OPTIMIZING ELECTRICITY PRODUCTION FROM FOOD WASTE: A CASE STUDY OF AMIN BAZAR LANDFILL USING HOMER PRO SIMULATION

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

We hereby declare that this project "**Optimizing Electricity Production from Food Waste: A Case Study of Amin Bazar Landfill Using Homer Pro Simulation**" represents our 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. We 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.

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To

Almighty Allah

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LIST OF ABBREVIATIONS

WtE	Waste To Energy
AD	Anaerobic Digestion
HTC	Hydrothermal Carbonization
MSW	Municipal solid waste
DNCC	Dhaka North City Corporation
MC	Moisture Content
DSCC	Dhaka South City Corporation
PPPs	Private Public Partnerships
JICA	Japan International Cooperation Agency
LCA	Life Cycle Assessment
ESA	Energy System Analysis
AHP	Analytic Hierarchy Process
PG	Plasma Gasification
HCV	Higher Calorific Value
BBS	Bangladesh Bureau of Statistics
FCC	Fixed Capital Cost
O&M	Operation and Maintenance Cost
NPC	Net Present Cost
AC	Alternating Current
EPA	Environmental Protection Agency
IEEE	Institute of Electrical and Electronics Engineers

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ABSTRACT

In this research paper presents a comparative analysis of electricity generation from waste through anaerobic digestion. Our work is highly recommended due to its provision of an estimation of power production capacity and its comprehensive economic effect study. The simulation was carried out using the Homer Pro software, with the Amin Bazar landfill serving as the reference site. We have segmented our entire task into multiple segments and successfully accomplished it. Firstly, how can we effectively gather the waste and transport it to the designated disposal area by using a comprehensive waste management system. This research analyzes diverse approaches to the conversion technologies of waste to energy, with particular emphasis on anaerobic digestion as a viable and environmentally friendly alternative. The study assesses the efficacy, cost-efficiency, and ecological consequences of anaerobic digestion in comparison to alternative waste-to-energy methods. This research offers valuable insights into the viability and possible advantages of employing anaerobic digestion as a means of generating power from waste, utilizing data analysis and simulation tools.

Keywords: Anaerobic Digestion, Homer Pro, Renewable Energy, MSW, Biogas, WtE.

Chapter 1
Introduction

1.1 Introduction

Biomass refers to organic material that comes from plants and animals. This broad category specifically encompasses various forms of wood harvested from forests (including both hardwoods and softwoods), a diverse range of agricultural crops (such as corn, sugarcane, and soybeans), their associated by-products or residues (like straw, bagasse, and husks), algae (used increasingly for biofuel production), and a wide array of organic waste materials (including food waste, yard trimmings, and organic municipal solid waste). Biomass is a significant renewable resource that can be continually replenished.

The issue of “waste” has become more prominent, this term is used to describe any type of material that is abandoned for any reason. The term “Waste” encompasses a wide variety of potentially hazardous materials, including but not limited to solids, liquids, gases, and radioactive materials, as defined under the Bangladesh Environment Conservation Act, 1995 [1].Waste can come in many forms and isn't limited to organic material. While it includes both organic and inorganic substances. Not every type of waste is considered biomass. Some waste, particularly organic waste such as food scraps, yard waste, and some types of agricultural and forestry residues, can be classified as biomass. This is because they are organic in nature and can be used as a renewable resource, particularly for energy production.

So, Biomass is a subset of waste when considering organic and renewable waste materials, not all waste can be classified as biomass. The sustainable management of both biomass and waste is crucial for environmental conservation, energy security, and advancing towards a more circular economy.

According to the World Population Review (2023) and the World Atlas (2023), Bangladesh has a population of 173.439096 as of September 9, 2023, placing it in eighth place among countries by population. According to the World Population Review (2023), 147600 people live per square kilometer and the population growth rate of the country is 1.03%. Most waste is produced because of the rapid rate of urbanization, industrialization, and subsequently, better standards of living[1].

Urbanization is causing cities, such as Dhaka City, to expand both in terms of land area and population as part of their developmental process. The growth of urban populations and economic progress is leading to higher rates of consumption, which, in turn, are contributing to a rise in waste generation in developing nations[2]. There is serious environmental degradation due to the rise in MSW. The primary origins of solid waste are households, businesses, institutions, and the industrial and agricultural sectors[2]. We can maintain a clean and eco-friendly atmosphere through proper recycling and waste management. In fact, waste can be a valuable resource if handled correctly. Organic fertilizer, power, and manufactured goods can all be made with the help of this resource. An efficient waste management system is essential to the success of urbanization and industrialization, and the growth of technology has led to an increase in waste generation[3].

1.2 Problem Statement and Proposed Solution

The rapid progress in urbanization, industrialization, and subsequent improvement in lifestyles are the main factors responsible for most of the waste production. The rising rates of municipal solid waste (MSW) have a detrimental impact on the environment, as well as the social and professional lives of city residents, urban planners, developers, and other relevant stakeholders. The main challenges correlated with the increasing amount of waste due to growing industrialization and urbanization involve:

- Ecological Contamination
- Exhaustion of Resources
- Degradation of land.
- Global warming
- Health hazards
- Biodiversity depletion
- Effects on Society and the Economy
- Challenges in Waste Management Infrastructure

This problem arises due to the lack of awareness among residents about a proper waste management system.

Humans can't avoid producing waste, so proper waste management is essential to maintaining a healthy and habitable ecosystem. The entire process of dealing with waste, from collection to disposal, is referred to as “waste management” (UN Statistics Di- vision-Environmental Statistics, 2017). Managing waste includes not only the disposal of waste but also its collection, transportation, treatment, and regulatory control. Its goal is to minimize the negative impact of waste on human health, the environment, resources, and overall aesthetics[2]. A modern waste collection and transportation system (that are introduced in chapter-3 in details) can efficiently address the problem of waste management. Furthermore, by treating this garbage, we can utilize waste-to-energy conversion technology to produce electricity. This highlights the need for an efficient waste management strategy, as it not only diminishes the overall volume of waste but also mitigates the contamination of land and other associated environmental effects. Implementing waste-to-energy conversion technology not only offers a sustainable method for trash disposal but also makes a substantial contribution to meeting the energy needs of the country.

1.3 Objectives of Our Research

In the contemporary context of environmental sustainability and energy efficiency, the utilization of municipal solid waste (MSW) for energy production presents a promising avenue for renewable energy generation. This thesis aims to explore the potential of converting MSW into biomass for electricity production, addressing the challenges of waste management and energy crisis concurrently. The work focuses on the collection, categorization, and processing of waste from diverse sources within the Dhaka North City Corporation (DNCC) area, with the ultimate goal of utilizing this waste in a biomass power plant.

- To identify the most efficient type of biomass for electricity generation and optimize the energy output from the waste-to-energy conversion process.

- To design an efficient and effective waste management system that adeptly collects waste from diverse sectors like commercial, industrial, municipal, institutional, etc.

- To categorize the accumulated waste into biodegradable and non-biodegradable materials, facilitating effective processing and recycling measures.

- To design an innovative infrastructure capable of converting biodegradable waste into bio-products.

- To quantify the potential biogas yield and electricity generation capacity from processed waste through detailed calculations and analysis, aiming to maximize resource utilization.

- To conduct a detailed feasibility analysis using Homer Pro software, evaluating technical, operational, environmental, and financial aspects to determine the project's viability and long-term sustainability.

- To assess the environmental impact of the biomass power plant, including emissions, waste by-products, and overall ecological footprint, to ensure environmental compliance and sustainability.

To conduct comparative studies with existing waste-to-energy plants, identifying best practices and potential areas for improvement in the proposed model.

1.4 Methodology

Keeping Earth safe from harmful pollution is a tremendous challenge. Waste collection, transportation and dumping is not the final solution of waste management. Although this approach is a positive step in reducing pollution in cities, the introduction of additional contaminants after dumping might harm the environment and the area where the waste is deposited. Therefore, it is necessary that we take the necessary steps to process this waste in order to eliminate the significant pollution that arises from its disposal. To carry out this process, we can utilize waste-to-energy technology, which involves utilizing waste materials (Biodegradable) to generate biomass. This biomass has the capability to produce electricity. This electricity can contribute to meeting the national demand.

The main contributions of the suggested approach are pointed out as follows:

- Designed a modern waste management system that primarily focuses on filtering waste collected from households and other sources.

- Through a literature review, various waste-to-energy technologies that can assist in processing the collected biodegradable waste, enabling the generation of biomass from this material.

- Environmentally sustainable and economically efficient waste-to-energy approaches are selected.

- An analysis has been conducted to evaluate the potential electricity output resulting from the primary products created by waste-to-energy (WtE) technology.

- Additionally, performed a manual calculation to estimate the daily electricity generation potential from the produced biomass.

- Furthermore, we endeavored to integrate the generated electricity into the grid. To accomplish this, we developed an on-grid system utilizing Homer Pro software, with the objective of collecting data on grid electricity purchases, self-generated electricity, and possible electricity sales to the grid.

1.5 Gantt Chart

A Gantt chart is a graphical tool used in project management to offer a detailed and inclusive depiction of a project's schedule. Gantt charts provide a comprehensive and interactive view of project schedules, allowing teams to efficiently organize, synchronize, and track work at every stage of the project's lifespan.

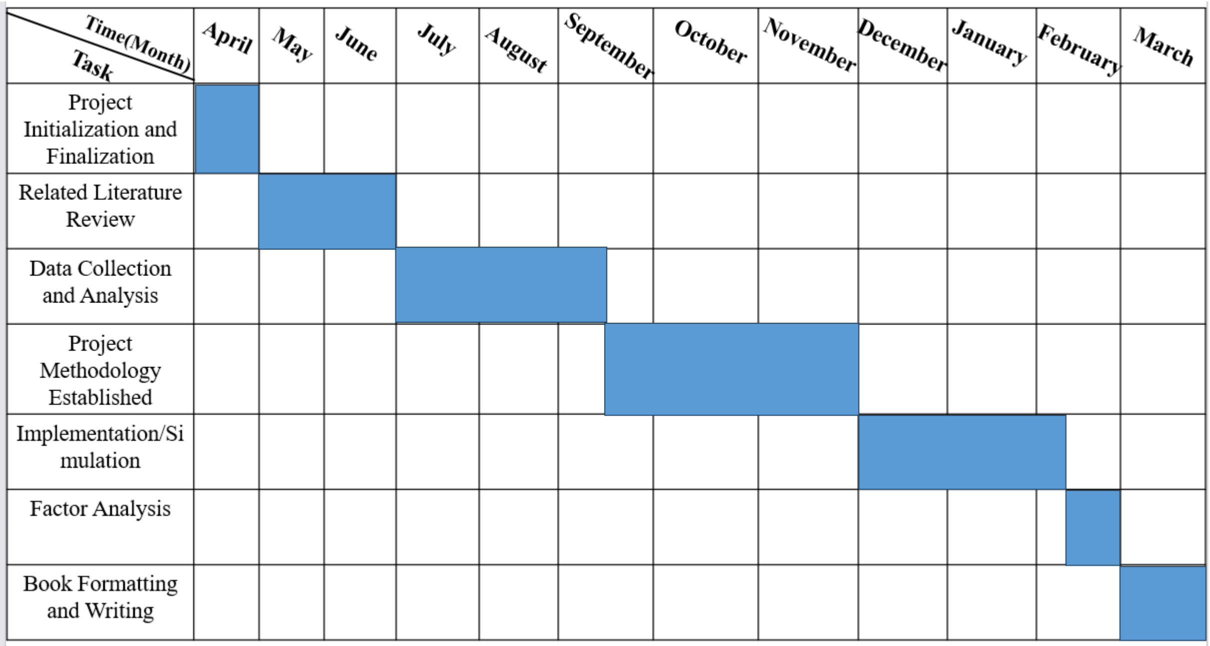


Figure 1.1: Project Schedule Gantt Chart

1.6 Structure of the Report

Chapter-01: In this chapter, we introduce our research, outlining its purpose and significance. We identify key problems and propose solutions, while also setting clear objectives. Our research methodology is succinctly described, including data collection and analysis approaches. A Gantt chart is provided for visual organization of milestones. Overall, this chapter lays the groundwork for our study, setting the stage for subsequent chapters to delve deeper into specific topics, starting with background study in the next chapter.

Chapter-02: This chapter aims to explore waste to energy conversion methods by an in-depth review of relevant literature. By analyzing the limitations of these technologies and conducting a comparative analysis, we seek to gain a deeper understanding of their potential applications.

Chapter-03: This chapter outlines the methods used in our study, focusing on waste collection and management techniques. Various technologies for converting waste into energy are highlighted, along with a proposed design and analysis of data to estimate electricity generation. The final section details the simulation's design and equipment needs.

Chappter-04: This chapter centers on simulated outcomes from Homer Pro software, emphasizing a hybrid power plant connected to the grid using biomass. Waste serves as the primary resource, generating electricity via a Biogas Generator. The chapter comprehensively assesses cost, viability, economic performance, and environmental implications of the planned power plant. Furthermore, sustainability and equipment efficiency are analyzed.

Chapter-05: This chapter has provided an overview of the project management aspects pertaining to the tasks, schedules, resources, and costs associated with our project.

Chapter-06: This chapter explores the potential impact of the project on several facets of our everyday lives. The analysis considers the economic, social, and global ramifications, in addition to environmental and ethical considerations. This study also examines the utilization of current guidelines and identifies prospective areas that require additional focus.

Chapter-07: Chapter 7 represents the culmination of our efforts, presenting the key findings of our study in a succinct manner. We distill our conclusions to provide a clear understanding of the implications of our research. However, our work doesn't end here; this chapter also offers insightful recommendations for future actions. By reflecting on the lessons learned throughout our journey, we aim to provide valuable insights that can guide and inform future endeavors in this field.

Chapter 2
Related Works

2.1 Introduction

Throughout the literature, several authors have contributed to the researched on the Amin Bazar landfill. They did different kinds of work. Some of them study about the current state and economic prospects of solid waste at Amin Bazar landfill, the effects of landfill leachate on the surrounding environment, the DNCC municipal solid waste management system, and current state, problems, and possible solutions. Some of the authors conducted research on technologies that can be utilized to handle the waste deposited at the Amin Bazar landfill. The predominant technologies utilized are Thermochemical, Biochemical, Chemical, and Mechanical [4], [5], [6], [7], [8], [9].

