An-Najah National University
Faculty of Graduate Studies

DEVELOPING A MANAGERIAL FRAMEWORK FOR WASTE-TO-ENERGY IN PALESTINE: THE CASE STUDY OF ZAHRAT AL-FINJAN LANDFILL

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Dedication

إلى أمّي، هدى، ملحمة الحب وفرحة العمر، ومثال التفاني والعطاء، من خلقت وجودي من جوفِ العدم

.إليها ابتهاجُ الرّوحِ في جسدي وتباشير الصباحِ الغضّ

إلى أبي، فواز، من تبدأ الحياة من يديهِ ويبزغ النّهار بطلّته قدوتي، ومثلي الأعلى في الحياة؛ الشخص الذي علَّمني كيف أعيش بكرامة وشموخ

إلى محمد و سلمى ويوسف وليلى الرّوح، سندي وعضدي ومشاطري أفراحي وأحزاني في هذه الحياة

الى عدي ... أسمى رموز الاخلاص والوفاء ورفيق الدرب.

إلى أرواح كلّ من سبقونا إلى الله

إلى فلسطين، البلاد التي هي بحجم القلب،

.لا شيءَ فيها بعيدٌ ولا شيء فيها قريبٌ

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Thank you.

[Sara]

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

DEVELOPING A MANAGERIAL FRAMEWORK FOR WASTE-TO-ENERGY IN PALESTINE: THE CASE STUDY OF ZAHRAT AL-FINJAN LANDFILL

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Date: ٢٠/١٠/٢٠٢٣م

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Abstract

Because of global population evolution and enhanced living standards, there's an orientation to renewable energy sources. One choice is using waste to generate electricity. The occupied Palestinian territories depends on imported electricity, encounter issues due to inaccurate waste management and large amount of municipal waste. This study focuses on the West Bank region, specifically Jenin's Zahrat Al-Finjan dump (88% capacity). It aims to evaluate the environmental and economic effects of waste-to-energy systemsfocusing on landfilling, incineration, and anaerobic digestion. Each method undergoes a SWOT analysis to distinguish its strengths, weaknesses, opportunities, and threats. This study started with a comprehensive literature review of Palestine's waste management andenergy demand. After that, it examines the waste-to-energy systems. Initial investment, potential electricity production, and environmental effects are compared between the three techniques. Information was collected through a set of semi-structured interviews with key members and officers in the relevant Palestinian government entities responsible for energy, environmental, and municipal solid waste management.

The economic analysis examines critical factors such as initial investment, Net Present Value (NPV), Levelized Cost of Electricity (LCOE), Internal Rate of Return (IRR), and Simple Payback Period (SPP). The analysis uses the data provided for each waste-to-energy system to evaluate their economic feasibility. The results showed the importance of having a managerial framework for waste-to-energy in Palestine. The LCOE analysis compares costs of investment and operation for electricity generation techniques. Landfill has the lowest cost, followed by incineration, then digestion. Landfill is most cost-effective because of small expenses. Digestion more costs due to investment and lower electricity potential. IRR analysis shows that digestion has the highest profit potential, then landfill, and incineration with a slightly lower return. SPP analysis ranks landfill first in payback time, then incineration, and digestion last, indicating quicker cost recovery. Landfills generate 18.62 GWh of electricity annually but encounter issues such as methane emissions and limited area. Incineration includes high-temperature waste burning, proposing a modern approach with startup costs of $110 million. It yields 200 GWh of annual electricity via steam-powered turbines. Anaerobic digestion processes organic waste without oxygen, generating biogas. Fixing and maintaining this system costs $90 million. Digestion produces 23 GWh/year of electricity, reduces emissions, and yields fertilizer-rich composte.

Keywords: landfill, Zahrat Al-Finjan landfill, NPV, Incineration, Waste to energy, SWOT analysis, Anaerobic digestion.

Chapter One

Introduction

1.1 Overview

The first part of this thesis provides a comprehensive summary of the actual situation with which an overview, an explanation of how the study is structured, a statement of the problem, goals, the scope of the work, what the work means and how essential it is, as well as a concise assessment of the relevant literature is conducted.

1.2 General Background

Energy is essential to human existence and economic activity. Pollution-free electricity can be produced using renewable resources including sunlight, wind, planet earth, and plants. Societies' economic progress, social advancement, and better standards of life are influenced by energy consumption and the continuous expansion of solid waste production (El Chaar, L., & Lamont, L. A. , 2010)(Thiam, 2011). Throughout most of human history, the production of energy has traditionally involved the burning of fossil fuels such as coal, gas, and oil as these processes are the primary contributors to the generation of polluting gases and acids, such as carbon monoxide (CO), carbon dioxide (CO_2), and hydrochloric acid (HCl).

