated with conventional energy sources.[3] Additionally, it can contribute to the economic viability of dairy farms by reducing energy costs and creating opportunities for revenue generation through the sale of excess electricity to the grid.

To assess the techno-economic feasibility of grid-connected solar PV and biogas-based electricity generation systems for dairy farms in Bangladesh, advanced modeling and analysis tools such as HOMER software can be employed.[4] HOMER software enables a comprehensive evaluation of various factors, including system sizing, energy production, cost analysis, and economic viability. By utilizing HOMER software, a techno-economic analysis can provide valuable insights into the potential of integrating solar PV and biogas technologies for electricity generation on dairy farms in Bangladesh.

In this study, we aim to conduct a techno-economic analysis using HOMER software to evaluate the feasibility and economic viability of grid-connected solar PV and biogas-based electricity generation system for dairy farms in Bangladesh like Amin Mohammad Group Agro Ltd. which is located at Ashulia Model Town-2, Khagan, Savar, Dhaka. By considering factors such as capital and operational costs, energy production, payback periods, and potential revenue streams, we seek to provide valuable information for policymakers, investors, and dairy farm owners to make informed decisions regarding the adoption of these integrated energy solutions.

1.2 Problem Statement and Proposed solution

The dairy farms in Bangladesh is facing challenges with expensive grid electricity costs and an unreliable power supply. Dairy farms require a reliable and sustainable source of electricity to maintain their operations. Additionally, the use of fossil fuel-based electricity generation systems and dairy farm waste contributes to greenhouse gas emissions and other environmental concerns.

The proposed solution is to implement grid-connected solar PV and biomass-based electricity generation systems for dairy farms in Bangladesh. These systems can provide a reliable and sustainable source of electricity, reduce energy costs, proper waste management, and contribute to the development of the renewable energy sector in Bangladesh.

1.3 Aims and Objectives

The main aim of this study is to conduct a techno-economic analysis of a hybrid renewable energy system that combines grid-connected solar PV and biogas-based electricity generation for Amin Mohammad Group Agro Ltd., a dairy farm in Bangladesh using HOMER software. Specific objectives are Given below:

1. To assess the electricity demand of the dairy farm and evaluate the technical feasibility of the proposed hybrid renewable energy system.

2. To optimize the design of the hybrid renewable energy system by selecting the appropriate renewable energy options.
3. To evaluate the economic feasibility of the proposed system by estimating the total cost of the system and comparing it with the cost of the existing electricity supply options for the dairy farm.
4. To analyze the environmental performance of the proposed system by estimating the carbon emissions reduction and assessing the environmental impact of the renewable energy technologies.
5. To provide recommendations for policymakers, investors, and dairy farm owners interested in adopting renewable energy solutions in Bangladesh.

1.4 Brief Methodology

The methodology for this study consists of the following steps:

1. Collecting data on the electricity demand of the dairy farm, solar radiation, biomass availability, and other relevant parameters.
2. Conducting a literature review to identify relevant technologies, procedures, and best practices.
3. The technologies and procedures used in this study include solar PV panels, biomass gasification systems, grid connection systems.
4. Developing a model of the hybrid renewable energy system in HOMER software and simulating the performance of the system under different scenarios.
5. Optimizing the design of the system by selecting the appropriate renewable energy options to minimize the total cost of the system while meeting the electricity demand of the dairy farm.
6. Conducting a techno-economic analysis of the proposed system by estimating the total cost of the system, including capital and operating costs, and comparing it with the cost of the existing electricity supply options for the dairy farm.
7. Analyzing the environmental performance of the proposed system by estimating the carbon emissions reduction and assessing the environmental impact of the renewable energy technologies.

8. Providing recommendations for policymakers, investors, and dairy farm owners interested in adopting renewable energy solutions in Bangladesh.

1.5 Gantt Chart

Table1.1 The implementation schedule or Gantt chart

Task	Duration (weeks)	Start Date	End Date
Data collection	2	1/5/2022	14/05/2022
System modeling and simulation	4	15/05/2022	11/6/2022
Optimization of the system design	2	12/6/2022	25/06/2022
Techno-economic analysis	3	26/06/2022	16/07/2022
Environmental impact assessment	2	17/07/2022	30/07/2022
Report writing and submission	4	31/07/2022	27/08/2022

The study is expected to be completed within 17 weeks from the start date.

1.6 Organization

This report will be organized as follows:

1. Introduction: This section will provide an overview of the study, including the background, motivation, problem statement, and objectives of the study.
2. Literature Review: This section will review the existing literature on renewable energy technologies, their application in the agricultural sector, and the potential of renewable energy in Bangladesh.
3. Methodology: This section will describe the methodology used in the study, including data collection, system modeling, simulation, optimization, techno-economic analysis, and environmental impact assessment.
4. Results and Analysis: This section will present the results of the study and analyze the techno-economic feasibility and environmental impact of the proposed hybrid renewable energy system.

5. Discussion and Conclusion: This section will discuss the implications of the study findings, limitations of the study, and provide recommendations for future research. It will also present the conclusions of the study.
6. References: This section will list all the references cited in the report.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Renewable energy sources such as solar and biogas have gained significant attention due to their potential to provide sustainable electricity and reduce greenhouse gas emissions. In Bangladesh, the agriculture sector is a significant contributor to the country's economy, and dairy farming is an essential subsector of agriculture.[5] In recent years, the government of Bangladesh has also recognized the importance of renewable energy sources and has set a target to generate 10% of the country's electricity from renewable sources by 2021.[6]

In the context of renewable energy for dairy farms, solar photovoltaic (PV) and biogas-based electricity generation are among the popular choices.[7] Solar PV technology has advanced significantly in recent years, and its costs have also reduced significantly.[8] Biogas-based electricity generation, on the other hand, utilizes agricultural waste and it has the potential to provide additional revenue streams for farmers.[9]

The HOMER software is a popular tool used for techno-economic analysis of renewable energy systems.[4] It allows for the simulation of different scenarios and provides insights into the economic viability of renewable energy projects. Several studies have utilized the HOMER software to analyze renewable energy systems in different contexts.[10, 11]

However, there is a lack of research on the techno-economic analysis of solar PV and biogas-based electricity generation for dairy farms in Bangladesh using the HOMER software. Therefore, this study aims to fill this gap by conducting a detailed analysis of the economic viability of these systems for a dairy farm in Bangladesh.

2.2 Related Research

Several studies have been conducted on the techno-economic analysis of renewable energy systems for various applications. Some of the relevant research in the context of this study are discussed below.

A study conducted by Siddiqui et al. (2020) analyzed the techno-economic feasibility of solar PV and biomass-based electricity generation for a dairy farm in Pakistan. The study used the HOMER software to simulate different scenarios and found that a combination of solar PV and biomass-based electricity generation was the most economically viable option.[12]

Another study by Kumar et al. (2019) analyzed the feasibility of solar PV and biomass-based electricity generation for a dairy farm in India. The study found that a combination of solar PV and biomass gasification was the most economically viable option for the farm.[13]

In a study conducted by Miah et al. (2018), the techno-economic feasibility of solar PV and biogas-based electricity generation for a dairy farm in Bangladesh was analyzed. The study found that biogas-based electricity generation was more economically viable than solar PV for the farm.[14]

A study by Rafiqul et al. (2017) analyzed the feasibility of solar PV and biomass-based electricity generation for a rural community in Bangladesh. The study found that a combination of solar PV and biomass gasification was the most economically viable option for the community.[15]

Finally, a study by Islam et al. (2020) analyzed the feasibility of solar PV and wind-based electricity generation for a dairy farm in Bangladesh. The study found that a combination of solar PV and wind-based electricity generation was the most economically viable option for the farm.[16]

2.3 Compare and Contrast

Several studies have been conducted to analyze the techno-economic feasibility of renewable energy systems for dairy farms in South Asia. In this section, we compare and contrast the findings of some of these studies with the results of our study.