2.2 Literature Review

Electricity production in Bangladesh mostly depends on non-renewable energy sources, with a significant proportion being imported from foreign nation (India). Gas is the primary source of energy generation, which will last no more than 10 years[10]. Renewable energy sources are becoming more popular around the world because fossil fuels are becoming harder to find. Environmental worries, the fact that fossil fuel reserves are limited, and the harmful effects of fossil fuel extraction and burning on both people's health and the planet's ecosystems are some of the things that are pushing this change. As viable alternatives to fossil fuels, renewable energy methods like solar, wind, hydroelectric, and geothermal power have grown in popularity. There are many benefits to using these sources, such as unlimited access, lower greenhouse gas emissions, less pollution in the air and water, and more energy liberty. Policies made by the government, improvements in technology, and more people becoming aware of climate change have all sped up the use of renewable energy sources. There are a lot of countries that have set high goals for renewable energy and created incentives to get people to invest in clean energy infrastructure and research and development. In the last few decades, researchers have researched into how to convert waste into energy. Some authors just researched into the technology for converting waste into energy, while others researched into the specifics of waste sites. Several feature extraction methods have been suggested. Every single one of them has pros and cons.

During the review of literature, our main goal is to clarify the fundamental ideas before analyzing the complexities of the approach and possible challenges raised in each study. This method helps us fully comprehend each biomass technique, including its basic ideas, useful ways of applying them, and possible problems or limitations. Following this organized style will help readers learn about the various biomass approaches and carefully decide which ones can be used in certain situations or to achieve certain goals.

2.2.1 Analysis of Solid Waste Management and Economic prospects

In 2015, Islam analyzed solid waste management and economic prospects at Amin Bazar waste dumping site[2]. To assess the present scenario, they took samples from the Amin Bazar dumping site to analyze the physical composition, pH levels, and moisture content of the discarded wastes. They took samples during the dry and wet seasons for the experiment. During both seasons, a total of 48 samples weighing 2 kg of solid waste were collected. Following that, the samples were allowed to dry in the laboratory before being stored at room temperature for analysis. They separated the particles in the samples by size, utilized forceps to handle them, wore gloves, weighed them with an electronic scale, and recorded the measurements after using a magnifying glass to find them in the samples. They sun-dried the samples and then crushed them into a powder to determine the pH. They next combined 100 milliliters of distilled water with 40 grammes of powder in a separate, sanitary container. Following 30 minutes of stirring, the pH was measured and recorded using a pH meter (SCHOTT equipment, model: lab 851).

The formula was used to determine the moisture content of solid waste using a microwave oven.

$$\text{Moisture content, MC (\%)} = \frac{W_w}{W_{DRY}} \times 100 \qquad - [3]$$

Following the experimentation, they analyzed the results to determine the percentage of dumped waste and sorted recyclable and non-recyclable waste for economic assessment. Additionally, they examined the pH and moisture levels of the collected sample wastes and made a chart of these results.

In the economic analysis, they calculated the amount of money that can be earned by selling recyclable waste in the local market as the local market value. They attempted to compost the organic (non-recyclable) waste to be used as soil amendment or plant growth medium. They determined the amount of compost that could be generated from the site and calculated the potential earnings by selling it at the local market price.

2.2.2 Municipal solid waste management system

In 2015, Kabir introduced the municipal solid waste management system[11]. The scope of their research was centered on the Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC). The objective was to evaluate the capacity of Dhaka North and South City Corporations in handling the growing amount of municipal solid waste. To accomplish this, they conducted extensive research on the history and origins of DNCC and DSCC. They conducted a comprehensive analysis of the present condition of Municipal Solid garbage (MSW) in Dhaka City, analyzed factors such as the quantity produced, fluctuations throughout the year, distribution across different sectors, average generation rates per person, characteristics of the waste, and the evolving patterns in its composition over time. Subsequently, they conducted an analysis of the fundamental composition of waste in Dhaka city. Studied waste management efforts in Dhaka by the DNCC and DSCC, with assistance from JICA. where mentioned the Clean Dhaka Master Plan, waste generation and collection data, and the corporations' roles in managing municipal waste. The authors analyzed the implementation of the Waste Management Department at the DNCC and DSCC as part of the Clean Dhaka Master Plan. It reviewed the department's duties, which encompassed collecting waste, transportation, and disposal. In addition, it emphasized the partitioning of Dhaka City into zones to facilitate effective trash management and the establishment of standing committees to tackle waste management concerns. The author discussed several categories of waste and explored the methods of waste disposal, specifically focusing on the Amin Bazar and Matuail landfills. The authors discussed multiple facets of waste management in Dhaka, encompassing organic diversion, recycling initiatives, private sector participation via Public-Private Partnerships (PPPs), waste-to-energy schemes, external assistance from organizations such as the Japan International Cooperation Agency (JICA), and the expenses linked to waste management. In addition, they addressed the implementation of awareness-raising programs and initiatives to improve waste collection efficiency.

2.2.3 Solid waste management system in Dhaka City

In 2016, Islam explored the possibilities and threats linked to the solid waste management in Dhaka City of Bangladesh[12]. To conduct this study, they collect data from primary sources such as field observation and focus group discussions with stakeholders, as well as secondary sources like papers, books, and journals. They highlighted solid waste management through DCC and investigated the impact of solid waste disposal on the environment. By evaluating qualitative and quantitative data, they discovered the composition of solid waste in Dhaka city. The analysis of solid waste in Dhaka city reveals four distinct waste streams: residential, commercial, industrial, and medical waste. They also highlighted the increasing rate of waste generation and the projected waste generation by 2025. From the qualitative survey he highlighted the education level of the respondent, where around 50% of the people are uneducated (encompassed mostly the rickshaw puller, day laborer). The final half of this research focuses on Islam's attempts to highlight the solid waste management process, particularly in recycling waste. Waste recycling helps reduce environmental pollution, support sustainability, provide jobs, and enhance the quality of life, especially in heavily populated and polluted urban regions like Dhaka City.

2.2.4 Limitation

All three papers ([2], [11], [12]) primarily focus on solid waste management, some focus specifically on the Dhaka North City Corporation[2] while others cover the entire Dhaka region [11], [12]. Moreover, their limitations seem to be very similar as well.

- The papers fail to explicitly explore the potential for generating electricity from solid waste as a viable solution within the context of their research on waste management.

- The papers lack a comprehensive examination of available technologies for processing solid waste to generate energy, thus failing to provide clarity on this aspect within the context of waste management strategies.

- The papers overlook the calculation of potential electricity generation from landfill sites, leaving this crucial aspect unaddressed in their analysis of waste management strategies.

2.2.5 Biomass WtE tech: Valuation, Emerging Perspectives, Socio-Enviro Impact

In 2021, Rasheed highlighted the biomass-based waste-to-energy technologies valorization and emerging perspective and their socio-environmental impact[9].This paper is focused on renewable energy and environmental sustainability, highlighted the rising energy demand spurred by economic growth. However, they emphasizes that this demand is often met through the exploitation of fossil fuel reserves, resulting in significant pollution. They are actively striving to transition away from reliance on traditional fossil fuels and towards renewable energy alternatives. In pursuit of this goal, they have researched technology to harness energy from biomass. It highlights the need for safe, renewable, and sustainable energy resources, with waste-to-energy (WtE) technologies being considered as a potential alternate source of energy. The review highlighted various WtE technologies, including thermal conversion methods (incineration, gasification, plasma supported gasification, pyrolysis, torrefaction, plasma technology), biochemical methods(anaerobic Digestion, Ethanol Fermentation, Landfill with gas capture, Composting), chemical and mechanical methods(Esterification, Microbial fuel cells, Microbial electrolysis cells, Generation of Biological Hydrogen and mechanical biological treatment) also some new trends of WtE technologies(Photo-biological processes, Dark fermentation and Ethanol fermentation). The review highlights the significance of pollution control mechanisms in incineration plants to mitigate emissions such as COx, NOx, SOx, furans, and dioxins, which are hazardous to public health. The authors also address the role of WtE technologies in mitigating climate change by reducing greenhouse gas emissions, particularly methane from landfills. The review concludes by emphasizing the potential of WtE technologies in managing MSW, the importance of considering MSW composition in technology selection, and the need for infrastructure development and government support, especially in developing countries.

2.2.6 Food Waste-to-Energy Tech: Current Status & Future Directions

In 2015, Pham highlighted the current status & future directions of food-waste-to-energy conversion technologies[4]. A significant portion of municipal solid waste consists of food waste which has the potential for energy production. However, converting food waste into usable energy is difficult because of their variable compositions, high moisture content, and low calorific value.

The aim of this paper was to provide a comprehensive understanding of the technologies used for food-waste-to-energy conversion and to identify the most effective and environmentally sustainable technologies for overcoming the barriers associated with this food waste. Various methods to generate energy from food waste were discussed in this paper including biological technologies (Anaerobic digestion, Fermentation), Thermochemical technologies (Incineration, Pyrolysis, Gasification and Hydrothermal Carbonization). This paper also discusses various technologies for food-waste-to-energy conversion, detailing their processes, working principles, and associated factors. The advantages and challenges associated with each of these conversion technologies are addressed in the paper. In the final section of this paper, a table was constructed to present an overall comparison of food-waste-to-energy conversion technologies, evaluating their environmental impact, energy-economic factors, and implications for health. From the analysis presented in the table, hydrothermal carbonization emerges as the most promising option, demonstrating superiority across all evaluated factors.

2.2.7 Selecting waste-to-energy technology for Dhaka City, Bangladesh

In 2017, Rahman diligently explored various options to determine the optimal waste-to-energy conversion technology for Dhaka City, Bangladesh, striving to mitigate environmental degradation caused by improper waste disposal methods[8]. Energy systems analysis (ESA) and life cycle analysis (LCA) were used to evaluate and select three technologies that are capable of generating electricity from waste. These three technologies are known as plasma gasification, anaerobic digestion, and pyrolysis. They also evaluated the essential characteristics of the chosen waste-to-energy (WtE) technologies. Following the application of the Analytic Hierarchy Process (AHP) model, an appropriate Waste-to-Energy (WTE) conversion technology for household waste was selected for their study area. The AHP model comprises various stages, such as defining the goal, choosing alternatives, and conducting pairwise comparisons among criteria and alternatives. They utilized a set of criteria to determine the most suitable waste-to-energy (WtE) conversion technology for Dhaka City, Bangladesh, which encompassed technology, environment, and financial aspects, each with its own set of sub-criteria. Upon meticulously executing all the steps, they successfully identified the optimal WtE conversion technology among the three options mentioned earlier. The PG technology received an overall priority percentage of 47%, while AD had 29% and Pyrolysis 26%, indicating their respective rankings in the evaluation process. So, according to this result

Plasma Gasification is the best option for WtE conversion technology for Dhaka City, Bangladesh.

2.2.8 Limitation

The three ([4], [8], [9]) highlighted research studies analyzed technologies for energy production from waste, aiming to determine the optimal technology through an evaluation of their environmental sustainability and economic viability. Moreover, their limitations seem to be very similar as well.

- They did not provide any information on the electricity generation potential of a power plant using waste-to-energy technologies.

- None of the papers provide insights into the potential costs associated with building a power plant for waste-to-energy conversion.

2.3 Compare and Contrast

In 2017, Nidoni explained how incineration effectively converts waste into energy. This research highlighted its proficiency in combusting organic waste materials and generating valuable byproducts such as heat, flue gases, and ash[13].The paper aimed to show the efficient utilization of incineration byproducts such as heat and ash. These can be utilized to produce electricity and enhance crop yield. The paper also discusses the utilization of cost-effective incineration and air pollution control equipment to maintain cleanliness. In 2011, Berge conducted an analysis of a thermochemical technology for processing municipal waste streams[14]. The purpose of this paper is to assess the characteristics of the primary product produced through hydrothermal carbonization, focusing on its physical, chemical, and thermal properties. Additionally, it aims to analyze the energy aspects of carbonization linked with various waste streams, and to examine the environmental impacts of carbonizing typical municipal waste streams, including the resulting gas and liquid byproducts. Nidoni[13] suggested using air pollution control systems to reduce the toxic gases released during the consumption of solid waste through incineration technology, recognizing that incineration has more significant environmental hazards than hydrothermal carbonization. However, Berge[14] did not suggest this type of system in their analysis. In 2019, Alam was researched the management, treatment, and disposal of municipal solid waste (MSW) in Bangladesh[15].

This study discussed the management system for Municipal Solid Waste (MSW), its disposal in various cities of Bangladesh, and the techniques utilized for processing this waste in developing countries. In 2017, Opatokun evaluates the effectiveness of industrial anaerobic digestion (AD), pyrolysis, and a combination of both (AD followed by pyrolysis) to dispose of food waste, analyzing their environmental impact through a life cycle assessment[16]. The research concluded that all three methods for managing food waste are more environmentally beneficial than traditional landfill disposal. When Patokun[16] brought up the concept of producing electricity or energy from waste through Waste-to-Energy (WtE) technology and associated power plants, Alam[15] didn't contribute any ideas regarding energy in their research. Nidoni[13],Berge[14],Alam[15],Optokun[16], those papers focus on solid waste management and waste-to-energy technologies. However, they do not provide any insight into the potential electricity generation from this waste, nor do they conduct any comprehensive calculations. In contrast, our proposed method includes calculations detailing the daily electricity production and the feasibility of constructing megawatt power plants. In 2014, Ferdous studied about the current situation of biomass energy in Bangladesh and what opportunities lie ahead for its future[17]. It highlighted the accessibility, appropriate choice, and quality of biomass nationwide, as well as the utilization of plant by-products. In 2014, Rathi conducted research on the potential for generating electricity from Municipal Solid Waste (MSW)[18]. They conducted two analyses on the MSW, including proximate and ultimate analyses. By utilizing the ultimate analysis results, they determined the Higher Calorific Value (HCV) of MSW, and ultimately calculated the amount of electricity that could be generated from this waste per day. In 2021, Alam highlighted the costs of generating renewable energy to meet Bangladesh's energy needs[10]. The study considered all forms of renewable energy, including biomass. The researchers concentrated solely on calculating the expenses involved in generating this electricity and estimating the approximate time needed to recoup these costs. Alam[10] and Rathi [18] have demonstrated the calculation of daily electricity production from biomass, whereas Ferdous[17] has not provided any such calculations. Ferdous[17], Rathi[18], Alam[10] those papers, apart[17] from the other two[10], [18], they focused on electricity generation. However, they did not conduct any simulations for feasibility analysis. This includes determining the per-unit cost of generating electricity from biomass and estimating the funds needed for constructing a power plant. Our proposed method addresses these calculations and simulates them using 'Homer Pro' for feasibility analysis, specifically for an On-Grid biomass system.

2.4 Conclusion

In this chapter, we reviewed various papers to understand their work, findings, and limitations. By comparing and contrasting different studies with related ones, we identified gaps where our proposed method can contribute. Our goal is to address these gaps, build upon existing research, and generate new insights in the field.