The emission of these gases has several adverse consequences including a decrease in ozone (O3) degrees, acidic rain, acidification of the ocean, as well as changes in the structure of plants and nutrients. Since the beginning of the industrial revolution in the 1970s, there has been a steady increase in the levels of Green-House Gases (GHG). A change of this scale in the concentration of CO_2 in the atmosphere would be equivalent to an increase of 473 parts per million (PPM) (Chen, 2017).

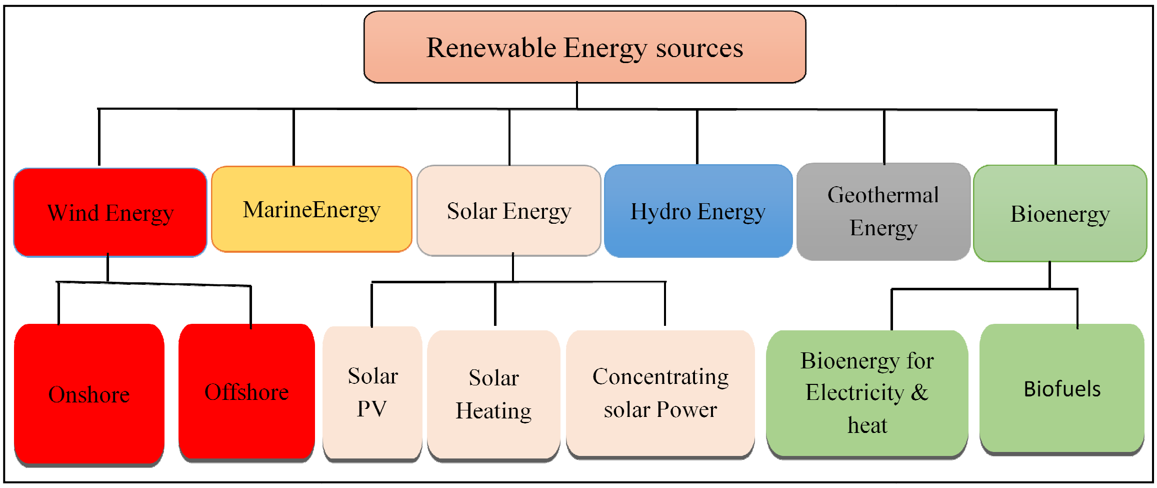
In essence, renewable energies refer to sources of energy that can be naturally replenished. These sources can be acquired directly from the sun, like through photo-chemical and photo-electric processes, or indirectly through wind, hydropower, and energy stored in biomass via photosynthesis. Additionally, other environmental movements and mechanisms, such as geothermal and tidal energy, can also provide sources of renewable (Ellabban, O., Abu-Rub, H., & Blaabjerg, F. , 2014). Figure (1) shows an overview of renewable energy sources. Roughly 15%-20% of the world's energy needs are met by renewable sources at the present time. Traditional biomass, mostly fuel wood used for cooking and heating, is the primary source, particularly in the areas of Asian countries, Africa, and Latin America that are the least developed in the world (Herzog, A. V, Lipman, T. E., & Kammen, D. M. , 2001), so, the cultivation of RE sources of power is of the vital important regarding the protection of the environment and the energy supply.

Both the production of waste and its disposal are issuing that society must overcome in this era. Waste is produced by all aspects of human life, including private houses, commercial enterprises, educational institutions, food service establishments, agricultural operations, and so on (Awogbemi, O., Kallon, D. V. V., & Bello, K. A., 2022). Municipal Solid Waste (MSW) is a term for the different kinds of trash that people often throw away in towns. There are both decomposable and non-decomposable components of MSW (Alao, M. A., Ayodele, T. R., Ogunjuyigbe, A. S. O., & Popoola, O. M., 2020). The quantity of municipal solid waste that is accessible and the effectiveness of the conversion path are two factors that influence the quantity of energy that can be extracted from MSW.

Other aspects, such as a region's or a municipality's level of population and revenue, are also significant in finding its success (Gohlke, 2009). MSW is a renewable energy source with stable and predictable attributes because the factors determining the amount of energy recovered from MSW are easy to control. This makes it useful for dealing with waste problems, reducing the effects of global warming, and generating electricity (Alao, M. A., Ayodele, T. R., Ogunjuyigbe, A. S. O., & Popoola, O. M., 2020).

Figure 1

Summary of renewable power options



Note: (Ellabban, O., Abu-Rub, H., & Blaabjerg, F. , 2014)

According to projections from the World Bank, the world's daily waste generation is around 1.3×10^9 tons, with expected growth to approximately 2.2×10^9 tons by 2025. For hygienic and public health reasons, solid trash must be collected daily and processed appropriately; this is one of the greatest challenges now confronting public authorities, particularly in developing nations(Burke, C. S., Salas, E., Smith-Jentsch, K., & Rosen, M. A., 2018). Based on the waste's structure and moisture concentration, the energy contained within MSW can be recovered to generate heat and/or power by bio-chemical or thermochemical mechanisms (Alao, M. A., Ayodele, T. R., Ogunjuyigbe, A. S. O., & Popoola, O. M., 2020).