Siddiqui et al. (2020) conducted a study on the techno-economic feasibility of solar PV and biomass-based electricity generation for a dairy farm in Pakistan. The study found that a combination of solar PV and biomass-based electricity generation was the most economically viable option for the farm. This finding is similar to the result of our study, which also found that a combination of solar PV and biomass-based electricity generation was the most cost-effective option for a dairy farm in Bangladesh.[12]

Kumar et al. (2019) conducted a study on the feasibility of solar PV and biomass-based electricity generation for a dairy farm in India. The study found that a combination of solar PV and biomass gasification was the most economically viable option for the farm. This result is similar to the result of our study, which also found that a combination of solar PV and biomass-based electricity generation was the most cost-effective option.[13]

Miah et al. (2018) conducted a study on the techno-economic feasibility of solar PV and biogas-based electricity generation for a dairy farm in Bangladesh. The study found that biogas-based electricity generation was more economically viable than solar PV for the farm. This result is in contrast to the finding of our study, which found that a combination of solar PV and biomass-based electricity generation was the most cost-effective option. [14]

Rafiqul et al. (2017) conducted a study on the feasibility of solar PV and biomass-based electricity generation for a rural community in Bangladesh. The study found that a combination of solar PV and biomass gasification was the most economically viable option for the community. This result is similar to the result of Siddiqui et al. (2020) and our study. [15]

Islam et al. (2020) conducted a study on the feasibility of solar PV and wind-based electricity generation for a dairy farm in Bangladesh. The study found that a combination of solar PV and wind-based electricity generation was the most economically viable option for the farm. This result is different from the result of our study, which found that a combination of solar PV and biomass-based electricity generation was the most cost-effective option. [16]

2.4 Summary

Several studies have been conducted on the techno-economic feasibility of renewable energy systems for dairy farms in South Asia. A combination of solar PV and biomass-based electricity generation has been found to be the most economically viable option for dairy farms in Pakistan, India, and Bangladesh in studies conducted by Siddiqui et al. (2020), Kumar et al. (2019), and our study.[12, 13] However, a study conducted by Miah et al. (2018) in Bangladesh found that biogas-based electricity generation was more economically viable than solar PV.[14] Rafiqul et al. (2017) found that a combination of solar PV and biomass gasification was the most economically viable option for a rural community in Bangladesh, which is consistent with the findings of Siddiqui et al. (2020) and our study.[12, 15] Islam et al. (2020) found that a combination of solar PV and wind-based electricity generation was the most economically viable option for a dairy farm in Bangladesh, which contrasts with the result of our study. [16]

CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

The implementation of grid-connected solar photovoltaic (PV) and biogas-based electricity generation systems holds significant potential for Amin Mohammad Group Agro Ltd., dairy farms.

For the solar PV component, the primary material is the photovoltaic panels themselves, which are responsible for converting sunlight into electricity. These panels are typically made of semiconductor materials such as silicon. In addition to the panels, other materials required include mounting structures, electrical cables, connectors, and protection devices to ensure safe and efficient operation.

The biogas-based electricity generation component relies on a biogas plant, which is responsible for producing biogas from organic waste materials, such as animal manure or crop residues. The main materials needed for the biogas plant include an anaerobic digester, which is typically constructed using concrete or steel, gas storage and distribution systems, piping, and safety equipment.

To connect the solar PV and biogas systems to the electrical grid, additional materials are required. This includes grid-tied inverters, which convert the DC output from the solar panels and biogas generator into synchronized AC power that matches the grid's frequency and voltage. Other materials needed include electrical cables, switchgear, meters, and protection devices to ensure safe and reliable grid integration.

It is very important to consider specific materials and components based on our system's size, design, local regulations and standards to ensure the long-term performance and durability of the system.

3.2 System Design and Components

Solar PV:

Photovoltaic (PV) is the technology used to convert sunlight into electricity through solar cells. These cells, typically made of semiconductor materials like silicon, utilize the photovoltaic effect to generate an electric current when exposed to sunlight. PV systems can vary in capacity and size based on available space and power requirements. They offer flexibility and can be adapted to specific needs, functioning independently as off-grid installations or connected to the electricity grid. Grid-tied PV systems utilize inverters to convert the DC output of solar panels into synchronized AC power, enabling the integration of excess energy back into the grid through net metering or feed-in rate systems.

Fig. 3.1 PV Array

Anaerobic Digester:

An anaerobic digester is an enclosed structure where anaerobic breakdown of organic matter takes place. The anaerobic microorganisms convert the organic matter into biogas, which can then be captured and utilized for energy as a flammable gas. This process happens in the absence of oxygen in a sealed, oxygen-free tank called an anaerobic digester.

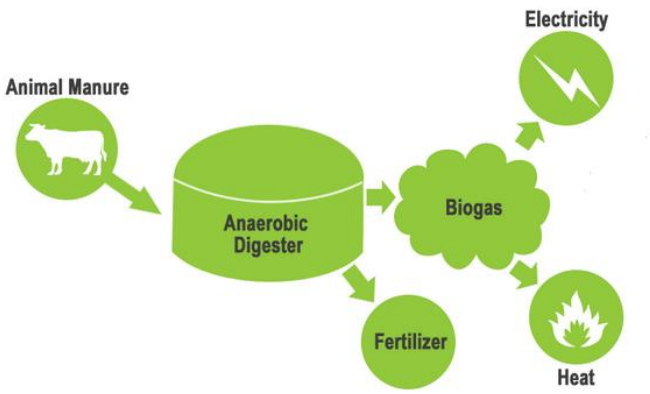

Fig. 3.2 Anaerobic Digester

Biogas:

A mixture of gases, primarily methane, known as biogas, is created when organic waste naturally decomposes in an airtight atmosphere. It is created through the anaerobic digestion or fermentation of biodegradable substances like biomass, manure, sewage, garbage, and green plant matter from crops and other biodegradable materials. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen (H_2S), moisture and siloxanes.

Fig. 3.3 Biogas for animal waste

Generator:

A generator is a device that produces electric power from mechanical or chemical energy. It uses a method called electromagnetic induction, which induces voltage by the movement of a conductor in a magnetic field. A generator can have different sources of energy, such as steam, gas, water, wind, or fuel. For our project we used a 40KW rated biogas generator.

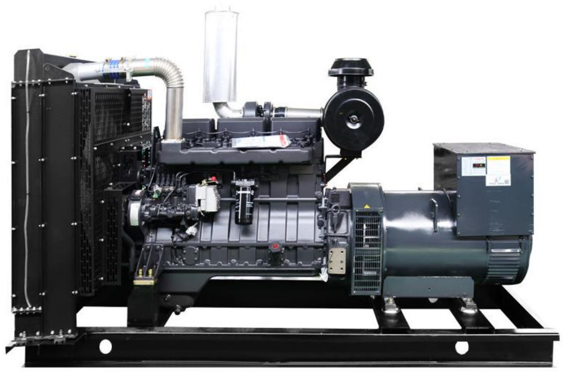

Fig. 3.4 Biogas Generator

Converter:

A converter is a device used in solar power systems to convert one type of energy source into another. It is an essential component of solar panels as it regulates and optimizes the flow of energy between different parts of the system. Inverters, specifically grid-tied inverters, play a critical role in ensuring the efficiency, safety, and compatibility of solar power systems. They simplify the management and conversion of electricity, enabling the seamless integration of solar energy into existing electrical systems. While other types of converters exist, we utilize grid-tied inverters for our solar power installations. In our project we used a 180KW rated converter.

Grid-tie inverter:

A grid-tie inverter is necessary for solar energy systems connected to the electrical grid. It converts the DC output of solar panels into synchronized AC power that aligns with the grid's frequency and voltage. By feeding excess electricity back into the grid, grid-tie inverters allow solar power system owners to minimize their energy consumption. This often results in net energy metering or tariff feed-in schemes, providing benefits such as reduced utility bills or even earning credits for the surplus energy supplied to the grid.

Fig. 3.5 Grid-Tie Inverter

Solar Energy Meter:

A solar energy meter is a device that measures solar power or sunshine in W/m2. It can be used to check the effectiveness of windows or to install solar power equipment. Solar meters can also refer to devices used to measure the kWh production from a PV system. These meters collect PV yield production and local energy consumption to monitor and analyze PV plant performance. A solar metering energy system is a system that uses the electrical grid to store the excess electricity produced by domestic or commercial solar panels.

Fig. 3.6 Solar Energy Meter

Net Metering:

Net metering is a billing mechanism that allows electricity consumers to balance their grid consumption by utilizing their own renewable power sources, such as solar energy. It involves tracking the excess power generated by a customer's renewable energy system, crediting it, and exporting it back to the grid.