Chapter 3
Materials and Methods

3.1 Introduction

To generate electricity from waste, the initial step entails devising an efficient method for collecting the waste. This collection process is crucial for facilitating subsequent transitions in the energy generation process. Through a series of meticulously planned steps, we can harness the potential of waste to produce the desired electricity. This chapter aims to elucidate each step comprehensively, outlining the intricate process involved in transforming waste into a viable source of energy.

3.2 Waste Management System and WtE Technology

3.2.1 Waste management system

Humans can't avoid producing waste, so proper waste management is essential to maintaining a healthy and habitable ecosystem. The entire process of dealing with waste, from collection to disposal, is referred to as "waste management" (UN Statistics Di- vision-Environmental Statistics, 2017) [3]. Managing waste includes not only the disposal of waste but also its collection, transportation, treatment, and regulatory control. Its goal is to minimize the negative impact of waste on human health, the environment, resources, and overall aesthetics. Globally, waste management is a major environmental issue, with waste generation heavily influenced by a country's economic and cultural norms[3]. As the global population continues to expand and economic prosperity increases, it is roughly estimated that the world produces around 7-10 billion tons of solid waste each year, out of this total amount, 2.01 billion tons consist of municipal solid waste (Global Waste Management Conference 2021)[3]. Culture, socioeconomic status, and geographical location all have a role in how waste is handled around the world. Different places, such as residential and industrial districts in cities and rural areas, have different requirements. Additionally, waste management methods vary according to the type of waste, whether it's solid or liquid, domestic or industrial, medical, or otherwise, and whether it's biodegradable or non-biodegradable[3]. Natural resources can be preserved if we practice proper waste management.

This way, everyone on Earth can live safely and enjoy the planet's benefits[19]. Waste management refers to the process of managing waste. Steps in the waste management process include collection, segregation, transport, treatment & disposal. Taking these steps helps to keep the environment clean, mitigate pollution's harmful impacts, and stops its pollution spread. As a result, all forms of life would find the new conditions to their liking[19].

Technology and creativity have both contributed to the evolution of modern waste management. We proposed a modern waste management system to ensure proper waste disposal. The plan is displayed below:

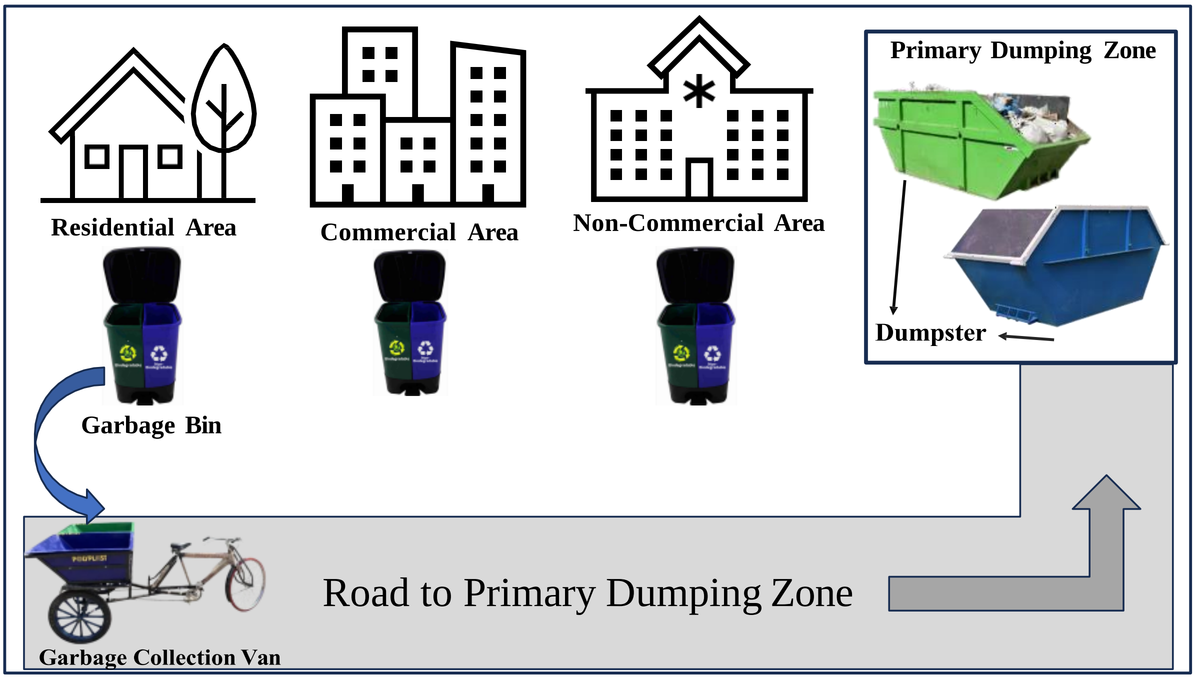


Figure 3.1: Primary waste collection system

In the proposed primary waste collection system, every residential, commercial, and industrial establishment will be equipped with medium bins designed to accommodate both biodegradable and non-biodegradable waste separately. These bins will feature adjustable partitions, allowing for segregation within the same container. The designated primary zones will cover the entire area, facilitating efficient waste management. Battery-operated vans will be deployed to collect the segregated waste from these zones, with each van equipped with two compartments dedicated to biodegradable and non-biodegradable waste respectively.

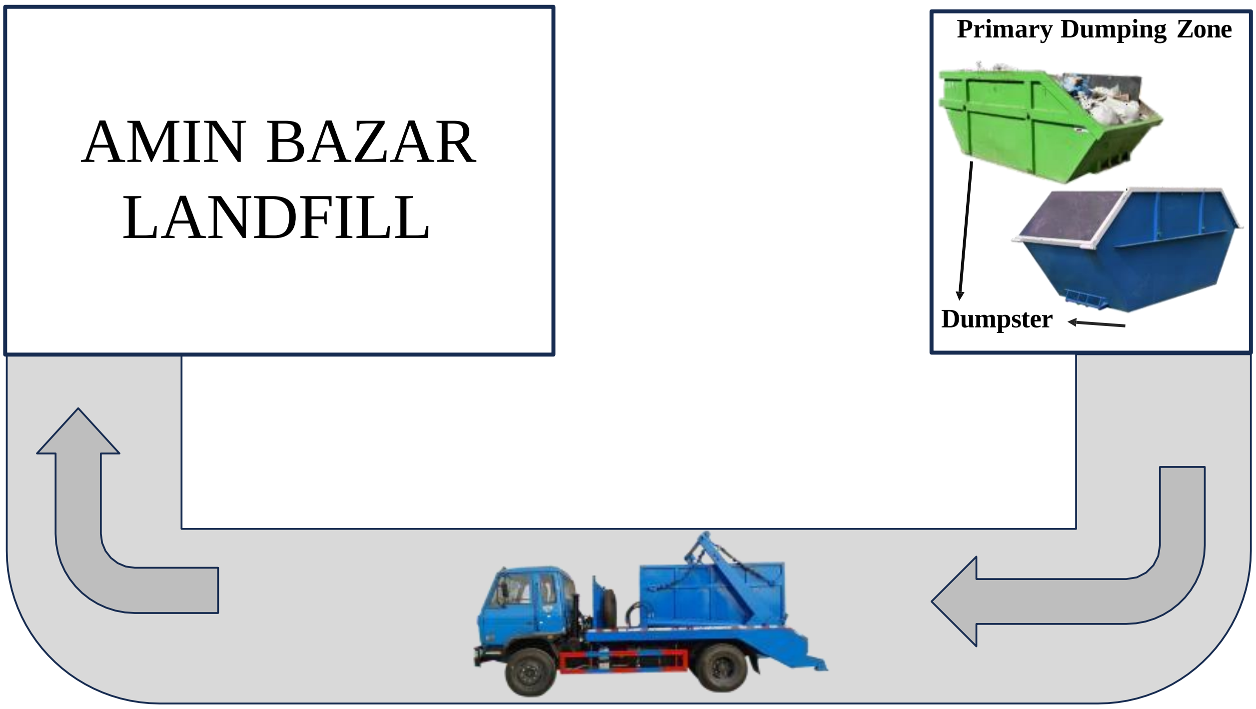


Figure 3.2: Secondary waste collection system

Once the waste is gathered at the primary zone via the initial collection system, it is then transported to the dumping zone utilizing a secondary collection system. Drum steer trucks will be employed for this purpose, with specific trucks designated to transport non-biodegradable waste to its respective dumping station, while others will handle the transportation of biodegradable waste to its designated dumping site.

The methodology proposed for the Amin Bazar landfill can serve as a blueprint for waste management systems in other cities. However, for this approach to yield effective results, it is imperative that management personnel and staff diligently execute their responsibilities. Additionally, the cooperation and responsibility of the public are essential; without it, the efficacy of this proposed method may be called into question.

3.2.2 Accumulated waste

People generate waste in various activities like household chores, farming, business operations, manufacturing, responding to emergencies, and providing medical services. In developing nations, as cities grow and economies expand, the amount of waste produced also increases. Out study area, the Amin Bazar landfill, situated in Savar Upazilla of Dhaka, Bangladesh, is positioned near the floodplain of the Karnatali River, with coordinates between 23°48'0.86" and 23°47'44.33" latitude and 90°17'51.03" and 90°18'12.03" longitude. It has been in use as a dumpsite since 2007, initially operating as an open dumpsite during its first phase.

Types of waste that are gathered in our study area-

1. Solid Waste from cities-
   - Organic (Food Waste)
   - Paper
   - Plastic & Polythene
   - Textile & Wood
   - Leather & rubber
   - Metal
   - Glass & Ceramics
   - Others
2. Construction & Demolition Waste -
   - Concrete
   - Wood
   - Bricks
   - Metals
   - Plastics
   - Other debris
3. Industrial Waste –
   - Packaging materials
   - Scrap materials
   - Plastics
   - Other debris
4. Hospital Waste –
   - Blood or other bodily fluids
   - Pharmaceutical & Medical Waste

5. Electronics Waste –
   - Computer
   - Mobile Phones
   - TVs
   - Others
6. Hazardous Waste –
   - Chemical
   - Solvents
   - Batteries

The above-mentioned list of waste has a combination of both biodegradable and non-biodegradable materials. Our primary emphasis is solely on biodegradable garbage.

Biodegradable Waste:

- Organic (Food Waste)
- Paper
- Textile & Wood
- Leather & Rubber
- Blood or other bodily fluids

Non-Biodegradable Waste:

- Plastic & Polythene
- Metal
- Glass & Ceramics
- Construction & Demolition Wastes
- Industrial Wates
- Hazardous Wastes
- Electronic Wastes
- Others

Solid waste, sometimes known as solid garbage or just garbage, is a comprehensive word employed to encompass wasted materials that do not possess a liquid or gaseous state. It encompasses a wide variety of waste materials generated by human activities, including residential, commercial, industrial, and institutional sources. Solid waste encompasses a wide range of materials, comprising both non-hazardous and hazardous substances.

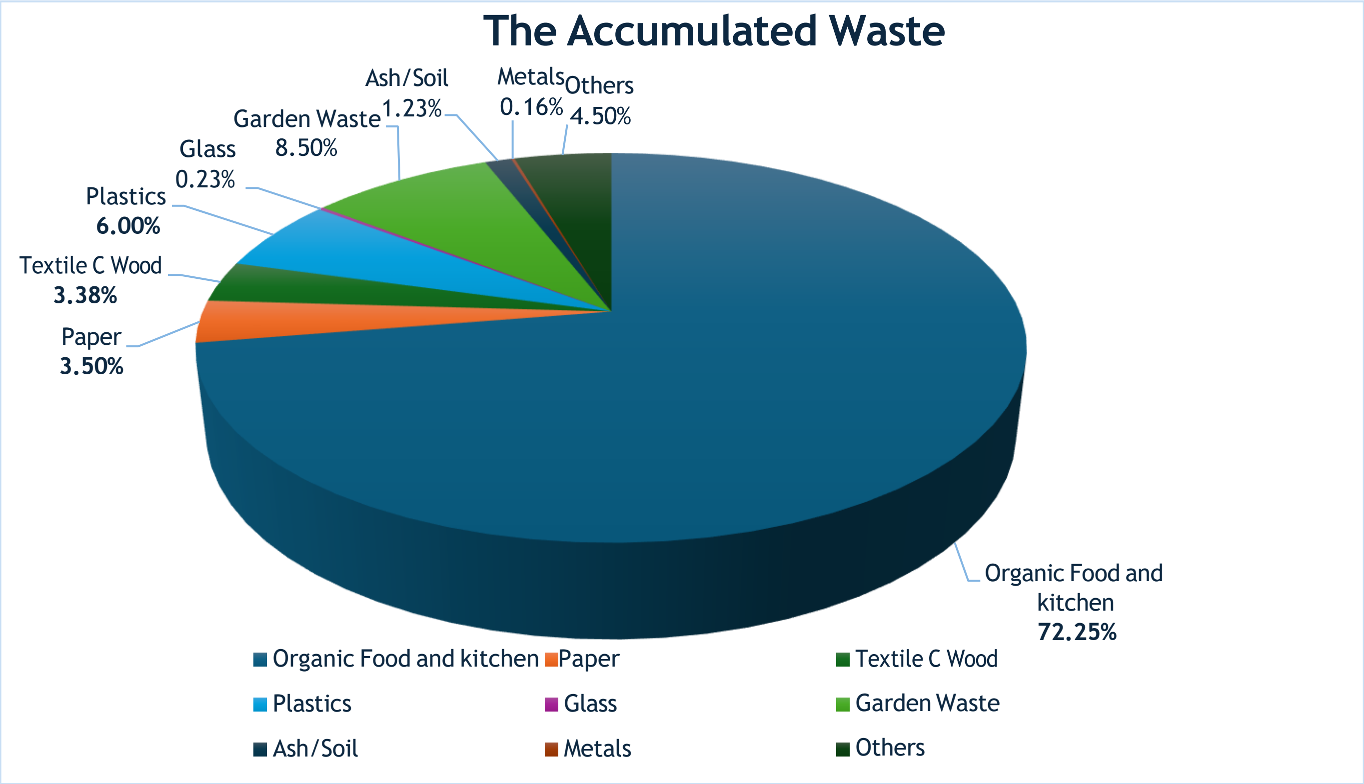


Figure 3.3: Waste accumulation percentage at the Amin Bazar landfill [2]

From the chart of collected waste, it can be seen that most of the solid waste collected from the urban area was biodegradable waste. The remaining waste items seen in the above-mentioned chart classified as non-biodegradable waste.