In Waste-To-Energy (WTE) operations, the waste would either be directly burned (via combustion, pyrolysis, or gasification), Furthermore, fuels made from chemicals like CH_4 and H_2 are created and used (Cheng, H., & Hu, Y., 2010). All decision makers must choose the best WTE techniques to implement based on technical, financial, ecologic, and social concerns, as the various WTE systems for MSW management perform well especially in waste-to-energy (WTE) plants, which convert trash into usable heat or electricity, have been popular in Europe for the better part of a century.

The United States, China, and Japan are just a few of the wealthy nations that convert garbage to power in their economies. In the 1960s, European governments began installing WTE facilities in response to rising worries about groundwater quality and a lack of suitable space for landfills. To generate heat, steam, and electricity, WTE facilities using solid wastes is a very straightforward idea. (Ham, G. Y., & Lee, D. H., 2017).

The energy scenario in Palestine is widely acknowledged to be very distinct from that of other Middle Eastern nations. There were (5354656) people living in Palestine as of the end of 2022 with (1540016) living in the Gaza Strip and (3188387) in the West Bank. (PCBS, 2018). While geographically located in the Middle East, Palestine is unlike any other Middle Eastern country. To begin with, Israeli occupation hinders the potential expansion of the region's energy infrastructure and policy and outlaws any expansion efforts in this area.

The Palestinian Authority (PA) is highly dependent on imported fossil energy for the great majority of their energy needs, with most of these fuels coming from Israel. Egypt and Jordan also provide a small but significant share of each. The transportation industry accounts for a lot of the world's consumption of fossil fuels. (Abu Hamed et al., 2012) It is clear from Fig. 2 that the Palestinian Lands rely on a variety of different sources of energy. Only 22% is derived from renewable energy references, whereas 78% comes from liquid fossil fuels like gasoline, diesel, and liquefied petroleum gas. (PCBS, 2018).

Palestine is a growing country that requires extensive amounts of all types of energy to fuel its economic development. Diversity exists in the number of Palestinians having constant access to electricity. In regions where power rates are high, saving energy has an immediate financial impact. The extra money spent on power electronics can be recovered within a reasonable amount of time. When people reduce their consumption, they naturally reduce their output, which in turn reduces pollution and global warming (Bosmans, A., & Helsen, L., 2010).

Currently, available dumping sites are either nearly full, will be full in the next five years with no expansion alternatives, or are overburdened. According to the Oslo Agreement, the PA needs Israel's approval to construct new locations. Because of the delicate political scenario in the last decade, this is not easy. Now is the time to completely accept WTF as one of the greatest essential potential sources of renewable energy and a realistic solution for economically and ecologically ethical disposal of solid waste(Baggio et al., 2008).

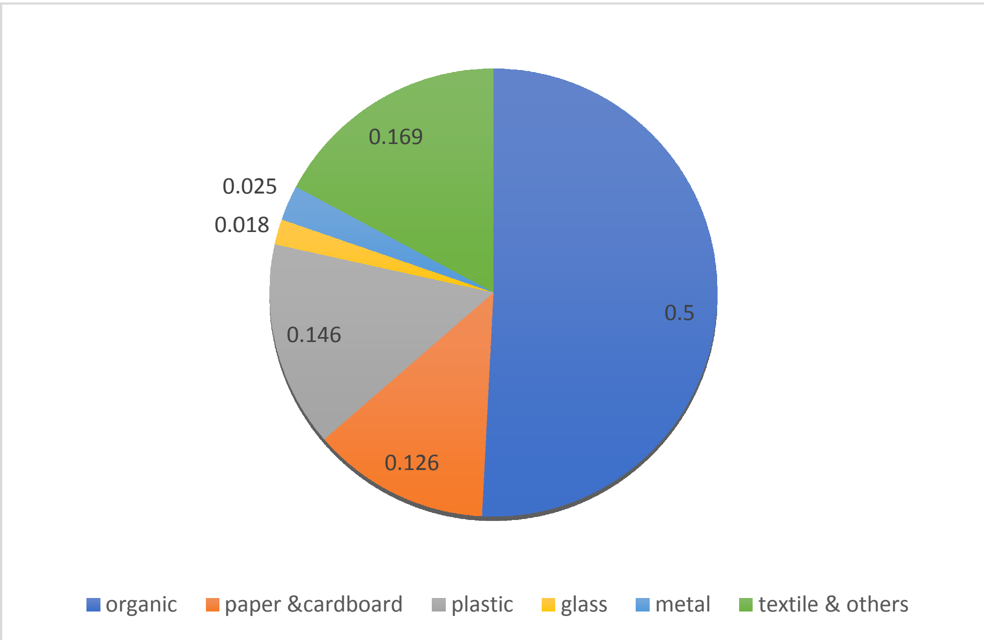
Among the greatest problems facing Palestine, and many other developing nations, is ensuring the long-term viability of their SWM infrastructure. In the Palestinian territory and especially in the West Bank, the removal of municipal solid waste is viewed as a challenging issue for many due to many factors. which might include the position of a groundwater aquifer, the limited region that makes up the West Bank, the absence of sanitary landfills, and the absence of any critical treatment facilities (Al-khatib et al., 2007). In addition, in Palestine, waste is regarded as a major environmental and health issue because of the increasing political situation and economic embargo, inadequate systems for collecting and disposing of wastes, high reliance on waste dumps, poor methods for reusing materials and disposing of waste, inadequate awareness programs regarding waste management and the lack of sufficient investment and other resources.