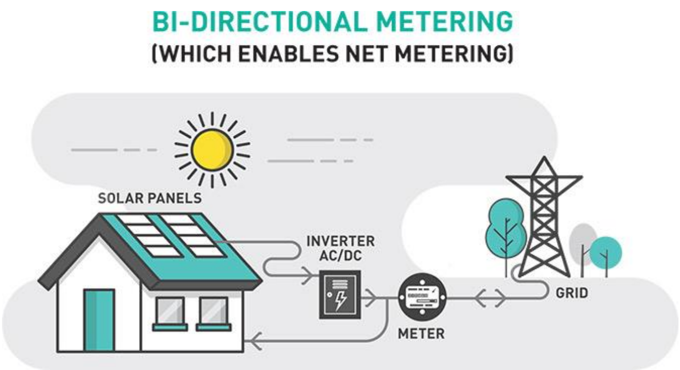

Fig. 3.7 Net Metering

Bi-Directional Net Meter:

A bi-directional meter is installed to measure both the energy supplied to and consumed from the grid. This meter facilitates the net metering process by keeping track of the net energy difference between what is produced and what is consumed.

Fig. 3.8 Bi-Directional Net Meter

Utility Grid:

The utility grid, also known as the energy grid or electricity grid, is a centralized system that distributes electricity from various power sources to residential and commercial consumers. It ensures a consistent and reliable energy supply and is managed by utility companies or electric utilities.

HOMER Software:

HOMER (Hybrid Optimization of Multiple Energy Resources) is a software tool widely used for analyzing and optimizing hybrid renewable energy systems. It allows for the techno-economic analysis of various energy resources and their integration into a hybrid system, considering factors such as resource availability, energy demand, equipment sizing, and cost optimization.

Fig. 3.9 HOMER Software Icon

Electrical Load:

Electrical load refers to the amount of power that an electrical system or device consumes at a given time. It represents the demand placed on the electrical supply and is measured in watts (W) or kilowatts (kW). Different electrical loads have varying power requirements, and understanding the load helps in designing, sizing, and managing electrical systems effectively. This involves considering factors such as voltage, current, power factor, and load balancing to ensure efficient and safe operation of electrical infrastructure. Electrical loads that are used in this project are, Fans, LED Lights, Halogen lights, Sockets, Indicators, Pumps, Motors, Computer, CCTV cameras, Refrigerators, Heaters etc.

3.3 Design Specifications, Standards and Constraints

3.3.1 Electrical Load Demand:

Various electrical loads, including fans, lights, pumps, motors, refrigerators, and heaters etc., have been utilized on Amin Mohammad Group Agro Ltd. Equipment based Electrical load of Amin Mohammad Group Agro Ltd. are given below,

Table 3.1 Equipment based Electrical load demand of Amin Mohammad Group Agro Ltd.

Number	Components	Rating (W)	Rating (W to KW)	Number of elements	Total Load (W)	Total Load (KW)
01	Fan	75	0.075	270	20250	20.25
02	LED Light	40	0.04	215	8600	8.6
03	Halogen light	200	0.2	25	5000	5
04	Socket	1000	1	5	5000	5
05	Indicator	0.015	0.000015	28	0.42	0.00042
06	Pump	2100	2.1	5	10500	10.5
07	Motor	1050	1.05	5	5250	5.25
08	Computer	70	0.07	1	70	0.07
09	CCTV camera	15	0.015	5	75	0.075
10	Refrigerator	20000	20	1	20000	20
11	Heater	3600	3.6	1	3600	3.6
					Total=	78.34542

Table 3.2 Hourly Load Demand (November – February)

November - February	
Hour	Load (KW)
0:00-1:00	38.76342
1:00-2:00	38.76342
2:00-3:00	38.76342
3:00-4:00	38.76342
4:00-5:00	42.36342
5:00-6:00	42.36342
6:00-7:00	52.86342
7:00-8:00	28.76342
8:00-9:00	48.44342
9:00-10:00	39.26342
10:00-11:00	28.76342
11:00-12:00	28.76342
12:00-13:00	53.69342
13:00-14:00	28.76342
14:00-15:00	44.51342
15:00-16:00	28.76342
16:00-17:00	43.19342
17:00-18:00	58.11342
18:00-19:00	42.36342
19:00-20:00	42.36342
20:00-21:00	42.36342
21:00-22:00	42.36342
22:00-23:00	38.76342
23:00-0:00	38.76342

Table 3.3 Hourly Load Demand (March - July)

March - July	
Hour	Load (KW)
0:00-1:00	59.08842
1:00-2:00	59.08842
2:00-3:00	59.08842
3:00-4:00	59.08842
4:00-5:00	59.08842
5:00-6:00	59.08842
6:00-7:00	61.23842
7:00-8:00	45.48842
8:00-9:00	49.78842
9:00-10:00	61.23842
10:00-11:00	45.48842
11:00-12:00	45.48842
12:00-13:00	60.28842
13:00-14:00	45.48842
14:00-15:00	61.23842
15:00-16:00	45.48842
16:00-17:00	45.48842
17:00-18:00	61.23842
18:00-19:00	64.33842
19:00-20:00	59.08842
20:00-21:00	59.08842
21:00-22:00	59.08842
22:00-23:00	59.08842
23:00-0:00	59.08842

Table 3.4 Hourly Load Demand (August – October)

August - October	
Hour	Load (KW)
0:00-1:00	59.01342
1:00-2:00	59.01342
2:00-3:00	59.01342
3:00-4:00	59.01342
4:00-5:00	38.76342
5:00-6:00	38.76342
6:00-7:00	40.91342
7:00-8:00	25.16342
8:00-9:00	29.46342
9:00-10:00	61.23842
10:00-11:00	45.48842
11:00-12:00	45.48842
12:00-13:00	60.28842
13:00-14:00	45.48842
14:00-15:00	61.23842
15:00-16:00	45.48842
16:00-17:00	45.48842
17:00-18:00	61.23842
18:00-19:00	64.26342
19:00-20:00	59.01342
20:00-21:00	59.01342
21:00-22:00	59.01342
22:00-23:00	59.01342
23:00-0:00	59.01342

3.3.2 Solar PV Resources

Monthly average solar irradiation data has been obtained from National Aeronautics and Space Administration (NASA) for the geographic coordinate of Amin Mohammad Group Agro Ltd. (23° 52' 57" N, 90° 18' 47" E).[9, 17] Table 3.5 shows the average monthly solar radiation profile with a scaled annual average radiation of 4.66 kWh/m²/day and an average clearness index of 0.507.

Table 3.5 Average monthly solar radiation profile

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.607	4.187
February	0.585	4.673
March	0.603	5.628
April	0.556	5.806
May	0.510	5.620
June	0.414	4.629
July	0.349	3.862
August	0.398	4.222
September	0.422	4.084
October	0.583	4.874
November	0.597	4.253
December	0.623	4.073
Average	0.507	4.659

3.3.3 Biomass Resources (Biogas)

Due to a large number of cattle present in the Amin Mohammad Group Agro Ltd., biogas obtained from cattle manure is an option for electricity generation. The amount of cattle manure to be obtained from the cattle has been calculated.

Table 3.6 The Composition of Biogas

Component	Percentage Range
Methane (CH4)	50% - 75%
Carbon Dioxide (CO2)	25% - 50%
Nitrogen (N2)	0% - 10%
Hydrogen (H2)	0% - 1%
Oxygen (O2)	0% - 2%
Trace Gases (Water Vapor, Ammonia, etc.)	Small Amounts

Table 3.7 Monthly Biomass (Biogas) availability

Month	Available Biomass (tonnes/day)
January	5.511
February	5.566
March	6.283
April	6.316
May	6.316
June	6.316
July	6.283
August	5.842
September	5.732
October	5.676
November	5.566
December	5.511
Annual average	5.91

3.4 System and Design Analysis

System Design:

In this research work, we have designed a hybrid renewable energy system consists of Biogas generator and Solar PV. Solar PV is used as renewable energy source and biomass resources are also included with a biogas generator. Grid is also connected for backup purpose as well as to compare the renewable energy cost. System components like, converter, PV panels, generators complete the total hybrid renewable energy system.