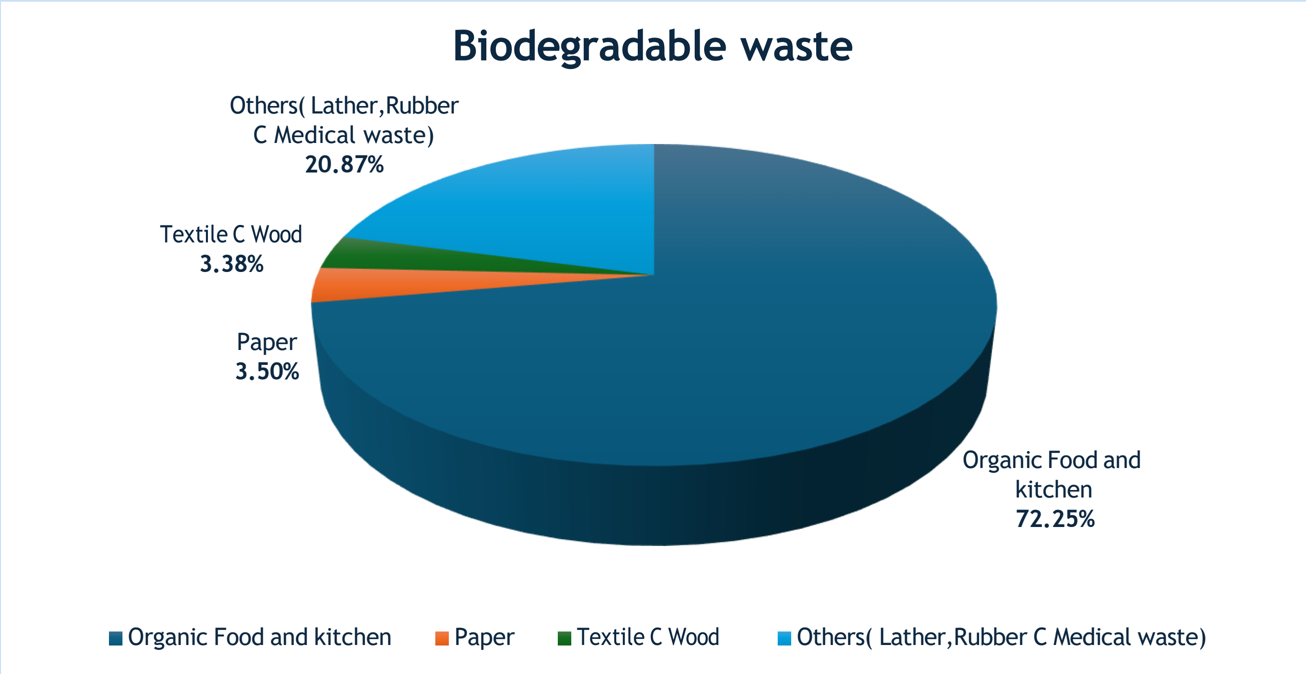


Figure 3.4: Biodegradable waste accumulation percentage at the Amin Bazar landfill [2]

Each person in Dhaka North City Corporation (DNCC) produces an average of 0.641 kilograms of waste per day[20]. According to the Population and Housing Census 2022 published by the Bangladesh Bureau of Statistics (BBS), the population of DNCC is estimated to be 5.979537 million.

So, according to the above information the Amount of waste generation per day:

$$= (0.641 \text{ kg/capita/day} \times 5979537)$$

$$= 3832883.217 \text{ Kg/day}$$

$$= 4225.0305 \text{ Ton/day}$$

Almost 4225.0305 tons of waste must be handled every day, which is a huge burden. In the past, waste was hauled away in open vehicles and dumped in random fields before being taken to Amin bazar Landfill. Waste management at DNCC has developed to keep up with the times; today, about 80% of waste is collected using a compactor, container carrier, and arm roller[3].

So, 80% of the daily waste generation amounts to 3,380.0244 tons. This means that 3,380.0244 tons of waste are collected at the Amin Bazar landfill every day.

3.2.3 Waste to Energy Technologies

Utilizing food waste for energy production is an attractive choice, especially when it comes to assuring energy security. The finding has prompted in-depth research into technology aimed at extracting useful fuels from food waste to decrease the environmental impact of its disposal, prevent the depletion of natural resources, reduce risks to human health, and maintain ecological equilibrium. This section provides a summary of various technologies studied for transforming food waste into energy[4]. As per the latest report from the World Energy Council (WEC), the conversion of waste to energy (WtE) can be accomplished using three different methods.

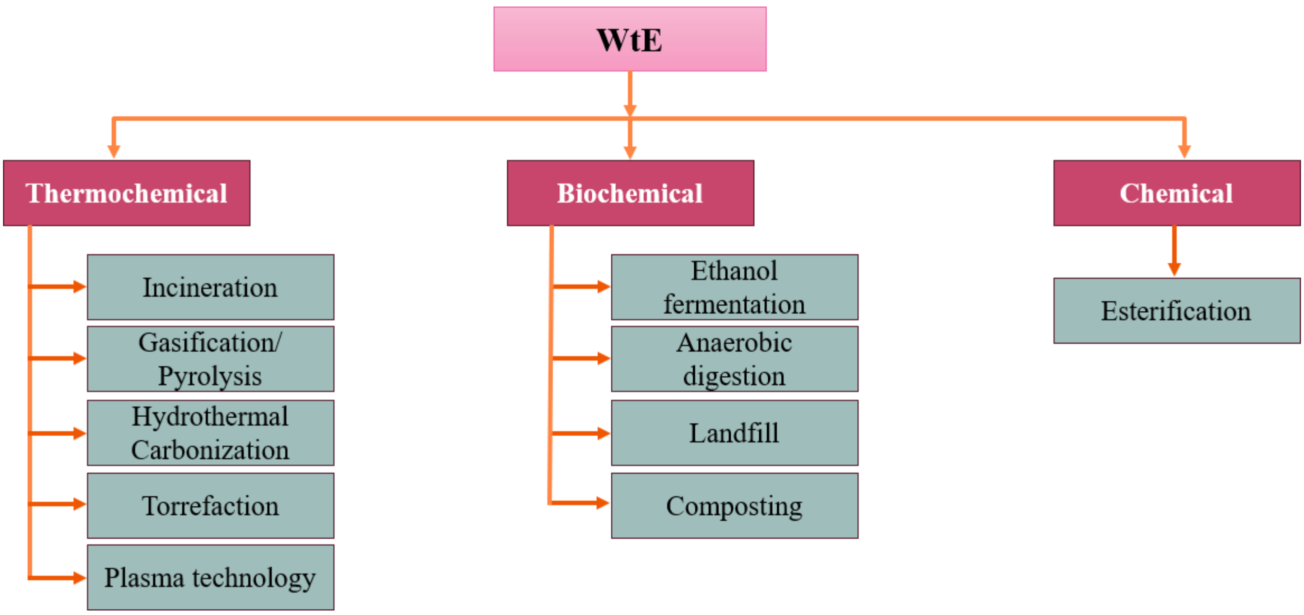


Figure 3.5: Waste-to-energy technologies

3.2.3.1 Thermochemical Technologies-

Incineration:

In developing nations, incineration is the most cost-effective and dependable method for burning garbage without pretreatment for energy production[9].

The primary benefit of this strategy is in its ability to facilitate the mineralization of organic material and the transformation of live organisms into harmless end products[9]. It is considered the lowest demand technique as the waste to energy conversion technology[21]. Incineration is an established technology for extracting energy and heat from waste through combustion. The heat produced during combustion can be used to drive steam turbines for generating energy or to run heat exchangers that heat process streams in workplaces[4].Incineration takes place in specialized furnaces called incinerators, which have combustion chambers designed to safely burn out possible hazardous materials. The technique has the capability to decrease the volume of solid waste delivered for disposal by approximately 80-85%[21]. The by-products of incineration are heat, flue gases and ash[13]. The benefit of incineration is that it reduces volume by 95-96% which is commendable[13]. Combustion is a widely recognized method for waste disposal; however, its environmental impact is a major concern for everyone.

Pyrolysis:

In the field of waste-to-energy conversion, pyrolysis is one of the oldest thermal technologies. Synthetic gas, oil, and biochar are the byproducts of pyrolysis[22]. Biochar is a carbon-rich substance used as a renewable fuel and to enhance soil quality. Depending on the biomass and pyrolysis temperature, its composition includes carbon, hydrogen, oxygen, nitrogen, sulfur, calcium, and silicon, among others[22]. It operates between 400 and 800 C in an oxygen- and air-free environment[9]. Slow pyrolysis, fast pyrolysis, catalytic pyrolysis, and pyrolysis with the aid of a microwave oven are all possible[6].

Gasification:

The process of gasification also involves heat. Gasification is the process by which organic waste is burned as fuel by partially oxidizing it at high temperatures (usually between 800 and 900 degrees Celsius)[4]. The gas is the primary byproduct of the gasification process and is used in the subsequent combustion process to generate energy. The process produces liquid fuels and chemical feedstock[9]. While compared to incineration, gasification technology produces significantly less carbon dioxide while processing the same amount of municipal solid waste[9]. The most effective methods for treating MSW, from the perspectives of energy recovery and environmental impact, are gasification and pyrolysis[9].

In comparison to incineration, gasification and pyrolysis can reduce waste volumes by up to 95% and require less extensive flue gas cleaning[9]. Synthesis gas, often known as syngas, is produced through the partial oxidation of organic compounds at high temperatures (500°C - 1800°C) and can be utilized as a feedstock (through certain reforming operations) as well as a fuel[7]. Syngas is made up of hydrogen (H_2), Methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), nitrogen (N_2), and oxygen (O_2), with small amounts of other hydrocarbons including propane and ethane[5].

Hydrothermal Carbonization:

HTC was first developed in 1913 as a technique of experimenting producing coal from cellulose[4].Without the need for a pre-treatment process, wet biomass or feedstock can be converted to solid (hydrochar), liquid (oils after extraction), or gaseous products using the thermochemical conversion technology known as hydrothermal carbonization (HTC)[21]. For waste streams with a high moisture content usually between 80 and 90 percent, hydrothermal carbonization (HTC) has become an increasingly popular thermal conversion technology[4]. HTC is a wet method that utilizes autogenous pressures and low temperatures (between 180 and 350 degrees Celsius), HTC transforms food scraps into a viable energy resource. HTC provides many benefits, such as reduced space required for treatment, increased waste volume reduction, and the absence of process-related smells[4]. Numerous studies have highlighted the environmental advantages of Hydrothermal Carbonization (HTC) in dealing with various food waste and residues while recovering nutrients. Wet agro-industrial waste was the topic of a study that looked at how factors like residence duration and temperature affected the waste product. The findings indicated a significant reduction in volume (to <30%) and more than 50% energy savings compared to conventional thermal treatments[21].

Plasma Technology -

This technology depends on a simple physical process involving the use of heat or energy to transform a substance from a solid to a liquid, and then from a liquid to a gaseous state. The resulting gaseous mixture can be ionized to produce a high-energy state known as plasma state by applying more energy[9].

Torrefaction-

Torrefaction is defined as the process of thermally enhancing biomass to create a more uniform product that can be condensed into denser energy sources, such as briquettes or torrefied pellets (TOPs), with properties like coal[9]. This form of energy is helpful to further thermochemical processes[23]. Torrefaction technology, which is also called mild pyrolysis, is a thermo-chemical process that takes place in an inert atmosphere at a low heating rate, typically between 200 and 300 °C[23]. The first step in this procedure is to chip the biomass so that it may be dried more efficiently. After being screened for contaminants, it is then sized before being dried to a moisture level of 20%[23].

3.2.3.2 Biochemical Technologies-

Biochemical technology entails harnessing the power of microorganisms, such as bacteria, to extract energy from waste materials, transforming it into a gas or liquid that can be subsequently used for electricity generation[24]. Microorganisms' enzymes are responsible for the waste-to-energy process[9].

Ethanol Fermentation:

When it comes to waste-to-energy conversion, ethanol production from food waste employs a distinct approach compared to biogas production. Various types of food waste have been successfully utilized as feedstocks for bio-ethanol production. These include materials like banana peels, sugar beet pulp, pineapple waste, grape pomace, potato peel waste, citrus waste, as well as cafeteria and household food waste[4]. The process typically involves fermenting the sugars present in these waste materials to produce ethanol, which can be used as a biofuel or chemical feedstock. This approach offers an alternative to biogas production and allows for the conversion of food waste into a valuable energy resource. There are a variety of pretreatment procedures such as acid, alkali, thermal and enzymatic that have been employed to increase cellulose digestibility due to the complicated structure of the lignocellulosic component of food wastes[4]. To make ethanol from food waste, enzyme hydrolysis is typically used as a pretreatment[4]. An alternate fuel for spark ignition engines is ethanol made from various renewable feedstock[23]. Ethanol is considered a biofuel because it is derived from plant-based sources, and the carbon it contains originates from these plants through photosynthesis. As a result, when ethanol is burned or combusted for energy, it releases carbon dioxide (CO_2) into the atmosphere, it will not contribute to the increase in CO_2 emissions[23].

Anaerobic digestion:

Anaerobic Digestion (AD) is a well-established method in the waste-to-energy sector for the treatment of organic wastes, on par with incineration and gasification[5]. It is one of the oldest wastes to energy process. Although manure and slurry are the primary feedstock for AD, other organic materials can also be used[5]. The TRL 9 status of anaerobic digestors reflects their widespread use in the UK. There are now 661 active digestors in the UK[5]. In the absence of oxygen and between 55 and 75 degrees Celsius, biodegradable organic compounds undergo biological conversion[8].

Landfill-

Compared to incinerating waste directly, landfilling is often regarded as a more cost-effective method. Landfills are large pits where waste can be buried and let to degrade over a period. Eliminating seepage, reducing odor, and reducing lower greenhouse gas emissions are all necessary for a landfill to function properly.[9]

Composting:

Under aerobic circumstances, biodegradable waste is broken down into heat, water, carbon dioxide, and compost (a rather stable waste product). Soil quality can be easily improved by using compost in subsequent applications. Bacteria, fungus, and actinomycetes are the three main types of microorganisms involved in the composting process.[9]

3.2.3.3 Comparison between technologies

The environmental, energy-economic, health, and waste aspects of different food-waste to energy conversion technologies are compared in this comprehensive review.