Consequently, having efficient waste management at all phases of the process is a safety mechanism that prevents damage from waste disposal or recycling operations. Besides being a national need, it has been given an important role in maintaining the national economy and projecting a beautiful, cultured image of society.

Waste is divided into two main categories: dry waste and wet waste. Wet waste includes organic waste, such as food waste, which constitutes 50% of the waste, while dry waste is plastic, metal, and paper.The daily rate of waste production in the West Bank is estimated at 2,622 tons and the daily rate per person is 1.0 kilogram. Only around 65% of daily municipal garbage is collected by the joint service councils JSCs (1,704 tons), with the remaining amounts being collected by LGUs and UNRWA (Abu Muferreh, 2019). Hence, waste with an organic content of 50% has a high potential for composting, digestion, and the generation of landfill-gas. While it's true that paper, plastic, and metal all show promise as potential recyclables, it's also true that only source separation has a chance of generating sufficient quantities and quality for recycling.

Figure 2

Solid Waste Composition in the West Bank



Note: Abu Muferreh, 2019.

Three landfills can be found in the West Bank, according to (Tayeh et al., 2021) scientific assessment, in the governorates of Jericho, Jenin, and Hebron. The first most essential, however, are Zahrat al-Finjan in Jenin and Al-Menia between Hebron and Bethlehem. Tragically, Zahrat Al-Finjan is going to reach its maximum capacity over the next years, with no plans to expand. Another in Jericho is now under load as there are no plans to extend it. In 2007, the northern part of the West Bank, specifically the Jenin region, was the location for the construction of Zahrat Al-Finjan dump. This was Palestine's first properly maintained landfill to make certain that Jenin's municipal solid waste was disposed of appropriately.

Even though it was originally constructed to manage garbage created in Jenin city, the space was later enlarged to include the cities of Nablus and Tulkarm, which are in the northern section of the West Bank. In other words, it was originally intended to treat waste produced in the Jenin region. Recently (2013), the Ministry of Local Government (MoLG) expanded the service area once more by covering all the remaining northern parts (Qalqilya, Tubas, and Salfit). As a direct consequence of this, the volume of waste that has been delivered has significantly increased during the period of planning (Salah, M. M., Al-Sari', M. I., Al-Khatib, I. A., & Kontogianni, S., 2020).

The methods utilized to dispose of waste in Palestine are old, and the occupation adds to the burden by posing difficulties and impediments. Furthermore, the occupation's control of around 64 % of Palestinian land lowers the likelihood of creating the infrastructure and basic services required for adequate solid waste disposal. The disposal of MSW has developed into an urgent and expensive issue. The conventional technique of burying waste in landfills takes up a significant amount of space and pollutes the air, groundwater, and land. The process of incineration, which is an alternate option, has the benefit of lowering the quantity of the garbage, and it also has the potential to create heat and electricity while releasing fewer gases into the environment (Porteous, 2001).

By negotiating a political settlement without Israel, the PA hopes to achieve statehood concentrating heavily on developing its institutions' capacity to control its own natural resources at this stage. The Palestinian Energy and National Resources Authority (PENRA), the Palestinian Environment Quality Authority (EQA), and the Ministry of Local Government (MoLG) are the three main governmental ministries in charge of the energy, environment, and waste - management sectors, respectively.

The PA oversees the ministries' preparation of strategic plans over five years at regular intervals. In 2017, the ministry based its road map for the next four years—through 2022—on these findings, as reflected in the strategic plans developed by each individual ministry. Managing the energy, environmental, and MSW sectors were all explicit goals and strategies in the 2017-2020 plans of each of the ministries. Here are some quick summaries of these techniques' most key features: (PENRA, 2016; PNA, 2016; PNA, 2017).

1. The first aim of the PENRA strategic plan is to increase the national capacity to meet and protect electricity needs. For this purpose, PENRA has accepted the diversification of resources and the implementation of a national energy storage strategy.
2. The management of municipal solid waste is going to be improved as the third strategic goal of MoLG. Two strategies have been selected to support policies and methods that aim to reduce the volumes of MSW, recycle, reuse, and generate electricity before its ultimate disposal, and to eliminate the use of randomized dumpsites by either closing them or restructuring them in order to decrease the negative effects on the natural world and public health.
3. The EQA has collaborated with the GCC United Nations framework convention's National Determined Contributions (NDC). The first scenario, which assumes a political agreement between the PA and the Israeli side, is the independence scenario. If this holds true, then landfill CH_4 reduction and trash-to-energy recovery might save 290 and 3 kt CO_2-eq, respectively, until 2040. Given the current political climate, the same goals in the two scenarios become 290 and 0.5 kt CO_2-equivalent, respectively.