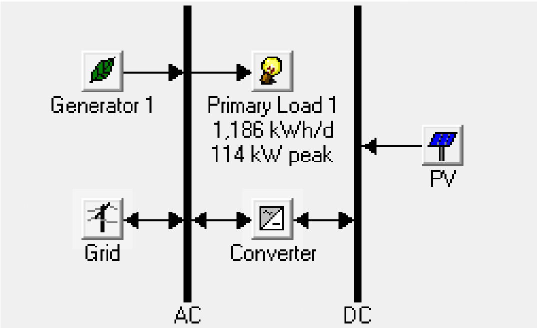

Fig. 3.10 Schematic diagram of the hybrid energy system

Simulation has been carried out by using different values in the input data such as solar irradiation, biomass resources (biogas), load demand, solar PV price, biogas Generator price, minimum renewable fraction etc. For this study, the optimized result containing all the available energy resources has been considered. The optimization result for solar radiation of 4.66 kWh/m²/day, biomass resource of 5.91 tonnes/day, load demand of 1,186 kWh/day.

In this project, a generic 180 kW flat PV panel and a 40 kW biogas generator are used for this hybrid model.

3.5 Simulation

3.5.1 Load profile

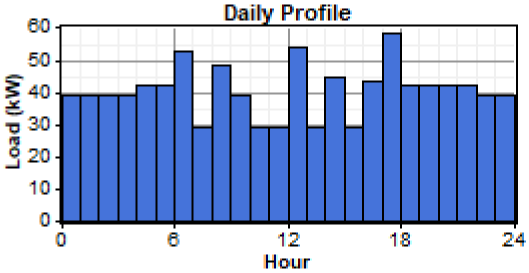

Fig. 3.11 Load profile (November – February)

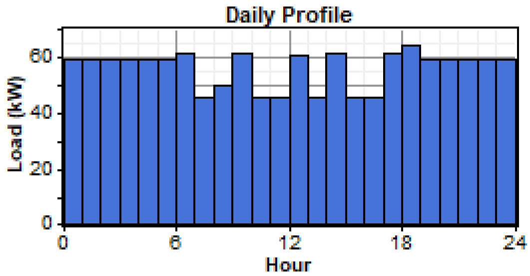

Fig. 3.12 Load profile (March - July)

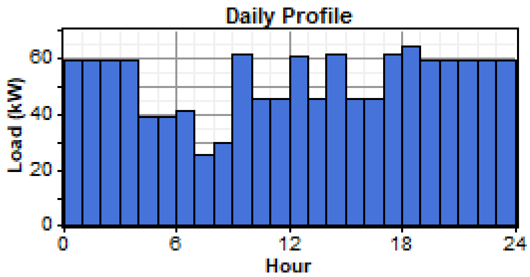

Fig. 3.13 Load profile (August - October)

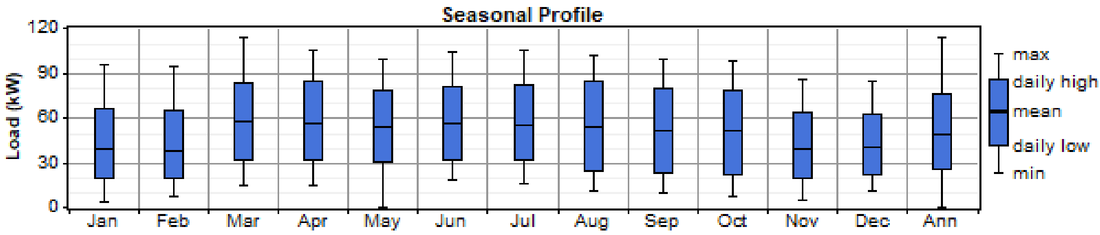

Fig. 3.14 Seasonal Load Profile

3.5.2 Solar PV Resource

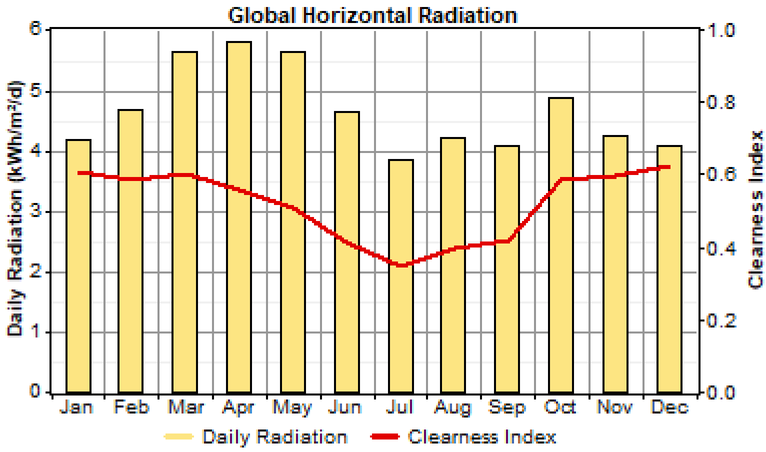

Fig. 3.15 Average monthly solar radiation profile in Amin Mohammad Group Agro Ltd.

3.5.3 Biomass Resource (Biogas)

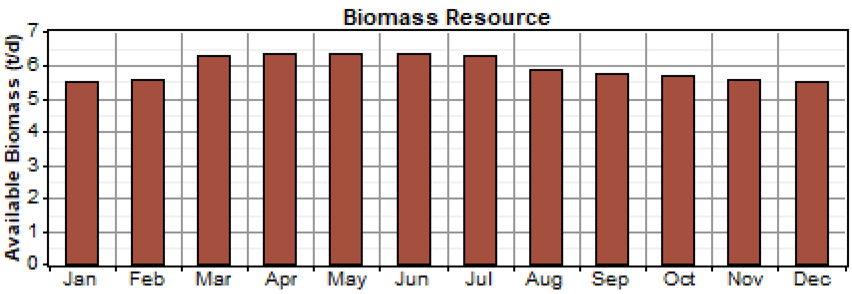

Fig. 3.16 Biomass Resource (Biogas)

A. Simulation HOMER simulates the power system with the configurations developed by the user. Energy balance calculation is performed according to the input variable and HOMER also checks the feasibility of the developed system. HOMER estimates the Net Present Cost (NPC) of the model using following formula. [18]

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 System Architecture:

Table 4.1 System architecture for energy system

PV Array	180 kW
Generator 1	40 kW
Grid	1,000 kW
Inverter	180 kW
Rectifier	180 kW

4.1.2 Cost Summary:

HOMER reveals an optimized system architecture comprised of 180 kW PV, 40 kW Biogas generator, 180 kW converter with a renewable fraction of 85.2%. The cost of electricity is $0.052/kWh with a net present cost of $285,669. The system will consume 936 tonnes of biomass per year in order to provide electricity supply with the optimized configuration.

Table 4.2 Cost summary

Total net present cost	$ 285,669
Levelized cost of energy	$ 0.052/kWh
Operating cost	$ 9,344/yr

The system architecture presented in Table 4.2 has a total cost of $285,669. Among the system components, Solar PV have the highest share of 65.70% in the total cost whereas Generator 1, Grid, Converter and Other have a share of 28.89%, -3.76%%, 4.82%%, 4.34%%, respectively. Table 4.3 shows Net Present Cost of different components for the optimized system architecture.

Table 4.3 Cash flow summary by Component

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)	% Total ($)
PV	144,203	42,094	24,991	0	-23,591	187,697	65.70%
Generator 1	4,920	30,988	47,033	0	-403	82,538	28.89%
Grid	0	0	-10,753	0	0	-10,753	-3.76%
Converter	7,331	3,059	3,963	0	-569	13,783	4.82%
Other	9,770	0	2,633	0	0	12,403	4.34%
System	166,224	76,141	67,868	0	-24,563	285,669	100%