Table 3.1: Food waste to energy conversion technologies comparison [4]

Technology		In	P &G	HC	EF	AD
Environmental Aspects	Green House Effect	★	★★★	★★★★★	★★★★	★★★★
	Odor Problem	★★★★★	★★★★★	★★★★★	★★	★
	Air/Water Pollution	★	★★★	★★★★★	★★★★★	★★★★
Energy Economics & Health Aspects	Human Health	★	★	★★★★★	★★★★	★★
	Process Speed	★★★★	★★★★	★★★★★	★★★	★
	Energy Production	★★★	★★★	★★★★★	★★★	★
	Relative Cost	★★	★★★	★★★	★★	★★
Waste Factor	Moisture	★★	★	★★★★★	★★★	★★★★★

In = Incineration, P = Pyrolysis, G = Gasification, HC = Hydrothermal Carbonization, EF = Ethanol Fermentation, AD = Anaerobic Digestion

★ Very Poor ★ ★ Poor ★ ★ ★ Moderate ★ ★ ★ ★ Good ★ ★ ★ ★ ★ Very Good

Conducting a comprehensive review of waste-to-energy conversion methods, encompassing thermochemical, biochemical, and chemical processes, has led us to emphasize hydrothermal carbonization and anaerobic digestion as promising technologies. The selection of these methods was influenced by their ability to produce hydrochar and biogas, in addition to factors such as environmental impact, energy efficiency, economic viability, public health implications, and waste management considerations. While exploring various alternatives like incineration, pyrolysis, gasification, ethanol fermentation, and anaerobic digestion, it became evident that hydrothermal carbonization and anaerobic digestion offer significant benefits for our environment. Through a meticulous comparative analysis, these two technologies have emerged as the optimal choices, meeting our specified criteria most effectively. We ultimately chose to focus on anaerobic digestion as my research avenue, given that hydrothermal carbonization remains largely unexplored on a large scale and is primarily confined to laboratory experimentation.

3.3 Design Specifications. Standards and Constraints

3.3.1 Electricity generation from waste utilizing anaerobic digestion process.

We have already been introduced to anaerobic digestion in the previous section on technologies. Now, we will delve into the schematic representation of the anaerobic digestion process to grasp its functioning in detail.

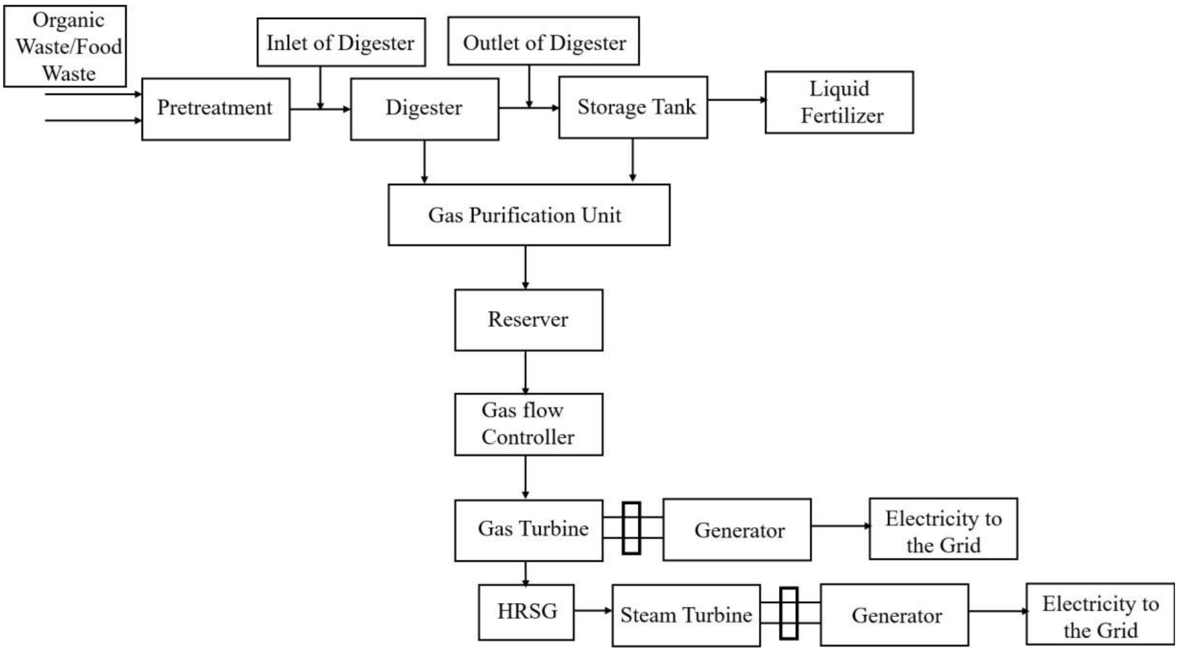


Figure 3.6: Block diagram of a standard grid-connected biogas electricity system

In the anaerobic digestion process, organic waste or food waste undergoes pretreatment before entering the digester through the inlet. Within the digester, a series of biochemical processes occur, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. These processes result in the production of biogas, primarily composed of methane (CH_4) and carbon dioxide (CO_2), along with trace amounts of other gases such as nitrogen (N_2), oxygen (O_2), and hydrogen sulfide (H_2S). Additionally, some liquid byproducts are directed to a storage tank via the outlet of the digester.

The biogas mixture is then sent through a biogas purification unit where only methane is separated and directed to a reserve. From this reserve, the gas flows to a gas engine via a gas flow controller. The rotor shaft of the engine is coupled with a generator, allowing for the generation of electricity.

The process of methanogenesis converts gas mixtures containing hydrogen (H_2) and carbon dioxide (CO_2), into biogas, which typically consists of methane (CH_4) comprising 60-70% and carbon dioxide (CO_2) making up 30-40% of its composition[25]. The biogas yield from food waste is 110 cubic meters per ton of fresh matter[25]. The HHV of methane (CH_4) that is produced from food waste through anaerobic digestion is 27.2 MJ/M^3[4]. The variation in heating value typically ranges from 21 to 23.5 MJ/M^3 for biogas, indicating that one cubic meter of biogas varies in energy content within this range[4], [25]. So, the Average HHV of Biogas is 25 MJ/M^3.

3.4 System Analysis

3.4.1 Electricity Generation calculation from Biogas (CH4)

According to the reference, the Biogas produce per ton Food waste 110 M^3 [25]. Total composition of biogas 75% are methane[25]. The average Food waste available per day 2500 Tons[2]. The calorific value of this produced methane average 25 MJ/M^3 . Modern combined cycle power plants can achieve overall efficiencies ranging from 50% to 60% or even higher under optimal conditions[26].

Step 1: Calculating Methane Gas Available

Methane Gas Available = (Biogas produced per ton of food waste) × (Methane content in biogas) × (Average food waste available per day)

= 110 m^3 × 0.75 × 2500 tons

= 206,250 m^3/day

Step 2: Calculating Total Energy

Total Energy = Methane Gas Available × Calorific Value

= 206,250 m^3/day × 25 MJ/m^3

= 5,156,250 MJ/day

Step 3: Calculating Available Electrical Energy

We know that 1 MJ is equivalent to 0.000277778 MWh. So according to this:

Available Electrical Energy = Total Energy × Conversion Factor

= 5,156,250 MJ/day × 0.000277778

= 1433.125 MWh/day

Step 4: Adjusting for Turbine Efficiency

Energy after Turbine Losses = Available Electrical Energy × Turbine Efficiency

= 1433.125 MWh/day × 0.60

= 859.875 MWh/day

Step 5: Adjusting for Alternator Efficiency

Final Available Electrical Energy = Energy after Turbine Losses × Alternator Efficiency

= 859.875 MWh/day × 0.95

= 816.88125 MWh/day

Therefore, after considering turbine and alternator efficiencies, the final available electrical energy per day is approximately 816.88 MWh. Therefore, based on the available electrical energy calculated, a power plant with a capacity of approximately 34 MW can be built.

3.5 Simulation

In the preceding discussion, we computed the potential electricity generation from accumulated Food & Kitchen waste in landfills. Now, our focus shifts to determining the per unit cost of generating electricity from this waste. To accomplish this, we devised a simulation using Homer Pro software. The HOMER software assists in determining the most effective way to produce power in a specific area by analyzing several technologies and equipment sizes to find the optimum solution.

The analysis considers costs and environmental impacts of conventional and renewable energy sources. HOMER simulates a power system's operations over a year to evaluate electricity demand and generation capacity. It then assesses if the system can fulfil the electrical needs and priorities setups according to cost effectiveness. HOMER additionally allows the evaluation of various scenarios by modifying inputs to analyze their effects on the results.

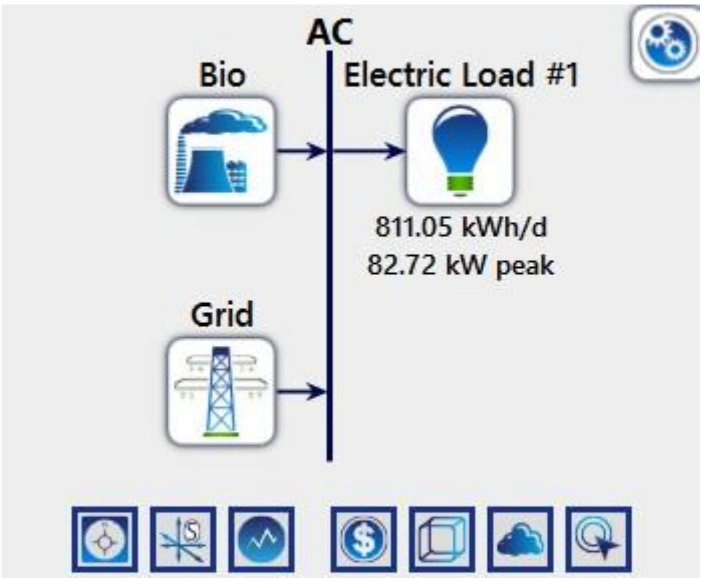


Figure 3.7: Schematic design of load and sources in Homer Pro

Biogas Generator:

A single biogas generator is considered appropriate for the construction of the system. To enhance efficiency using HOMER Pro for required sizing while considering the most economical operational sequence, inputs spanning from 0 to 40 MW are provided within the search space. Indeed, the market offers various types of biogas generators with prices varying based on factors such as brand, model, capacity, fuel type, and additional features. It's essential to carefully consider these factors when selecting a generator for a specific application to ensure it meets the requirements efficiently and cost-effectively.

The 250 kW Biogas Generator, adaptable for natural gas, biogas, and LPG, is priced at $31,590 on Alibaba, equating to a per kilowatt cost of $126.36. Comparing this to larger generators, a 1 MW generator costs $180,000, or $180 per kW, while a 500 kW generator costs $80,000, or $160 per kW. Even larger generators, like a 2500 kW one, can cost $240,000, making each kW approximately $96[27].

Grid:

A grid integrated distributed generation has recently become popular. In this paper, we explore the possibility of linking a microgrid system such that Bangladesh's national grid can receive any excess power. By making it possible to sell excess electricity back to the grid, this integration aims to promote economic development.

Medium Tension (MT): 11 kV Electricity

Supply: Medium Tension AC 11 kV

Frequency: 50 Hz

Sanctioned Load: Immediate above of 50 kW to up to 05 MW

Table 3.2. Scheduled rate of National Grid Electricity in Bangladesh[28]

Model Rate (for 11kV Line)	Grid Power Price ($/kWh)	Sell Back Rate($/kWh)	Demand rate ($/kW/month)
Off Peak	0.087	0.051	0.68
Flat rate	0.096	0.061	0.68
Peak	0.12	0.080	0.68

Auxiliary Load Profile:

While this power plant may not be as widely recognized as others, it still holds the potential to make a modest contribution towards meeting the nation's electricity demand. During its operation, various electrical equipment, known as auxiliary power equipment, are also utilized. For instance, in every sub-station, there exists an auxiliary transformer (11/0.440 KV) responsible for supplying power to the sub-station, facilitating the operation of its electrical equipment. Similarly, certain other equipment consumes electricity generated by the power plant itself.

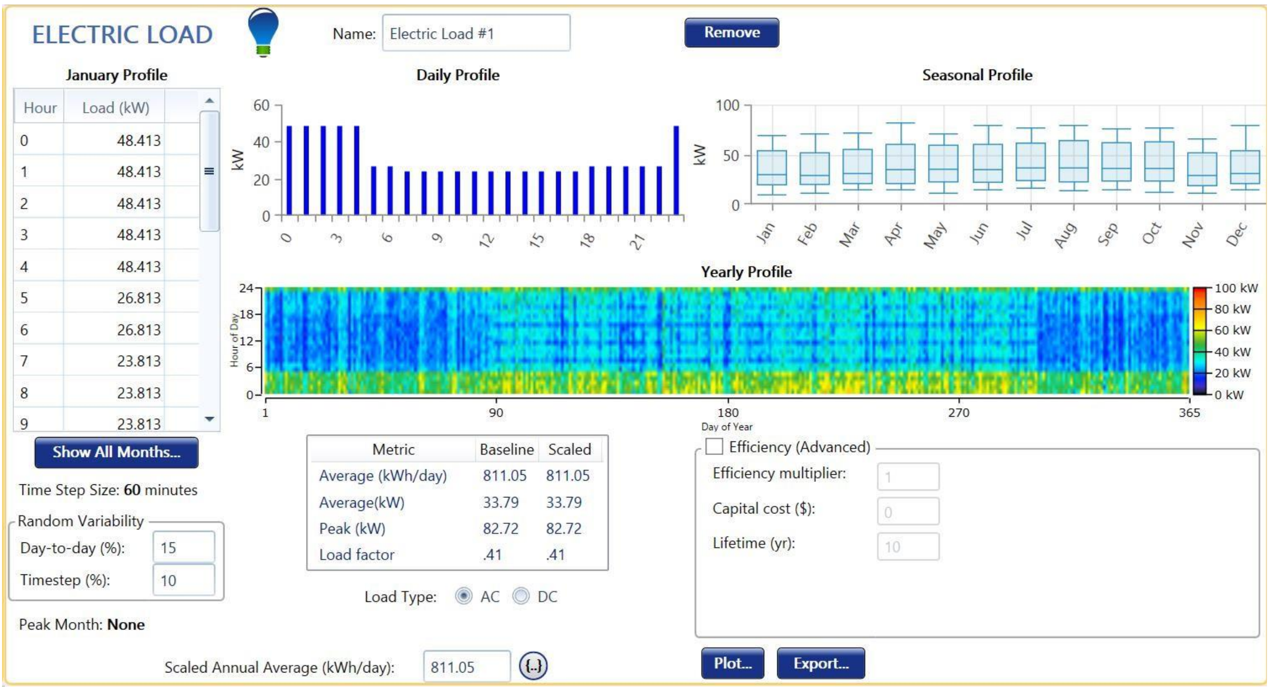


Figure 3.8: Auxiliary Consumption Load Profile

Table 3.3. Estimation of auxiliary load

Load Type	W rating	No of units	Total W
LED Light (Room)	12	50	600
Flood Light	100	30	3000
Celling and Cooling Fan	50	20	1000
CC Camera	15	100	1500
3-phase induction motor	1471	3	4413
Electric Vehicle Charging station	7200	3	21600
AC	1000	6	6000
Exhaust fan	70	16	1120
PC	118	10	1180
Motor (Conveyor belt)	3000	5	15000
			= 55413 watts
			= 55.413 kW

Here, we have compiled a table detailing the auxiliary load utilized during power plant operations. The loads presented in the table may vary depending on factors such as power plant capacity, operational mode, technological advancements, maintenance frequency, and grid stability considerations.