(Lawínska et al., 2022) noted that the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis is a standard strategic planning tool that is used for the comprehensive assessment of an organization's internal capabilities (strengths and weaknesses), as well as for assessing the external situation. The key internal components, which are referred to as "Strengths and Weaknesses," and the external aspects, which are referred to as "Opportunities and Threats," are evaluated with the use of the automated and efficient strategic process known as the SWOT analysis. The analysis can be broken down into two primary stages. In the first phase, the SWOT matrix is developed by determining the SWOT factors. In the second phase, the internal and external factors are coupled in order to provide the most successful possible mix of tactics (Pasek, A. D., Gultom, K. W., & Suwono, A. , 2013).

Plans make use of the organization's own strengths and advantages in order to mitigate or eliminate the impact of external threats. WO approaches involve seizing chances presented by external sources in order to make up for deficiencies in one's own operations. WT strategies aim to shore up internal weaknesses in order to reduce the impact of external threats (Saxena, R. C., Adhikari, D. K., & Goyal, H. B., 2009). SWOT analysis helps decision-makers make the most informed decisions possible by providing helpful information about internal and external factors that may have a beneficial or detrimental effect on the growth of the business.

When it comes to waste management, a SWOT analysis is a useful technique for assessing the advantages, disadvantages, prospects, and risks of various approaches. Inadequate public knowledge and financing for waste management initiatives may be weaknesses, whereas effective garbage collection systems and cutting-edge recycling technologies may be strengths. Threats include environmental pollution and a lack of available landfill space, while opportunities include the rising use of eco-friendly garbage disposals. Waste management agencies can benefit from doing a SWOT analysis since it helps them plan, establish concrete objectives, prioritize tasks, and pinpoint weak spots. It helps with the development of efficient waste management plans and the identification of novel answers for more environmentally friendly procedures.

This study compares three waste disposal strategies, landfilling, incineration with energy recovery, and compost to find a solution for Zahrat A-Finjan Landfill problems. It will also look at the environmental and economic implications of these three approaches. In addition to that, the SWOT Analysis will be used for each strategy. In this qualitative study, the importance of SWOT Analysis in the strategic management process will be outlined first, and then the components of SWOT Analysis will be examined.

1.3 Structure of the thesis

There are four sections of this thesis; the first is an introduction that provides context for the research and discussing the study's objectives. The second one is the chapter of the methodology; in this section, you will get a description of the procedures that were utilized to collect data, as well as any restrictions or assumptions that were made. The results and analysis are presented in the third chapter. The findings of the study are summarized in the section titled "The Results," which makes use of language that is both clear and succinct, tables, graphs, and other visual aids to emphasize essential themes. Analyze: provide a detailed interpretation of the results, describing what they mean and how they relate to the study questions or objectives. Analysis: provide detailed explanation of the data. The conclusion and recommendations chapter serves as the final chapter of the thesis. It provides a summary of the most important findings as well as recommendations for how any faults or problems noted in the study might be resolved.

1.4 Problem Statement

In 2020, the Palestinian Central Bureau of Statistics (Central & Bureau of Statistics - PCBS, 2021) released a report estimating daily solid waste production in the West Bank of 2,335 tons with about 853,000 tons of garbage are produced annually. The survey also indicated that while both urban and rural regions produce waste, most of the West Bank solid waste (67.7%) is produced in urban areas. Most of the trash comes from homes (54.5%), businesses (21.8%), then factories (10.4%), and finally building and demolition (8%).

The main gap here is that few studies have been done before comparing landfilling, incineration, and anaerobic digestion waste disposal strategies. However, prior studies have not considered the fact that methane output fluctuates year to year, as well as the amount of gas trapped underground. Also, previous studies did not consider the electrical network's ability to absorb the electrical energy produced near Zahrat al-Finjan landfill (Tayeh et al., 2021).

The key players in this dilemma are PENRA, EQA, and MoLG. Each of these ministries is addressing its own set of national difficulties. EQA and MoLG interact actively to monitor present MSW landfills and generate new sustainable and environmentally acceptable solid waste disposal solutions as PENRA is committed to eliminating power shortage and promoting self-sufficiency in the country's energy sector. Despite their ongoing efforts to identify adequate solutions to the waste problem at Zahrat Al-Finjan landfill, they omitted to conduct a comparison analysis of landfilling, incineration, and composting.