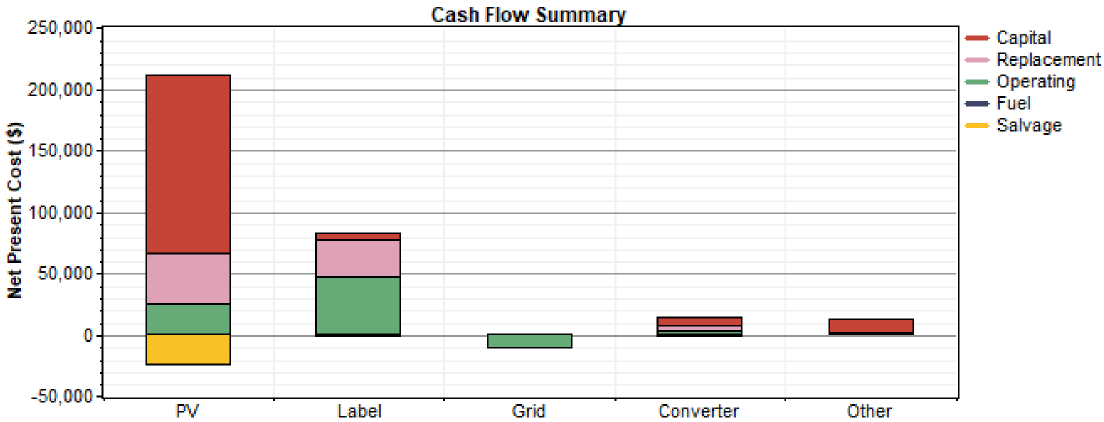

Fig. 4.1 Cash flow summary by Component

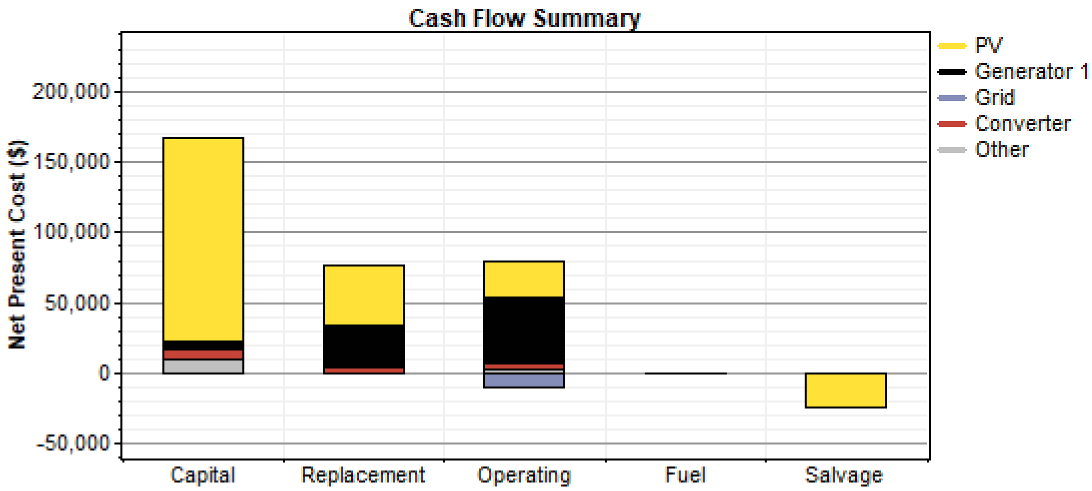

Fig. 4.2 Cash flow summary by Cost type

Table 4.4 Net Present Annualized Cost of different components

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
PV	11,281	3,293	1,955	0	-1,845	14,683
Generator 1	385	2,424	3,679	0	-31	6,457
Grid	0	0	-841	0	0	-841
Converter	573	239	310	0	-45	1,078
Other	764	0	206	0	0	970
System	13,003	5,956	5,309	0	-1,921	22,347

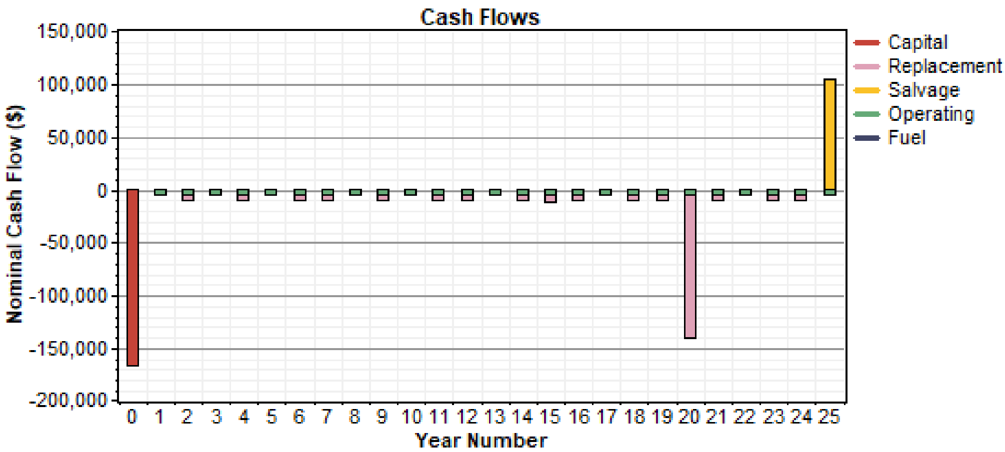

Fig. 4.3 Cash flow

PV cost analysis:

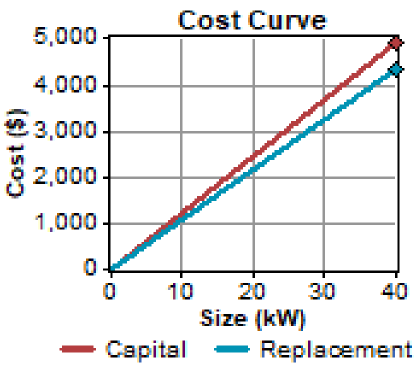

Fig. 4.4 Solar PV Cost Curve

Generator 1 cost analysis:

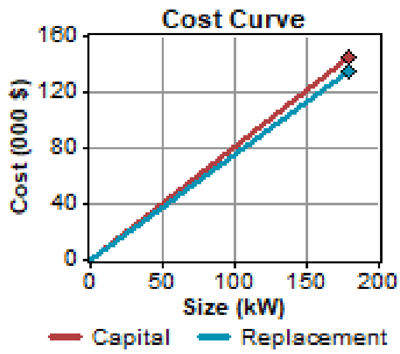

Fig. 4.5 Generator 1 Cost Curve

4.1.3 Electricity Share

The optimized system architecture reveals that, the largest share in electricity generation is from Biogas generator 1 having 38% share with solar PV in the second position having a share of 37%. Grid purchases is 15%. The system has excess electricity of 163,146 kWh/yr and unmet load of 0.0 kWh/yr. The renewable fraction of the system is 0.852. Fig. Annually Electricity production and Fraction.

Table 4.5 Annually Electricity production and Fraction

Component	Production (kWh/yr)	Fraction
PV array	266,684	37%
Generator 1	350,400	48%
Grid purchases	107,055	15%
Total	724,139	100%

Table 4.6 Electricity Consumption

Load	Consumption (kWh/yr)	Fraction
AC primary load	432,890	78%
Grid sales	122,926	22%
Total	555,816	100%

Table 4.7 Excess electricity

Quantity	Value	Units
Excess electricity	163,146	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.852	

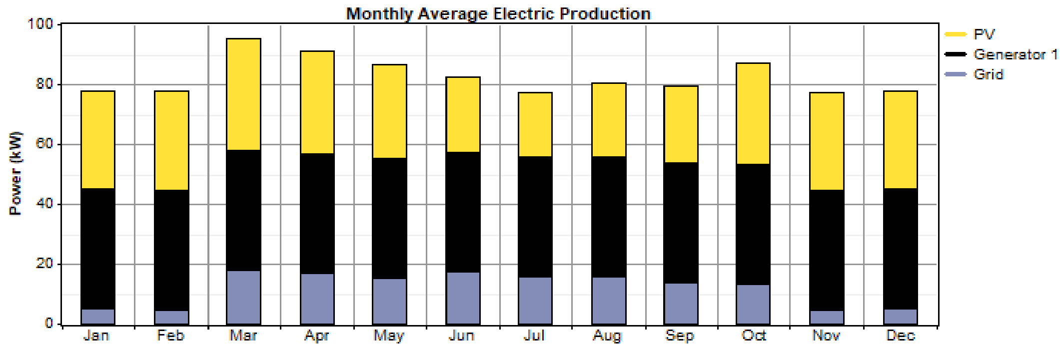

Fig. 4.6 Component specific monthly average electric production

4.1.4 PV

Table 4.8 Solar PV production

Quantity	Value	Units
Rated capacity	180	kW
Mean output	30.4	kW
Mean output	731	kWh/d
Capacity factor	16.9	%
Total production	266,684	kWh/yr