Figure 3.9: Monthly average available biomass resource

Economics:

System Fixed Capital Cost-

Fixed Capital Cost (FCC) and are crucial elements in evaluating the economic feasibility of microgrid projects within the Economics module of Homer Pro. The FCC denotes the initial capital outlay for establishing infrastructure. These characteristics are vital in assessing project profitability and sustainability. For a 1 MW power plant, the projected investment is estimated at €3,555 per 1 kW, with total annual expenditures are estimated at €0.092 per kWh, amounting to approximately €0.68 million[29]. So, For 40 MW power plant.

Fixed Capital cost = $35121993

System fixed O&M cost-

The assessment of the economic viability of microgrid projects inside the Economics module of Homer Pro heavily relies on the consideration of Fixed Operation and Maintenance (O&M) Costs. The term "operating costs" (Co) refers to all the money spent on things like raw materials filter and processing, transportation, energy, labour, and chemicals that are part of the typical production cycle. These expenses are critical for maintaining day-to-day operations and guaranteeing that production processes will not be interrupted. The estimated operational expenses for the year are €0.36 million, or €0.048 per kilowatt-hour[29]. The estimated yearly maintenance expenditures (Cm) amounting to €70,000, or €0.009 per kWh, will cover charges for spare parts, services, routine and preventative system maintenance, labor, and more[29].

So, System fixed O&M costs = $21760365

3.6 Summary

This chapter provides an overview of the methods employed in our study. We have deliberated on the appropriate methods for collecting and handling waste, and we have given the information that was collected. We have endeavoured to emphasize the various technologies that can be utilized to transform waste into energy. The proposed design has been provided, and an analysis of the obtained data has been conducted to provide an estimation of the electricity generation. In the final section of this chapter, we provide a detailed description of the simulation's design and the necessary equipment requirements.

Chapter 4
Results and Discussions

4.1 Results/Observations

4.1.1 Optimization Results

Architecture			Cost				System		Bio					Grid	
Bio (kW)	Grid (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)	Energy Purchased (kWh)	Energy Sold (kWh)
40,000	999,999	LF	$276M	$0.0734	$18.0M	$42.3M	100	870,670	7,261	290,212,448	870,670	8,713,200	0	45,844	289,962,272
40,000	999,999	CC	$276M	$0.0734	$18.0M	$42.3M	100	870,670	7,261	290,212,448	870,670	8,713,200	0	45,844	289,962,272
35,000	999,999	LF	$280M	$0.0849	$18.5M	$41.4M	100	766,468	7,300	255,488,736	766,468	7,665,000	0	43,814	255,236,528
35,000	999,999	CC	$280M	$0.0849	$18.5M	$41.4M	100	766,468	7,300	255,488,736	766,468	7,665,000	0	43,814	255,236,528
30,000	999,999	LF	$286M	$0.101	$19.0M	$40.5M	100	657,000	7,300	219,000,000	657,000	6,570,000	0	43,814	218,747,776
30,000	999,999	CC	$286M	$0.101	$19.0M	$40.5M	100	657,000	7,300	219,000,000	657,000	6,570,000	0	43,814	218,747,776
20,000	999,999	LF	$296M	$0.157	$19.9M	$38.7M	100	438,000	7,300	146,000,000	438,000	4,380,000	0	43,814	145,747,776
20,000	999,999	CC	$296M	$0.157	$19.9M	$38.7M	100	438,000	7,300	146,000,000	438,000	4,380,000	0	43,814	145,747,776
10,000	999,999	LF	$306M	$0.324	$20.8M	$36.9M	99.9	219,000	7,300	73,000,000	219,000	2,190,000	0	43,814	72,747,784
10,000	999,999	CC	$306M	$0.324	$20.8M	$36.9M	99.9	219,000	7,300	73,000,000	219,000	2,190,000	0	43,814	72,747,784
5,000	999,999	LF	$311M	$0.659	$21.3M	$36.0M	99.9	109,500	7,300	36,500,000	109,500	1,095,000	0	43,814	36,247,780
5,000	999,999	CC	$311M	$0.659	$21.3M	$36.0M	99.9	109,500	7,300	36,500,000	109,500	1,095,000	0	43,814	36,247,780
1,000	999,999	LF	$316M	$3.32	$21.7M	$35.3M	99.4	21,900	7,300	7,300,000	21,900	219,000	0	43,814	7,047,781
1,000	999,999	CC	$316M	$3.32	$21.7M	$35.3M	99.4	21,900	7,300	7,300,000	21,900	219,000	0	43,814	7,047,781
500	999,999	LF	$316M	$6.62	$21.7M	$35.2M	98.8	10,950	7,300	3,650,000	10,950	109,500	0	43,814	3,397,781
500	999,999	CC	$316M	$6.62	$21.7M	$35.2M	98.8	10,950	7,300	3,650,000	10,950	109,500	0	43,814	3,397,781
400	999,999	LF	$316M	$8.25	$21.7M	$35.2M	98.5	8,760	7,300	2,920,000	8,760	87,600	0	43,814	2,667,781
400	999,999	CC	$316M	$8.25	$21.7M	$35.2M	98.5	8,760	7,300	2,920,000	8,760	87,600	0	43,814	2,667,781
250	999,999	LF	$316M	$13.10	$21.8M	$35.2M	97.7	5,475	7,300	1,825,000	5,475	54,750	0	43,814	1,572,781
250	999,999	CC	$316M	$13.10	$21.8M	$35.2M	97.7	5,475	7,300	1,825,000	5,475	54,750	0	43,814	1,572,781
100	999,999	LF	$317M	$31.64	$21.8M	$35.1M	94.3	2,190	7,300	730,000	2,190	21,900	0	43,814	477,781
100	999,999	CC	$317M	$31.64	$21.8M	$35.1M	94.3	2,190	7,300	730,000	2,190	21,900	0	43,814	477,781
	999,999	LF	$317M	$82.77	$21.8M	$35.1M	0	0						296,033	0
	999,999	CC	$317M	$82.77	$21.8M	$35.1M	0	0						296,033	0

Figure 4.1: Optimization Results

The optimization results derived from simulation calculations are depicted in the above figure. The figure shows different system configurations, with NPC values listed in ascending order from lowest to highest. The plant with the lowest NPC stands out as the most financially viable option. The combination of Grid and a 40 MW Biogas Generator emerges as the most economically viable option.

4.1.2 Analysis of Electrical energy production

Production	kWh/yr
Generic Biogas Genset (size-your-own)	290,212,446
Grid Purchases	45,844
Total	290,258,290

Figure 4.2: Production of Electricity

Consumption	kWh/yr	%
AC Primary Load	296,033	0.102
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	289,962,257	99.9
Total	290,258,290	100

Figure 4.3: Consumption of Electricity

The figures represent the total power output of the biogas generator and grid system. In this setup, all energy needed to meet the load demand is generated from biomass energy sources. The generator is temporarily shut down for the purpose of maintenance, during which a limited amount of electricity is purchased from the grid to power the auxiliary load.

In the above figures shows the system efficiently utilizes biomass energy to meet the majority of its load demand, with only 0.102% consumed by the AC primary load. The surplus electricity, accounting for 99.9%, is sold to the grid, indicating a significant potential for revenue generation. This approach not only reduces reliance on fossil fuels but also contributes to environmental sustainability by minimizing greenhouse gas emissions. Moreover, the system achieves energy independence by not purchasing electricity from the grid, enhancing stability and resilience. Looking ahead, there may be opportunities to further optimize or expand the system for increased efficiency and revenue generation.

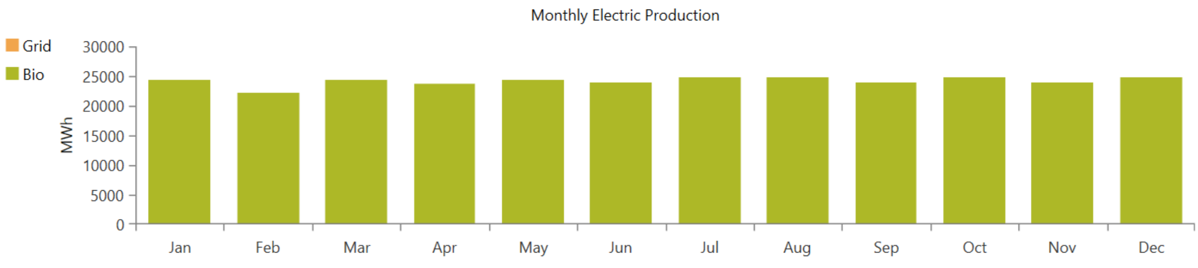


Figure 4.4: Monthly share of Electricity from Biomass-grid system

The energy purchase from the grid is significantly lower than the generation, which is why the above figure is not clearly visible. However, a small percentage of the energy is purchased from the grid every month.

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	0	%

Figure 4.5: Renewable energy fraction of Biomass-grid

100% of the total power produced comes from renewable energy sources indicates a portion of the energy generated is derived from sustainable sources such as biomass. This suggests a commitment to reducing reliance on non-renewable resources and addressing environmental concerns associated with energy production.

4.1.3 Analysis of Fuel

Quantity	Value	Units
Total feedstock consumed	870,670	tons
Avg feedstock per day	2,385	tons/day
Avg feedstock per hour	99.4	tons/hour

Figure 4.6: Fuel share of Biomass-grid system

Based on the above figure given information, the biogas generator consumes a total of 870,670 tons of feedstock, with a daily consumption of 2,385 tons from food and kitchen wastes. This translates to an average feedstock consumption of 99.4 tons per hour. The Biomass resource, when scaled to an annual average, exhibits a daily availability of 2,436 tons of food waste.

4.1.4 Comparing Economies

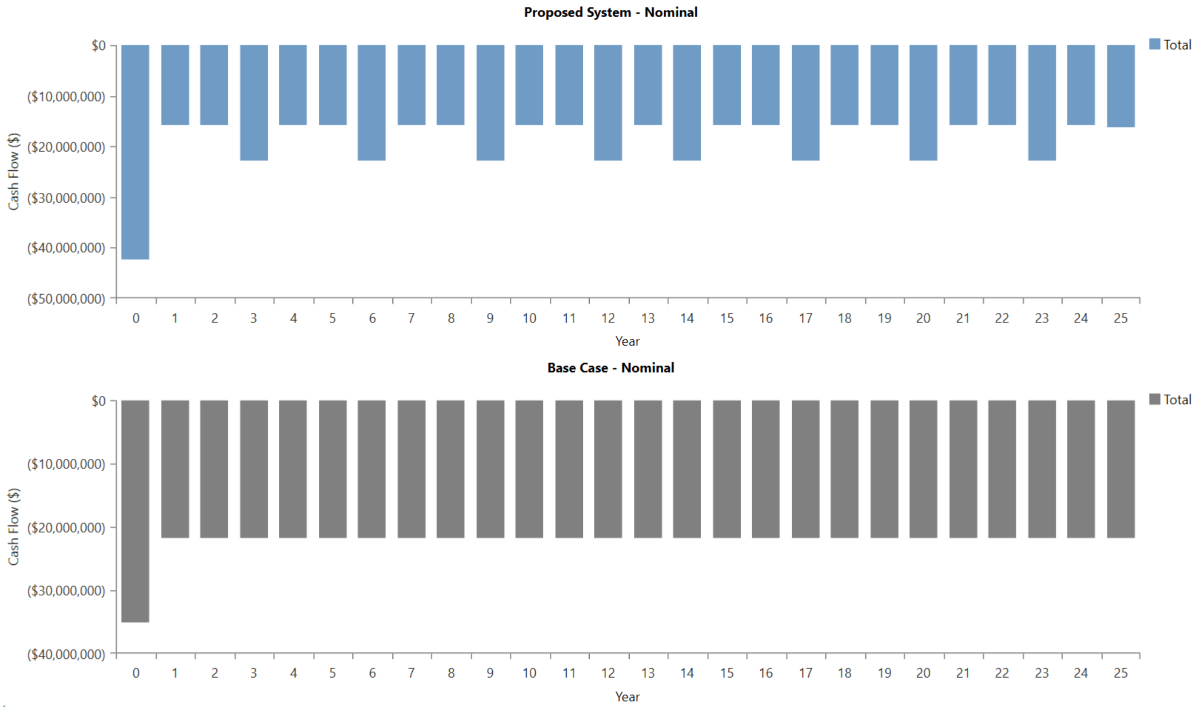


Figure 4.7: Economic comparison of Proposed and Based System

The figure displayed above shows that the costing exhibits an initial increase in the first year, followed by a subsequent decrease in following years relative to the base case. The comparison between the grid system and the hybrid system demonstrates the clear economic advantages of opting for the hybrid approach.

Not only does the hybrid system significantly reduce the Net Present Cost (NPC) from $317 million to $276 million, but it also slashes the cost of electricity from $82.7 to $0.0734. These substantial cost savings highlight the efficiency and financial benefits of integrating renewable energy sources into the energy generation mix. By leveraging a hybrid system, not only are operational costs lowered, but there's also a tangible impact on reducing the overall cost of electricity for consumers. This underscores the importance of considering sustainable and hybrid energy solutions for achieving both economic and environmental goals.

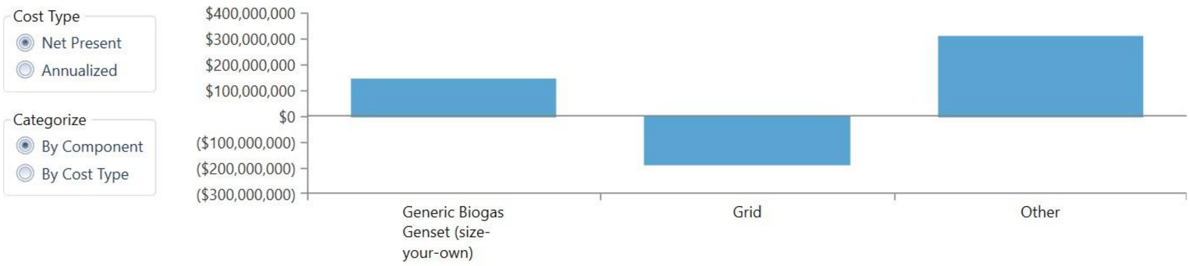
4.1.5 Analysis of Emissions

Quantity	Value	Units
Carbon Dioxide	1,143,596	kg/yr
Carbon Monoxide	1,741	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	126	kg/yr
Nitrogen Oxides	1,150	kg/yr

Figure 4.8: Emission of Hybrid system

Comparing renewable energy options to our existing fossil fuel energy system highlights the environmental advantages of adopting renewable energy. Integrating renewable energy sources into the hybrid system greatly decreases greenhouse gas emissions if compared to the conventional grid system. The reduction in greenhouse gases shows a clear approach to reducing climate change and improving environmental sustainability. By making the transition to a hybrid system, not only are we able to achieve financial savings, but we are also making substantial progress towards reducing our impact on the environment and establishing a more environmentally friendly and cleaner future for future generation. In our simulation, it was observed that the annual carbon dioxide (CO_2) emissions amounted to 1,143,159 kilograms, equivalent to 1260.12 tons per year. Additionally, the annual emissions of nitrogen dioxide (NO_2) were measured at 1,150 kilograms, corresponding to approximately 1.3 tons per year.