This study aims at developing a managerial framework for the waste-to energy in Palestine. More specifically, it aims at comparing the three potential alternatives, namely, landfilling, incineration, and AD, for waste-to-energy. Zahrat al-Finjan landfill in northern Palestine will be considered as a case study, and the SWOT analysis tool will be employed to compare these alternatives to come up with a managerial framework that could help in generalizing the results for other landfills in Palestine.

1.5 Objectives

This study aims at:

- Analyzing Zahrat Al-Finjan landfill waste problem to find waste to energy solutions by comparing three waste disposal options, which are landfilling, incineration for energy recovery, and anaerobic digestion.
- Examining the environmental (the emissions of gases such as CO_2 and CH_4) and economic (funding and capital sources, financial estimates, the possibility of success) consequences for the three wastes to energy options.
- Conducting a SWOT Analysis for each option of the three waste disposal methods to develop a managerial framework for waste-to-energy in Palestine.

1.6 Importance of the Study

This study is an attempt to find a solution to the problem of Zahrat al-Finjan landfill by comparing landfilling, incineration, and anaerobic digestion. After a precise economic feasibility assessment, which is largely determined experimentally by the flows of solid waste produced with potential energy, this will show a great opportunity for the Palestinians. The process of producing energy through proper waste management is attracting growing interest in countries around the world, particularly in developed nations since it is seen as one of the most important sources of financially rewarding economic return. Also, doing a detailed analysis of economic feasibility studies, environmental impact assessment, studying deeply the emissions of certain gases like

CO_2 and CH_4, and conducting a SWOT Analysis for each one of the three waste disposal methods.

1.7 Literature Review

Solid wastes have been commonly categorizedbased on their sources. They can be divided into three types: municipal solid waste (MSW), hazardous waste, and infectious waste (Ogunjuyigbe et al., 2017). MSW contains both organic (degradable and non) and inorganic (recyclable) elements. Organic (biomass) materials include food scraps, garden waste, paper, pasteboard, fabrics, leather, and wood. Inorganic waste materials include glass, ceramic materials, rubber, and metal alloys (Troschinetz, A. M., & Mihelcic, J. R. , 2009).

MSW disposal is among the most major and contentious urban challenges affecting governments all over the world (Assamoi & Lawryshyn, 2012). Individuals are throwing garbage away increasing amounts of waste globally, and its content is much more complicated than ever before since polymer and electronic consumer goods expanded (Vergara, S. E., & Tchobanoglous, G. , 2012). There is a large amount of variation in the amount as well as the structure of waste from one day to the next and from one season to another. Not only are there big variations between nations, but there are also important variations between nearby counties and types of property within the same town (Idris, A., Inanc, B., & Hassan, M. N. , 2004). Collection and stockpiling systems are getting more complicated and expensive because the different kinds and sources of rubbish created have expanded and the accessibility of dump sites within collection areas has become constrained (Idris, A., Inanc, B., & Hassan, M. N. , 2004).

Since improper waste treatment has various adverse effects on the environment, the disposal of MSW is receiving a lot of attention. The quality of ground water may be affected, as well as the release of greenhouse gases and dust (Palmiotto et al., 2014). On the other hand, recognizing that municipal solid waste is continually produced and contains energy, it might be considered a source of energy that is easily accessible (Lombardi, L., Carnevale, E., & Corti, A. , 2015).

Municipal waste management refers to the integration, stockpiling, transportation, manufacturing, resource renewal, recycling, and safe disposal of waste (Ikpeze, 2014).

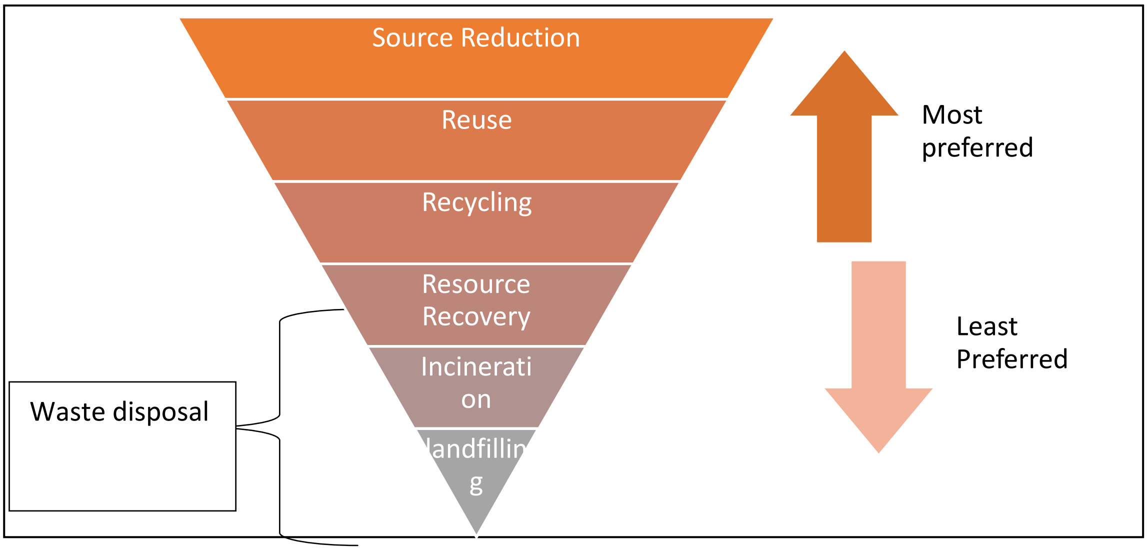
Based on the country, the scenario concerning rewards for waste management hierarchy (reducing, reusing, and recycling), and the type of pricing employed, the policy measures by municipalities to enhance their condition can differ. Despite local conditions, the investment is vital for the delivery of high-quality, environmentally friendly activities (Alzamora, B. R., & Barros, R. T. D. V., 2020).