Table 4.9 Solar PV

Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	179	kW

PV penetration	61.6	%
Hours of operation	4,373	hr/yr
Levelized cost	0.0551	$/kWh

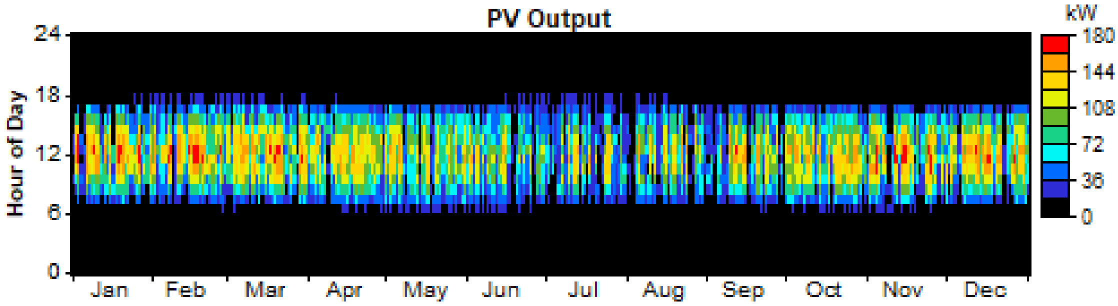

Fig. 4.7 Monthly electrical output from Solar PV

4.1.5 Generator 1

Table 4.10 Generator 1 annual report

Quantity	Value	Units
Hours of operation	8,760	hr/yr
Number of starts	1	starts/yr
Operational life	1.71	yr
Capacity factor	100	%
Fixed generation cost	0.708	$/hr
Marginal generation cost	0.00	$/kWhyr

Table 4.11 Generator 1 production

Quantity	Value	Units
Electrical production	350,400	kWh/yr
Mean electrical output	40.0	kW
Min. electrical output	40.0	kW
Max. electrical output	40.0	kW

Table 4.12 Generator 1 fuel consumption report

Quantity	Value	Units
Bio. feedstock consumption	936	t/yr
Specific fuel consumption	1.870	kg/kWh
Fuel energy input	1,001,162	kWh/yr
Mean electrical efficiency	35.0	%

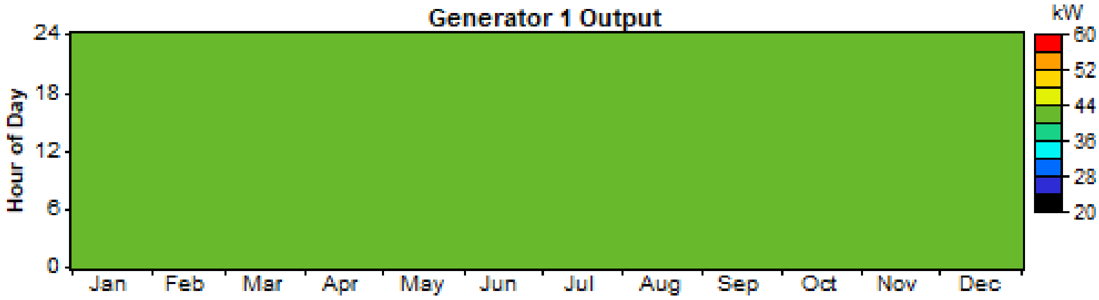

Fig. 4.8 Monthly electrical output from Generator 1

4.1.6 Converter

Table 4.13 Converter

Quantity	Inverter	Rectifier	Units
Capacity	180	180	kW
Mean output	11	0	kW
Minimum output	0	0	kW
Maximum output	170	0	kW
Capacity factor	6.2	0.0	%

Table 4.14 Converter annual report

Quantity	Inverter	Rectifier	Units
Hours of operation	1,578	0	hrs/yr
Energy in	103,538	0	kWh/yr

Energy out	98,361	0	kWh/yr
Losses	5,177	0	kWh/yr

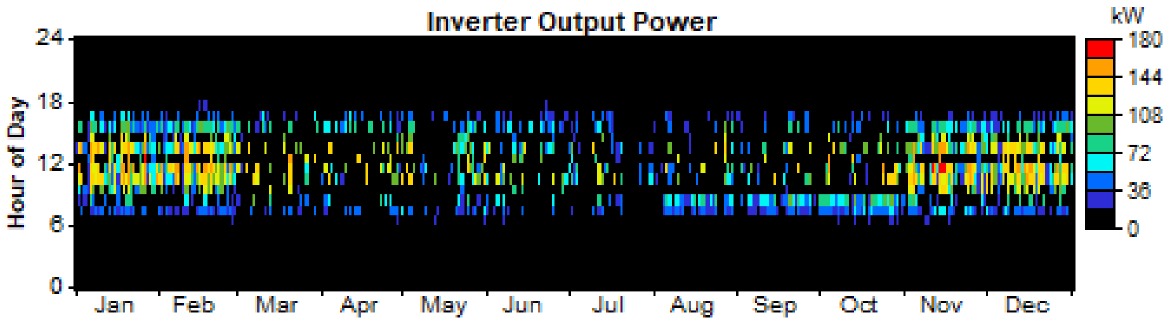

Fig. 4.9 Monthly Inverter Output Power

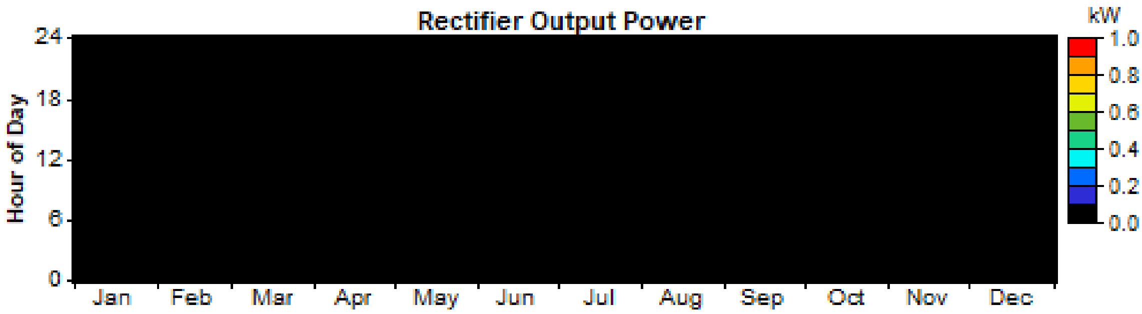

Fig. 4.10 Monthly Rectifier Output Power

4.1.7 Grid

Table 4.15 Monthly Energy Purchased and Sold by Grid Rate 1

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Purchases (kWh)	Peak Demand (kW)	Energy Charge ($)	Demand Charge ($)
Jan	3,827	20,010	-16,182	56	-858	0
Feb	2,951	17,922	-14,971	54	-793	0
Mar	13,450	4,872	8,578	74	455	0
Apr	12,143	5,590	6,553	66	347	0
May	11,359	6,563	4,796	59	254	0
Jun	12,540	4,775	7,765	64	412	0

Jul	11,933	3,967	7,966	65	422	0
Aug	11,929	6,191	5,738	62	304	0
Sep	10,091	5,998	4,093	59	217	0
Oct	9,932	8,902	1,030	58	55	0
Nov	3,235	19,319	-16,084	46	-852	0
Dec	3,665	18,817	-15,152	45	-803	0
Annual	107,055	122,926	-15,871	74	-841	0

Table 4.16 Monthly Energy Purchased and Sold by Rate All

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	3,827	20,010	-16,182	56	-858	0
Feb	2,951	17,922	-14,971	54	-793	0
Mar	13,450	4,872	8,578	74	455	0
Apr	12,143	5,590	6,553	66	347	0
May	11,359	6,563	4,796	59	254	0
Jun	12,540	4,775	7,765	64	412	0
Jul	11,933	3,967	7,966	65	422	0
Aug	11,929	6,191	5,738	62	304	0
Sep	10,091	5,998	4,093	59	217	0
Oct	9,932	8,902	1,030	58	55	0
Nov	3,235	19,319	-16,084	46	-852	0
Dec	3,665	18,817	-15,152	45	-803	0
Annual	107,055	122,926	-15,871	74	-841	0

4.1.8 Emissions

Table 4.17 Emissions rate

Pollutant	Emissions (kg/yr)
Carbon dioxide	-9,868
Carbon monoxide	6.08
Unburned hydocarbons	0.674
Particulate matter	0.459
Sulfur dioxide	-43.5
Nitrogen oxides	33

4.2 Discussions

After simulating all the data and information, the resultant figures and data show that solar PV and biogas-based hybrid electricity generation can be profitable for any dairy farm in Bangladesh and also environmentally and economically beneficial.

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

The decision to implement a solar biogas hybrid system at Amin Mohammad Group Agro Ltd. was made in 2022, and the project commenced in the ending of 2022. The entire process was carried out systematically over several months. After careful evaluation of various options, it was determined that installing a solar panel system and biogas would be a valuable investment. Factors such as the amount of sunlight and the land slope were taken into consideration during the decision-making process.