4.1.6 Analysis of Cost Summary



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic Biogas Genset (size-your-own)	$7,200,000.00	$31,988,471.38	$112,640,037.19	$0.00	($1,593,299.26)	$150,235,209.31
Grid	$0.00	$0.00	($191,121,525.42)	$0.00	$0.00	($191,121,525.42)
Other	$35,121,993.00	$0.00	$281,307,478.63	$0.00	$0.00	$316,429,471.63
System	$42,321,993.00	$31,988,471.38	$202,825,990.41	$0.00	($1,593,299.26)	$275,543,155.53

Figure 4.9: Cost summary of Biomass-grid integrated system

The total cost of the electricity generation from the biogas project amounts to $275 million with the expenses distributed across different categories. The largest portion, totaling $316,429,471.63, is allocated to "Other," indicating ongoing operational expenses associated with the project. Within this category, capital costs amount to $35,121,993.00, likely covering expenses unrelated to the biogas plant or grid connection, such as buildings or equipment. The operation and maintenance (O&M) cost for "Other" stands at $281,307,478.63, reflecting the ongoing expenses needed to maintain other aspects of the project. Meanwhile, the "Generic Biogas" category encompasses core lifecycle costs related to the biogas plant, including construction, maintenance, and potentially fueling. This section amounts to $150,235,209.31, with $7,200,000.00 attributed to capital costs, $31,988,471.38 to replacement costs (likely for replacing components after their lifespan), and $112,640,037.19 to O&M costs (the ongoing expenses to keep the plant running). The "Grid" category, totaling $191,121,525.42, suggests the significance of connecting the biogas plant to the electricity grid for injecting biogas-produced electricity. This category incurs no capital, replacement, or fuel costs but reflects a considerable negative O&M cost, possibly indicating revenue generated by selling electricity back to the grid.

4.1.7 Annual Electricity Selling Summary

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Load (kW)	Energy Charge $
January	3,688	24,377,858	-24,374,170	68	($1,242,949.91)
February	3,169	22,060,208	-22,057,039	55	($1,124,794.88)
March	3,716	24,411,036	-24,407,321	63	($1,244,639.58)
April	4,412	23,655,385	-23,650,973	68	($1,206,040.82)
May	4,360	24,409,374	-24,405,014	68	($1,244,498.74)
June	3,988	23,977,845	-23,973,857	50	($1,222,523.13)
July	3,965	24,777,452	-24,773,487	46	($1,263,305.13)
August	4,224	24,776,094	-24,771,870	48	($1,263,213.30)
September	3,973	23,977,885	-23,973,912	47	($1,222,526.51)
October	4,082	24,777,214	-24,773,132	46	($1,263,282.76)
November	3,031	23,981,500	-23,978,469	36	($1,222,792.82)
December	3,236	24,780,405	-24,777,169	39	($1,263,519.11)
Annual	45,844	289,962,257	-289,916,413	68	($14,784,086.70)

Figure 4.10: Revenue generated from the sales of electricity

The visualization above figure monthly data related to electricity consumption and potential sales to the grid throughout a span of one year. The average monthly revenue generated from the sale of electricity to the grid amounts to $1.24 million. The financial gain derived from the sale of electricity to the grid amounts to $14,784,086 per annum.

4.1.8 Summary of Biogas Generator Generation

Quantity	Value	Units
Hours of Operation	7,261	hrs/yr
Number of Starts	1,096	starts/yr
Operational Life	2.75	yr
Capacity Factor	82.8	%
Fixed Generation Cost	1,560	$/hr
Marginal Generation Cost	0	$/kWh

Quantity	Value	Units
Electrical Production	290,212,446	kWh/yr
Mean Electrical Output	39,969	kW
Minimum Electrical Output	36,991	kW
Maximum Electrical Output	40,000	kW

Quantity	Value	Units
Fuel Consumption	870,670	tons/yr
Specific Fuel Consumption	2.10	kg/kWh
Fuel Energy Input	1,185,078,402	kWh/yr
Mean Electrical Efficiency	24.5	%

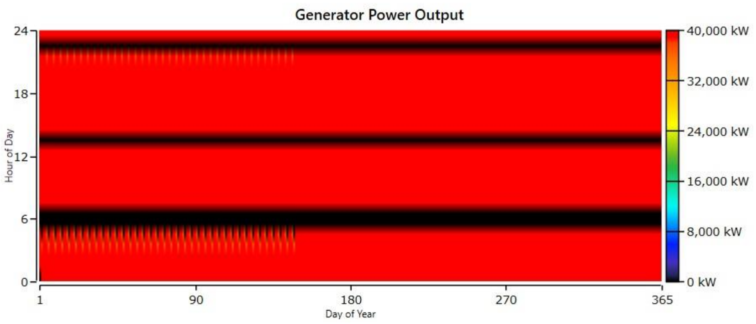


Figure 4.11: Summary of Biogas Generator Generation

The figure shown above illustrates the operational specifications, annual electricity production rate, and fuel consumption rate of the Biogas generator. The generator operates for a total of 7261 hours every year. This implies that around 20 hours are operated on a daily basis. The operational lifespan of the generator is 2.75 years, while its capacity factor is 82.8%. The hourly fixed generating cost amounts to $1560. Annual power generation amounts to 290,212,446 kilowatt-hours (kWh). A total of 870,670 tons of fuel are consumed annually, with a specific fuel consumption of 2.10 kg/kWh. An average electrical efficiency of 24.5% was observed.

4.2 Discussions

This chapter primarily focuses on the simulated outcomes generated by the Homer Pro software. The focus of our project was a hybrid power plant that was connected to the grid using biomass. Our primary resource consisted of waste, which we harnessed to generate electricity through the utilization of a Biogas Generator. The cost, viability, economic performance, and environmental implications of our planned power plant were thoroughly evaluated. Additionally, an analysis was conducted on the sustainability and efficiency of the equipment. According to the provided analysis, it can be suggested that this project has the potential to not only mitigate environmental pollution but also contribute to the satisfaction of our electrical demand. By implementing this approach, the generation of green energy will simultaneously generate employment opportunities and decrease reliance on fossil fuels. Additionally, it can significantly contribute to the Gross Domestic Product (GDP).

Chapter-05
Project Management

5.1 Tasks, Schedule, and Milestones

As final year students, our initial task for a capstone project was to assemble a group consisting of three or more members and provide a list of advisors. The group is assigned the primary duty of finding a significant issue that possesses educational, societal, or scientific importance, afterwards developing a complete approach to address it in an effective manner. To accomplish this, every one of the groups must perform an in-depth review of the current body of literature to gain a deep understanding, and then develop a proposal that includes well-defined goals and methodologies. After implementing the suggested solutions, it is common to conduct testing, gather data, and analyze the results. The final stage of the project involves the creation of a comprehensive report that outlines the results and conclusions, in addition to delivering a presentation to a wider audience. Collaboration, communication, and respect for academic norms are essential factors in guaranteeing the project's success.

The completion of our capstone project involves multiple sequential processes.

Project Initialization and Finalization:

We initiate the project by establishing the foundation and completing our goals and boundaries.

Related Literature Review:

A thorough review is carried out to collect pertinent data and perspectives from the current body of literature on waste-to-energy technologies and the production of electricity from Biogas.

Data Collection and Analysis:

Data from diverse sources, such as scholarly articles, industry reports, and case studies, is collected and subjected to analysis in order to shape our project approach and methodology.

Project Methodology Established:

Based on the findings of our comprehensive literature review and meticulous data analysis, we have developed a rigorous methodology for our project. This methodology defines the sequential procedures entailed in the implementation of Anaerobic Digestion as a means of producing electricity.

Implementation/Simulation:

To assess the viability and effectiveness of utilizing Anaerobic Digestion technology for energy generation from waste, we will proceed with it simulate the process in Homer Pro Software.

Factor Analysis (Environmental and Economical):

A thorough review is being conducted to evaluate the environmental and economic aspects linked to our project, evaluating its sustainability and feasibility from multiple viewpoints**.**

Book Formatting and Writing:

Ultimately, the study findings, methodology, and results are consolidated into a thorough report format, so guaranteeing lucidity and consistency in the dissemination of our work to wider community.

The milestone of our project is to save the environment from the detrimental effects of garbage disposal and explore methods to harness this waste for energy generation.

5.2 Resources and Cost Management

The key resource utilized in the management of resources and expenses for our Electricity Generation from Waste project is municipal solid waste (MSW). To maximize the efficient use of waste materials for the purpose of producing electricity using waste to energy generation technologies. This includes the management of waste collection, transportation, and processing to optimize its value extraction.

Our Electricity Generation from Waste project involves various costs crucial to resource management. These include initial capital for infrastructure setup, fixed and variable operation expenses, fuel and transportation costs, environmental compliance, and monitoring expenditures. Efficiently addressing these costs is essential for ensuring project sustainability and economic viability. According to the Homer Pro program, it was determined that the estimated cost for a 40 MW power plant is approximately $276 million. Nevertheless, it is imperative to acknowledge that this numerical value is not static and can fluctuate based on a multitude of elements and circumstances, including but not limited to equipment expenditures, personnel outlays, regulatory mandates, and market dynamics. Hence, it is necessary to engage in meticulous discussion and continuous surveillance of these variables in order to effectively evaluate and oversee the financial needs of the project.

5.3 Lesson Learned

From start to finish, our project taught us important lessons. Planning well and involving everyone early on is crucial. We acquired the ability to adjust and maintain our resilience in the face of difficulties. Collaborating and engaging in transparent communication enabled us to surmount challenges. We recognized the significance of considering the environment and society in our operations. It has been recognized that the process of learning is perpetual, and each encounter contributes to our personal development and advancement in subsequent endeavours.

Chapter-06

Impact Assessment of the Project

6.1 Economical, Societal and Global Impact

6.1.1 Economical Impact

Economical impact describes how an event, policy, or decision affects the economy. The proposal to establish a power plant in a waste disposal landfill not only decrease the environmental effect as well as provide economic value by producing sustainable energy. The Bangladeshi industry and agriculture sectors rely heavily on electricity, collectively contributing 50.3% to Bangladesh's GDP. This underscores the critical role of electricity as a key determinant of economic growth in the country.

Revenue Generation:

Waste-to-energy conversion technology can be utilized to generate electricity by harnessing the energy obtained from waste. This electricity will not only meet the country's energy needs, but it can also generate cash through its sale. This revenue will not only contribute to the country's GDP, but it can also compensate the initial capital costs of the project and enhance its financial viability of the project.

Job Creation:

The development and operation of this type of project create employment opportunities in diverse industries, including construction, engineering, operations, and maintenance. These jobs contribute to the growth of employment and the development of the local economy. These also provide locals with opportunities to earn their livelihoods and contribute to encouraging the development of skilled labour.

Investment Opportunities:

These types of projects attract investment from both public and commercial sectors for numerous factors includes that long-term returns on investment, government incentives, and renewable energy subsidies make this project an attractive investment prospect for stakeholders seeking sustainable and profitable projects.

Cost Savings for Energy Consumers:

When we make electricity by utilizing fossil fuels and there's a shortage or the prices drop globally, it can lead to higher electricity costs for consumers. But if we switch to renewable energy sources, it can give us more stability and security for the future, even though it might be expensive at first. Producing renewable energy on a large scale could bring down costs for consumers in the long run.

6.1.2 Societal and Global Impact

The societal impact of a project includes the effects or results that the project has on society at large or on certain segments within society. On the other hand, the global impact of a project refers to its impacts that are beyond national boundaries and have significant implications on a global scale. This impact can have beneficial and detrimental effects and can be witnessed in several aspects of society and global lives. The proposed project/ initiative that will have significant effects on waste management, energy generation, and the overall welfare of society and globally. This initiative not only decreases environmental pollution but also creates economic value and contributes to the progress of social and global sustainability goals.

Impact on Society:

- Enhanced public health by mitigating pollution and preventing the spread of diseases linked to open dumping.
- Enhancing community empowerment and engagement by actively participating in these types of initiatives.
- Job creation in many sectors such as construction, engineering, operations, and maintenance.
- Promoting economic development and growth by creating improved livelihood possibilities for local populations.

Global Impact:

- Reducing greenhouse gas emissions from landfills as a means of mitigating climate change.
- Utilizing renewable sources for energy generation will decrease reliance on imported fossil fuels from the global market.
- Bangladesh's waste management practices will mitigate the impact of global warming.

6.2 Environmental and Ethical Issues

An environmental issue includes any issue or concern related to the environment that causes detrimental impacts on ecosystems, habitats, creatures, or human health and well-being. The practice of openly disposing of waste has significant effects on the ecosystem. While the proposed initiatives do release harmful gases into the environment, the quantity is far lower compared to the number of hazardous gases emitted by openly dumping of waste in the landfill. In 2023 toha, performed an analysis of estimations and forecasts regarding the generation of methane gas at the landfills in Dhaka, primarily focusing on Amin Bazar and Matuail. Multiple models are employed for this purpose. The authors of the study observed that the SP1 model exhibits a high degree of suitability in forecasting methane emissions arising from landfills in Bangladesh. According to their estimation in 2023, the methane gas emission at Amin Bazar Landfill was 27.58 Gg or 30402 tons [30]. Considering the global warming potential (GWP), one ton of methane (CH4) traps as much heat as 21 tons of carbon dioxide (CO2) over a 100-year period. Therefore, considering the GWP, the estimated CO2e emission from Amin Bazar Landfill in 2023 is approximately 638,442 tons per year. This indicates a significant contribution to greenhouse gas emissions. In our simulation, it was observed that the annual carbon dioxide (CO_2) emissions amounted to 1,143,159 kilograms, equivalent to 1260.12 tons per year. Additionally, the annual emissions of nitrogen dioxide (NO_X) were measured at 1,150 kilograms, corresponding to approximately 1.3 tons per year. The selection between open dumping and waste-to-energy methods exhibits a notable disparity in terms of their impact on the environment. The annual emission of carbon dioxide equivalent (CO_2e) from open dumping amounts to a significant 638,442 tons, making it a substantial contributor to the greenhouse impact. Surprisingly, the process of producing electricity from identical waste results in just 1,150 tons of CO_2 emissions. By choosing waste-to-energy, there is a remarkable decrease of more than average 637,292 tons of CO2e annually. Waste-to-energy presents a significantly more sustainable alternative, effectively mitigating greenhouse gas emissions and promoting environmental well-being.