Waste management operations are ranked in the hierarchy according to the positive impact they have on the environment or the amount of energy they save. When it comes to preserving resources, coping with a lack of landfill space, reducing water pollution and air pollution, and preserving human health, hierarchy is a helpful method. In recent years, several innovative systems have been created, one of which is the 3 R's technique in the effective solid waste management hierarchy. Figure 3 shows the 3 R's technique (Reduce, Reuse, and Recycle) that suggested with focus on source reduction, medium processing, and ultimate disposal, and waste generators were encouraged to practice the 3R's as a considerable way to reduce, reuse, and recycle the collected solid waste every day (Azim et al., 2018).

Recycling and reusing garbage decreases the amount of waste that is transported to incinerators and landfills which in turn helps to preserve natural resources, minimize energy consumption, eliminate pollution and contamination, and bolster the manufacturing industry. The recycling of wastes generated by the industrial sector cuts down on the consumption of new raw materials, diminishes the negative effects on the environment caused by waste disposal methods, reduces costs, and guarantees that the least amount of energy is used while producing products (Awogbemi et al., 2022).

Figure 3

Solid waste management hierarchies



Note: (Azim, K., Soudi, B., Boukhari, S., Perissol, C., Roussos, S., & Thami Alami, I., 2018)

When 'going to throw away' rubbish, the complexities of the process and the interconnected nature of materials and pollution become clear. Waste disposal, for example, is costly and problematic in terms of air pollution and ash disposal. Because the majority of the waste stream is non-combustible, disposal demands the containerization of rubbish dumped outside for collection in order to stay dry (Ouda et al., 2017). One of the most pressing concerns in society is the need for the development of a sustainable society, which is prompted by environmental, social, and economic issues caused by globalization. As shown in a study by (Jouhara et al., 2017), the average European Union member produces 475 kg of waste per year, while the average American citizen produces 730 kg. In an ideal world, selecting the most appropriate ultimate waste disposal option calls for doing a comprehensive study that considers all the benefits and expenses included, often known as a thorough societal cost–benefit analysis(Dijkgraaf & Vollebergh, 2005).

In China, most Municipal Solid Waste (MSW) is disposed of by landfilling. Research by (Idris, A., Inanc, B., & Hassan, M. N. , 2004) conducted on 138 cities in 2000 found that 96.9% of municipal solid waste (MSW) was sent to landfills, 1.3% was composted, and 1.8% was incinerated. Several Chinese cities cannot afford the costs associated with incinerator construction and maintenance. Currently, the basic landfill is preferred over doing nothing at all.

As the world's population and standard of living continue to improve through rapid industrialization, globalization, modernity, and increased wealth are predicted to continue driving a large increase in worldwide power consumption over the coming decades (Pazheri, F. R., Othman, M. F., & Malik, N. H. , 2014). 14% of the energy needs are supplied by renewable energy sources (RES) (Demirbaş, 2006). RES consists of bioenergy, hydropower, geo-thermal, sunlight, winds, and ocean energy. Resources for renewable energy include those that are main, local, and pure (Panwar et al., 2011). During the last three decades, the technological energy efficiency of equipment has advanced significantly, while the home electricity demand has risen. This is due to an increase in electrically powered devices, such as kitchen tools, heating systems, and floor lighting (Nilsson et al., 2014).

For sustainable solid waste management, (Kumar, A., & Samadder, S. R., 2017) have indicated that WTE is a realistic option because it is one of the most important renewable energy resources, financially feasible, and environmentally friendly. for all that, four key variables explain the possibility of creating electricity from MSW: (1) the quantity of MSW produced, (2) the properties and efficiency of a waste materials, (3) the category of devices used for power generation, and (4) the economic circumstances of the WTE plant's site (Ofori-Boateng, C., Lee, K. T., & Mensah, M. , 2013). According to (Arani, 2012), WTE refers to every waste processing that generates energy in the manner of either heat or electricity. Numerous different fuel ingredients, such as H_2 or ethanol, may be produced by more developed WTE systems. A study by (Moya et al., 2017) has incorporated Waste-to-Energy Technologies (WTE-T) regarding biological and heat treatment systems, landfill gas consumption, and bioenergy.