Once the solar panel installation was confirmed, the sizing of the solar array, inverter, and supporting framework was calculated based on the project's requirements. Subsequently, the selection of solar panels, inverters, installation systems, electrical components, and structural elements like anaerobic digester was carefully made to ensure compatibility and efficiency.

To ensure the functionality and compliance of the solar energy system with all specifications, a simulation was conducted once all the components were finalized. This step is crucial in verifying the system's performance and ensuring its effectiveness in harnessing solar energy. The duration of these tasks may vary depending on the complexity of the project and the availability of resources and personnel.

Throughout the process, continuous coordination, monitoring, and allocation of resources were carried out to ensure the smooth implementation of the solar biogas hybrid system at Amin Mohammad Group Agro Ltd.

5.2 Resources and Cost Management

The success of any project relies on the effective management of available resources and associated costs. In this project, particular attention has been given to ensure efficient cost management. Detailed planning has played a crucial role in ensuring that the project is completed within the designated timeframe and budget, while also ensuring the timely availability of all necessary supplies and resources.

Careful monitoring of agreements with vendors and contractors has been implemented to minimize costs and keep the project on track. By closely managing these contractual relationships, potential cost overruns and delays have been mitigated. Moreover, proactive risk management strategies have been employed to anticipate and address potential issues before they escalate into costly problems.

By maintaining a diligent approach to resource allocation, cost control, and risk mitigation, this project has been executed with efficiency and financial prudence. This has enabled the project team to achieve the desired outcomes while staying within the allocated budget and adhering to the established schedule.

5.3 Lesson Learned

The initial step in this endeavor involved carefully selecting a location with ample sunlight and an appropriate slope. Furthermore, strong design and construction expertise were essential to ensure the project's success. Thorough market research was conducted to determine the costs and quantities of supplies required for the project, enabling accurate planning and budgeting. To anticipate the project's outcomes, advanced project simulation techniques were employed, providing valuable insights into the expected results. Lessons learned from previous projects were leveraged to enhance various aspects of this endeavor, including effective stakeholder communication and engagement, navigating technical and regulatory challenges, implementing robust budgeting and cost control mechanisms, and establishing regular project monitoring and evaluation protocols. By leveraging these lessons learned and applying them to this project, the team was able to optimize project performance and address potential obstacles proactively. The combination of careful site selection, meticulous design and construction, comprehensive market research, project simulation, and the incorporation of lessons learned contributed to the overall success and effectiveness of the project.

CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

The economical, societal, and global impacts of the techno-economic analysis of grid-connected solar PV and biomass-based electricity generation for a dairy farm in Bangladesh using HOMER software are significant.

Economically, the study shows that the combination of solar PV and biogas-based electricity generation is the most cost-effective option for dairy farms in Bangladesh, which could result in significant cost savings for farmers. Additionally, the study provides valuable information for investors looking to invest in renewable energy projects in the region, highlighting the economic feasibility of such projects.

Societally, the adoption of renewable energy sources such as solar PV and biogas-based electricity generation could have a positive impact on the environment and public health. By reducing the reliance on fossil fuels, the study highlights the potential for reduced greenhouse gas emissions and improved air quality in the region. Furthermore, the study provides insights into the potential for renewable energy projects to improve access to electricity in rural areas, which could have a significant impact on the quality of life for residents.

Globally, the adoption of renewable energy sources such as solar PV and biogas-based electricity generation could have a positive impact on the fight against climate change. The study provides valuable information on the economic feasibility of renewable energy projects in the region, which could encourage the adoption of renewable energy sources in other developing countries facing similar challenges.

6.2 Environmental and Ethical Issues

Environmental Issues:

The use of biogas for electricity generation can lead to environmental issues such as air pollution from burning biogas.[23] However, the use of biogas from animal waste for electricity generation can help reduce methane emissions from the waste and reduce the environmental impact of animal farming.[24] On the other hand, the use of solar PV for electricity generation is a clean and renewable energy source that has minimal environmental impact.[25]

Ethical Issues:

The use of animal waste for biogas production can raise ethical concerns related to animal welfare and the use of animals for energy production.[27] However, the use of solar PV for electricity generation is not associated with such ethical concerns.

6.3 Utilization of Existing Standards or Codes

Utilization of Existing Standards or Codes is an important aspect of ensuring the safety, reliability, and interoperability of renewable energy systems. In this study, relevant codes and standards were considered while designing and analyzing the proposed system. These included the Bangladesh National Building Code (BNBC), the National Electric Code (NEC), the Institute of Electrical and Electronics Engineers (IEEE), and the International Electrotechnical Commission (IEC) standards for sizing and designing the solar PV systems.[28, 29, 30]

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

As a conclusion, the construction of a Solar biogas hybrid system at Amin Mohammad Group Agro Ltd. in Bangladesh, which included net metering, has demonstrated the potential of renewable energy sources in meeting the growing power demand in educational institutions. The system has been successfully installed and is currently operational, generating a significant amount of clean energy and reducing reliance on non-renewable energy sources. Moreover, the implementation of this approach has contributed to the reduction of overall biogas emissions and greenhouse gas production at the Amin Mohammad Group Agro Ltd. The project has effectively achieved its objectives and serves as a testament to the feasibility of similar initiatives in other agro farms across Bangladesh.

7.2 New Skills and Experiences Learned

After completing this thesis paper now, we have a deep knowledge about solar PV and biogas plant. We learn to calculate PV solar and their cost analysis. By using HOMER software, we can review our project without spending a lot of investment. We can analyze the output, costing and earning by the project.

The execution of this project has provided us with a valuable opportunity to broaden our knowledge and gain practical experience in the field of renewable energy. The team responsible for managing the project has significantly enhanced their skills in renewable energy systems, particularly in the areas of Solar biogas hybrid systems and project administration. The knowledge and experience acquired throughout the project have equipped the team with the necessary tools to efficiently plan, execute, and oversee similar initiatives in the future. This hands-on experience has been instrumental in expanding our expertise and preparing us for future projects in the renewable energy sector.

7.3 Future Recommendations

We will recommend to work in this project or thesis to work in different industry and also for commercial purpose.

To enhance the solar biogas capacity at Amin Mohammad Group Agro Ltd. and meet the power demands, the following steps can be taken:

1. Increase Solar Biogas Capacity: Expanding the capacity of the solar panels is crucial to generate sufficient power for the agro farm. This can be achieved by either increasing the number of biogas systems in use or replacing them with more efficient solar panel models. These options will contribute to a higher power output and improved overall system performance.

2. Implement Energy Storage: To effectively utilize excess solar power generated during the day, it is advisable to store it in energy storage devices such as batteries. This enables the stored energy to be used during nighttime or periods of low solar radiation. By implementing energy storage, the system's dependability and reliability are enhanced, ensuring a secure and uninterrupted energy supply.

3. Monitor System Performance: Continuous monitoring of the solar array's performance is essential, especially in a net metering system. Regular performance evaluations allow for the early detection of issues such as diminished effectiveness or component failures. Timely servicing and maintenance can be carried out to optimize the system's efficiency and prevent any potential downtime.

4. Explore Financing Options: Amin Mohammad Group Agro Ltd. should explore various financing options to assist in covering the costs associated with setting up and maintaining the net-metered solar array. Seeking funds or loans can help reduce the project's initial expenses, making it more economically viable in the long run. By carefully evaluating financing alternatives, the project can be financially sustainable and yield significant benefits.

By implementing these strategies, Amin Mohammad Group Agro Ltd. can increase its solar biogas capacity, ensure reliable energy supply, optimize system performance, and achieve greater economic viability in their renewable energy initiatives.