6.3 Utilizing of Existing Standards or Codes

It is crucial to employ established standards and rules in order to achieve the successful development of a renewable energy project that is safe, efficient, and compliant. There are multiple codes and standards that are considered such as:

Environmental Protection Agency (EPA) Regulations: Establish acceptable emission limits for air and water contaminants originating from renewable energy sources.

National Fire Protection Association (NFPA) Standards: Outline the recommended protocols for ensuring fire safety throughout renewable energy facilities.

National Electrical Code (NEC): This code, which has been universally accepted, sets forth the minimal requirements for the secure placement of electrical cabling and equipment in the United States.

Institute of Electrical and Electronics Engineers (IEEE) Standards: These global standards include comprehensive technical specifications for electrical systems and apparatus. Although not technically required, they frequently function as a point of reference for the NEC and other electrical regulations. Notable IEEE standards pertaining to renewable energy encompass:

- **IEEE 1547:** It is a well-recognized standard that facilitates the interconnection of distributed resources with electric power systems.
- **IEEE 902:** High-Voltage Power Transmission Standard

6.4 Other Concerns

Although the utilization of anaerobic digestion technology and the subsequent generation of power from its output resources offer several benefits, it is crucial to consider some potential concerns.

Process disturbances: The equilibrium of bacteria within the digester may be disrupted by several causes, such as variations in the composition of the feedstock, fluctuations in temperature, or the existence of toxins. This phenomenon may result in inefficiencies in the generation of biogas, necessitating vigilant monitoring and necessary modifications.

Air pollution: Although most of the methane is captured during the process, it can still be released into the atmosphere due to leaks or equipment failures. Methane is a highly potent greenhouse gas; hence it is imperative to minimize emissions.

The Management of Digestive Matters: The residual digestate, although a beneficial fertilizer, may still contain pathogens or deleterious substances, contingent upon the type of feedstock used. Ensuring the appropriate storage, treatment, and delivery of digestate is crucial to prevent the pollution of soil or water resources.

Chapter-07

Conclusions and Recommendations

7.1 Conclusions

As aspiring electrical engineering students, each capstone project should be centred around an innovative electrical engineering endeavour, symbolizing the culmination of our academic journey. Our capstone project centres around the production of electricity using waste materials. This effort seeks to tackle the dual challenges of meeting our country's electrical demand and mitigating the detrimental pollution resulting from the open disposal of waste. We have proposed a process for an efficient waste collection and management system. We have identified and discussed various technologies that can be utilized to generate energy from waste, evaluating their overall effectiveness and determining which ones are superior. We have collected data on the amount of waste deposited at the Amin Bazar Landfill. We attempted to estimate the potential electricity generation from this waste if a power plant were to be constructed at the Amin Bazar Landfill. We have calculated the amount of costing needed for constructing the power plant, and based on this estimation, the electricity price per unit has been analysed using home pro software. We have conducted an analysis of the greenhouse gas emissions generated by the power plant and compared them with the emissions resulting from the open dumping of waste.

7.2 New Skills and Experiences Learned

The capstone project has played a crucial role in developing a diverse set of skills and experiences that will be beneficial in our future endeavours. Here's a breakdown of the key points:

Technical Proficiency:

Mastery of waste management techniques: I acquired a comprehensive comprehension of several waste management methodologies and their practical implementations.

Understanding and knowledge of renewable energy and WtE technologies: The project afforded us the opportunity to gain familiarity with various renewable energy sources and waste to energy technologies.

Specialization in the field of data analysis and modeling pertaining to energy generation projects: We have acquired proficient abilities in analyzing and modeling data to enhance the efficiency of energy generation projects, with a special focus on utilizing Homer Pro software.

Improved comprehension of techniques for evaluating environmental impact: The undertaking provided me with the necessary expertise to evaluate the environmental impacts of engineering endeavours.

Practical Skills:

Project management experience: I acquired hands-on expertise in effectively overseeing project schedules and allocating resources through collaborative efforts.

Collaboration: Collaborating with teammates developed robust teamwork abilities.

Communication: The project enhanced my communication skills through the necessity of engaging in productive interactions with a wide range of audiences.

Proficiency in Software:

Homer Pro software: We have acquired expertise in utilizing Homer Pro, a prominent software application utilized for the purpose of developing and optimizing hybrid microgrids that incorporate renewable energy source integration.

7.3 Future Recommendations

The main goals of this project are to investigate effective waste management practices and explore the potential for utilizing waste materials to generate energy, such as biogas. Additionally, the study aims to determine the potential electricity generation capacity at the Amin Bazar Landfill. Numerous prospective areas for future investigation that are relevant to this study encompass, including:

- In addition to food waste, there are various additional biodegradable wastes that can be utilized in combination.
- Besides anaerobic digestion, there exist alternative waste-to-energy technologies that warrant further investigation. This will enable the determination of the technology capable of generating the highest amount of electricity.

- The utilization of RETScreen software can facilitate a more accurate assessment of economic viability.

References

[1] Md. Ashikuzzaman and Md. H. Howlader, “Sustainable Solid Waste Management in Bangladesh,” pp. 35–55, Oct. 2019, doi: 10.4018/978-1-7998-0198-6.ch002.

[2] M. S. Islam, A. Sultana, M. Rasheduzzaman, G. K. Kundu, A. K. I. Kamal, and M. K. Uddin, “Assessment of the Present State and Economical Prospects of Solid Waste at Amin Bazar Waste Dumping Site, Dhaka, Bangladesh,” *Journal of Scientific Research*, vol. 7, no. 3, pp. 129–137, Sep. 2015, doi: 10.3329/jsr.v7i3.23415.

[3] “2021-12-22-08-41-89a35db9d8246b8cc971978cea774687,” 2020. Accessed: Feb. 17, 2024. [Online]. Available: https://www.dncc.gov.bd/site/view/annual_reports/-

[4] T. P. T. Pham, R. Kaushik, G. K. Parshetti, R. Mahmood, and R. Balasubramanian, “Food waste-to-energy conversion technologies: Current status and future directions,” *Waste Management*, vol. 38, no. 1. Elsevier Ltd, pp. 399–408, 2015. doi: 10.1016/j.wasman.2014.12.004.

[5] W. Foster *et al.*, “Waste-to-energy conversion technologies in the UK: Processes and barriers – A review,” *Renewable and Sustainable Energy Reviews*, vol. 135. Elsevier Ltd, Jan. 01, 2021. doi: 10.1016/j.rser.2020.110226.

[6] R. Nandhini, D. Berslin, B. Sivaprakash, N. Rajamohan, and D. V. N. Vo, “Thermochemical conversion of municipal solid waste into energy and hydrogen: a review,” *Environmental Chemistry Letters*, vol. 20, no. 3. Springer Science and Business Media Deutschland GmbH, pp. 1645–1669, Jun. 01, 2022. doi: 10.1007/s10311-022-01410-3.

[7] L. Helsen and A. Bosmans, “Waste-to-Energy through thermochemical processes: matching waste with process.”

[8] S. M. S. Rahman, A. Azeem, and F. Ahammed, “Selection of an appropriate waste-to-energy conversion technology for Dhaka City, Bangladesh,” *International Journal of Sustainable Engineering*, vol. 10, no. 2, pp. 99–104, Mar. 2017, doi: 10.1080/19397038.2016.1270368.

[9] T. Rasheed *et al.*, “Valorisation and emerging perspective of biomass based waste-to-energy technologies and their socio-environmental impact: A review,” *J Environ Manage*, vol. 287, Jun. 2021, doi: 10.1016/j.jenvman.2021.112257.

[10] M. Tawhidul Alam, S. Hassan Eon, and M. Mamon Rana, “Cost Analysis for the Renewable Energy Generation to meet the Energy Security in Bangladesh SEE PROFILE,” 2021. [Online]. Available: www.matjournals.com

[11] M. R. Kabir, “Municipal Solid Waste Management System: A Study on Dhaka North and South City Corporations,” 2015.

[12] F. A. S. Islam, “Solid Waste Management System in Dhaka City of Bangladesh,” 2016.

[13] P. G. Nidoni, “INCINERATION PROCESS FOR SOLID WASTE MANAGEMENT AND EFFECTIVE UTILIZATION OF BY PRODUCTS,” *International Research Journal of Engineering and Technology*, 2017, [Online]. Available: www.irjet.net

[14] N. D. Berge, K. S. Ro, J. Mao, J. R. V. Flora, M. A. Chappell, and S. Bae, "Hydrothermal carbonization of municipal waste streams," *Environ Sci Technol*, vol. 45, no. 13, pp. 5696–5703, Jul. 2011, doi: 10.1021/es2004528.

[15] O. Alam and X. Qiao, "An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh," *Sustainable Cities and Society*, vol. 52. Elsevier Ltd, Jan. 01, 2020. doi: 10.1016/j.scs.2019.101775.

[16] S. A. Opatokun, A. M. Lopez-Sabiron, G. Ferreira, and V. Strezov, "Life cycle analysis of energy production from food waste through anaerobic digestion, pyrolysis and integrated energy system," *Sustainability (Switzerland)*, vol. 9, no. 10, Oct. 2017, doi: 10.3390/su9101804.

[17] M. S. Ferdous, K. A. Sagar, F. Rahman, B. Karim, and M. M. Rashed, "A Case Study on Present Scenario of Biomass energy in Bangladesh and its future prospect."

[18] S. Rathi and M. Tech, "Electrical Energy Recovery from Municipal Solid Waste of Kanpur City," 2014. [Online]. Available: www.ijsret.org

[19] V. Murugesan and M. Vijayalakshmi, *Modern Waste Management Techniques-A Critical Review IOC-2020 INNOVATION AND SUSTAINABILITY THROUGH E-STEM-14th & MODERN WASTE MANAGEMENT TECHNIQUES-A CRITICAL REVIEW*. 2020. [Online]. Available: https://www.researchgate.net/publication/345687135

[20] R. H. Hredoy, M. A. B. Siddique, M. A. Akbor, M. A. A. Shaikh, and M. M. Rahman, "Impacts of Landfill Leachate on the Surrounding Environment: A Case Study on Amin Bazar Landfill, Dhaka (Bangladesh)," *Soil Syst*, vol. 6, no. 4, Dec. 2022, doi: 10.3390/soilsystems6040090.

[21] A. Sridhar, A. Kapoor, P. Senthil Kumar, M. Ponnuchamy, S. Balasubramanian, and S. Prabhakar, "Conversion of food waste to energy: A focus on sustainability and life cycle assessment," *Fuel*, vol. 302, Oct. 2021, doi: 10.1016/j.fuel.2021.121069.

[22] M. Maniscalco, G. Infurna, G. Caputo, L. Botta, and N. T. Dintcheva, "Slow pyrolysis as a method for biochar production from carob waste: Process investigation and products' characterization," *Energies (Basel)*, vol. 14, no. 24, Dec. 2021, doi: 10.3390/en14248457.

[23] R. Gumisiriza, J. F. Hawumba, M. Okure, and O. Hensel, "Biomass waste-to-energy valorisation technologies: A review case for banana processing in Uganda," *Biotechnology for Biofuels*, vol. 10, no. 1. BioMed Central Ltd., Jan. 03, 2017. doi: 10.1186/s13068-016-0689-5.

[24] I. Khan and Z. Kabir, "Waste-to-energy generation technologies and the developing economies: A multi-criteria analysis for sustainability assessment," *Renew Energy*, vol. 150, pp. 320–333, May 2020, doi: 10.1016/j.renene.2019.12.132.

[25] M. J. B. Kabeyi and O. A. Olanrewaju, "Biogas Production and Applications in the Sustainable Energy Transition," *Journal of Energy*, vol. 2022, pp. 1–43, Jul. 2022, doi: 10.1155/2022/8750221.

[26] B. Zohuri, "New Approach to Energy Conversion Technology," *Molten Salt Reactors and Integrated Molten Salt Reactors*, pp. 85–136, Jan. 2021, doi: 10.1016/B978-0-323-90638-8.00003-5.

[27] Institute of Electrical and Electronics Engineers and IEEE Communications Society, *2017 14th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT (HONET-ICT)*.

[28] "†iwR÷vW© bs wW G-1 evsjv ‡`k †M ‡RU AwZwi³ msL¨v KZ… © cÿ KZ… © K cÖ KvwkZ g½jevi, †deª aeqvwi 28, 2023."

[29] P. Odavić, V. Zekić, and D. Milić, "LIFE CYCLE COST OF BIOMASS POWER PLANT-MONTE CARLO SIMULATION OF INVESTMENT," 2017.

[30] M. Toha and M. M. Rahman, "Estimation and prediction of methane gas generation from landfill sites in Dhaka city, Bangladesh," *Case Studies in Chemical and Environmental Engineering*, vol. 7, Jun. 2023, doi: 10.1016/j.cscee.2023.100302.

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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	Depth of knowledge required	Knowledge in waste management operations, biogas production, and the utilization of Homer Pro for simulation is required.
P2	Range of conflicting requirements	Ensuring compliance to environmental regulations and optimizing energy generation while emphasizing cost-effectiveness and revenue growth.
P3	Depth of analysis required	Analyze the waste at the Amin Bazar landfill, estimates the possibility for biogas production from food waste, using Homer Pro to simulate energy generation, and reviews the financial and environmental issues.
P4	Familiarity of issues	Waste management challenges, biogas production, and renewable energy grid integration.
P5	Extent of applicable codes	Follows all applicable electrical codes for grid-connected generating and environmental regulations on waste and renewable energy.
P6	Extent of stakeholder involvement and conflicting requirements	Collaborates energy regulators.
P7	Interdependence	Interconnectedness of waste management, energy production, and sustainability, understanding their mutual influence while considering broader social, economic, and environmental implications.

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	Range of resources	Manages a wide range of resources, such as waste, biogas equipment, and electrical infrastructure.

A2	Level of interaction	Engages many participants, including communities, regulators, environmentalists, waste authorities, landfill operators, and energy consumers.
A3	Innovation	Develops fresh ideas by recycling food waste as fuel and by simulating energy scenarios with Homer Pro software.
A4	Consequences of society and environment	Assesses the long-term effects on people and the planet of various energy generation and waste management strategies.
A5	Familiarity	knowledge of waste management, biogas production, renewable energy, Homer Pro simulation software