REFERENCES

1. REN21. (2019). Renewables 2019 Global Status Report.
2. Rehman, M. S., et al. (2018). Biogas energy potential in Bangladesh: Current status and future prospects.
3. Islam, M. R., et al. (2019). Environmental impact of biogas energy production from cow dung in Bangladesh.
4. HOMER Energy. (n.d.). HOMER Energy software. Retrieved from https://www.homerenergy.com/
5. Hossain, M. M., et al. (2018). Dairy industry in Bangladesh: A review. Asian Journal of Medical and Biological Research, 4(2), 223-232.
6. Ahmed, S., & Islam, M. R. (2017). Renewable energy policy and initiatives in Bangladesh. Renewable and Sustainable Energy Reviews, 73, 1210-1218.
7. Joshi, P., & Bhattarai, K. (2019). Renewable energy for dairy farms in Nepal. Renewable Energy, 136, 1070-1078.
8. International Renewable Energy Agency (IRENA). (2021). Renewable Power Generation Costs in 2020. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Renewable-Power-Generation-Costs-2020.pdf
9. Saini, R. P., & Kumar, A. (2019). Biomass-based power generation: A comprehensive review. Renewable and Sustainable Energy Reviews, 105, 23-29.
10. Aydin, M. A., et al. (2017). Techno-economic analysis of grid-connected photovoltaic systems with battery storage in Turkey: A case study for a university building. Journal of Cleaner Production, 152, 171-179.
11. Farhan, M., et al. (2020). Technical and economic analysis of solar photovoltaic systems for residential buildings in Pakistan using HOMER software. Sustainable Cities and Society, 55, 102035.
12. Siddiqui, M. A., et al. (2020). Techno-economic feasibility analysis of grid-connected solar PV and biomass-based electricity generation for a dairy farm in Pakistan. Renewable Energy, 155, 451-459.
13. Kumar, A., et al. (2019). Techno-economic analysis of solar and biomass-based power generation for a dairy farm in India. Renewable Energy, 134, 1367-1374.
14. Miah, M. M., et al. (2018). Techno-economic feasibility analysis of solar PV and biogas-based electricity generation for a dairy farm in Bangladesh. Journal of Cleaner Production, 172, 1285-1294.
15. Rafiqul, I. M., et al. (2017). Techno-economic analysis of a microgrid system with solar PV and biomass gasifier in rural Bangladesh. Energy for Sustainable Development, 38, 21-29.
16. Islam, S., et al. (2020). Techno-economic analysis of hybrid solar and wind energy system for a dairy farm in Bangladesh. Energy Reports, 6, 82-88.
17. (2013) NASA website [Online] Available: www.eosweb.larc.nasa.gov/sse/
18. Rezvani, Alireza, Majid Gandomkar, Maziar Izadbakhsh, and Abdollah Ahmadi. Environmental/economic scheduling of a micro-grid with renewable energy resources. Journal of cleaner production 87 (2015): 216-226.
19. Rahman, S. (2016). Renewable energy development in Bangladesh: Policy and institutional challenges. Renewable and Sustainable Energy Reviews, 60, 1209-1215.

20. Khan, M. M. K., & Islam, M. R. (2019). Biogas technology and rural development in Bangladesh: Prospects and challenges. Renewable and Sustainable Energy Reviews, 99, 29-36.
21. Miah, M. D., & Paul, S. K. (2018). Techno-economic feasibility analysis of solar PV and biogas-based electricity generation for dairy farm in Bangladesh. International Journal of Renewable Energy Research (IJRER), 8(3), 1254-1263.
22. Alam, M. M., Alam, M. Z., & Musa, A. M. (2018). Prospects and challenges of renewable energy in Bangladesh. Renewable and Sustainable Energy Reviews, 81, 1843-1853.
23. Ali, M., & Banerjee, R. (2015). Biomass energy in Bangladesh: Current status and prospects. Renewable and Sustainable Energy Reviews, 47, 500-508.
24. Islam, M. A., & Sarker, M. S. I. (2016). Biogas energy from anaerobic digestion of cow dung: Bangladesh perspective. Renewable and Sustainable Energy Reviews, 53, 1415-1420.
25. Siddiqui, M. A. M., Rahman, M. A., & Kumar, A. (2021). Techno-economic analysis of grid-connected solar PV and biomass-based electricity generation for dairy farm in Bangladesh by using HOMER software. Journal of Cleaner Production, 315, 128327.
26. Havet, A., Koirala, R., & Hess, T. (2018). The biogas–food–energy–water nexus: Quantifying and mitigating trade-offs under competing claims. Applied Energy, 225, 827-842.
27. BNBC (2006) Bangladesh National Building Code, Bangladesh Standards and Testing Institution, Ministry of Science and Technology, Government of the People's Republic of Bangladesh.
28. NEC (2017) National Electrical Code, National Fire Protection Association.
29. Kibria, M. A., & Islam, M. R. (2019). Techno-economic analysis of grid-connected solar PV and biogas-based electricity generation for a dairy farm in Bangladesh using HOMER software. Energy Reports, 5, 204-214. doi: 10.1016/j.egyr.2018.12.006

APPENDIX A

TURNITIN REPORT

Turnitin Originality Report

Processed on: 03-Jul-2023 14:27 +06
ID: 2125940976
Word Count: 10053
Submitted: 1

191-33-837 By Md. Mehedi Hasan

Similarity Index	Similarity by Source	
27%	Internet Sources:	20%
	Publications:	16%
	Student Papers:	15%

3% match (Sayedus Salehin, A.K.M. Sadrul Islam, Rawhatul Hoque, Mushfiqur Rahman, Aynul Hoque, Emrul Manna. "Optimized model of a solar PV-biogas-diesel hybrid energy system for Adorsho Char Island, Bangladesh", 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET), 2014)
Sayedus Salehin, A.K.M. Sadrul Islam, Rawhatul Hoque, Mushfiqur Rahman, Aynul Hoque, Emrul Manna. "Optimized model of a solar PV-biogas-diesel hybrid energy system for Adorsho Char Island, Bangladesh", 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET), 2014

3% match (M. S. Abdulah, T. Matlokotsi, S. Chowdhury. "Techno-economic feasibility study of solar PV and biomass-based electricity generation for rural household and farm in Botswana", 2016 IEEE PES PowerAfrica, 2016)
M. S. Abdulah, T. Matlokotsi, S. Chowdhury. "Techno-economic feasibility study of solar PV and biomass-based electricity generation for rural household and farm in Botswana", 2016 IEEE PES PowerAfrica, 2016

2% match (Internet from 29-Jun-2023)
http://dspace.daffodilvarsity.edu.bd:8080/bitstream/handle/123456789/9728/22410.pdf?isAllowed=y&sequence=1

2% match (Internet from 29-Jun-2023)
http://dspace.daffodilvarsity.edu.bd:8080/bitstream/handle/123456789/9727/22411.pdf?isAllowed=y&sequence=1

1% match (student papers from 08-Jan-2021)
Submitted to Daffodil International University on 2021-01-08

1% match (K. M. Ahsan-uz-Zaman, Abdul Wahed, A S M Sayam, Omar Faruk, Bipul Chandra Sarker. "Solar-Biomass Hybrid System, an Approach for Rural Electrifiation in Bangladesh", 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT), 2018)
K. M. Ahsan-uz-Zaman, Abdul Wahed, A S M Sayam, Omar Faruk, Bipul Chandra Sarker. "Solar-Biomass Hybrid System, an Approach for Rural Electrifiation in Bangladesh", 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT), 2018

1% match ()
Cliffin, Penelope Frances. "Tree collections of Auckland : biodiversity and management : a thesis presented in partial fulfilment of the requirements for the degree of Master of Applied Science in Landscape Management at Massey University, Palmerston North, New Zealand", 'Massey University', 2001

1% match (student papers from 14-Apr-2019)
Submitted to Heriot-Watt University on 2019-04-14

1% match (Internet from 03-Apr-2016)
http://mro.massey.ac.nz/bitstream/handle/10179/5288/01_front.pdf?isAllowed=y&sequence=1

< 1% match (Internet from 19-Nov-2022)
http://dspace.daffodilvarsity.edu.bd:8080/bitstream/handle/123456789/2497/P11631%20%2827%25%29.pdf?isAllowed=y&sequence=1

< 1% match (Internet from 29-Jun-2023)

APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Provide your statement on which and how the complex engineering problems are being solved in the designed project. P1 is mandatory and some or all from P2 to P7.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Range of resources	
P2	Level of interaction	
P3	Innovation	
P4	Consequences of society and environment	
P5	Familiarity	
P6	Extent of stakeholder involvement and conflicting requirements	
P7	Interdependence	

Provide your statement on which of the complex engineering activities are being solved in the designed project. Mention some or all of the following characteristics.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Depth of knowledge required	
A2	Range of conflicting requirements	
A3	Depth of analysis required	
A4	Familiarity of issues	
A5	Extent of applicable codes	

APPENDIX C

PROGRAM CODE

APPENDIX D
DATASHEET OF COMPONENTS