The public is concerned about WTE technologies for health and environmental reasons (Arani, 2012). The hierarchy of waste management which is depicted in Figure (2), and WTE comes before disposal. This demonstrates that the WTE alternative is beneficial, both economically and environmentally. In addition, it is seen as a potentially fruitful method of waste management since it may solve issues related to trash creation and has the potential to be a source of renewable energy(Kumar & Samadder, 2017).

Different studies have attempted to determine which WTE process is better suited for a particular land or area by assessing the economic and environmental effects. In terms of energy output, environmental and economic impact, and health repercussions, WTE technologies can be compared. Incineration, pyrolysis, gasification, anaerobic digestion, and landfilling with gas recovery were discussed as methods for generating energy (Kumar, A., & Samadder, S. R., 2017). They evaluated technological options in terms of economic, environmental, and health implications using a variety of case studies from both industrialized and developing countries. Their findings showed that for both organic and mixed garbage, anaerobic digestion and incineration are the most practicable solid waste management strategies in poor nations. For plastic, electronic equipment, wood waste, and electric waste, pyrolysis, and gasification are preferable, whereas landfilling is best for inert wastes (Lino, F. A. M., & Ismail, K. A. R. , 2018). Based on the waste composition and moisture levels, stored energy in the organic component of MSW could be utilized to generate electricity using two paths. These paths of transformation are biochemical and thermochemical(Ogunjuyigbe et al., 2017).

Waste incineration and gasification are two examples of thermal treatment procedures that yield useful by-products like heat and power. Anaerobic digestion is a type of biological treatment for WTE that results in the production of biogas and fertilizers, while landfill gas may be processed in combination facilities to create power and steam (Tan, S. T., Lee, C. T., Hashim, H., Ho, W. S., & Lim, J. S. , 2014). The outputs and properties of each technology are distinct, and each makes use of a unique mix of waste components (Münster, M., & Lund, H., 2010).

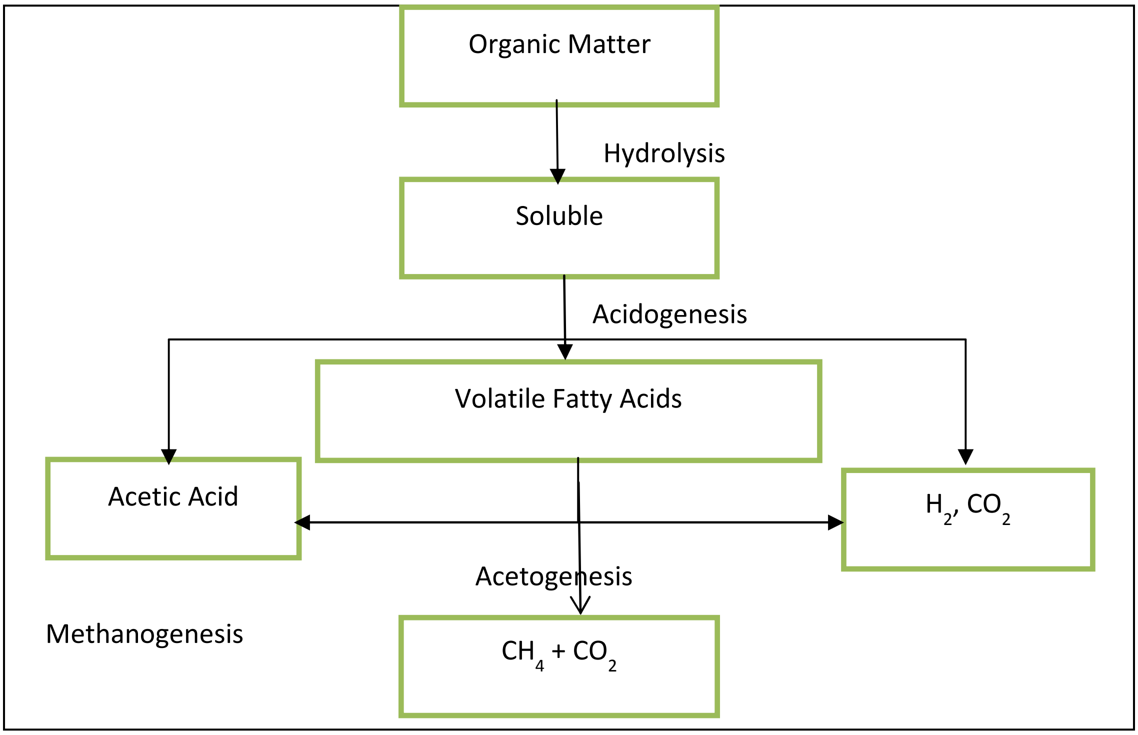
Anaerobic Digestion (Bio Methanation)

AD can be run at temperatures ranging from thermophilic (55–60 °C), mesophilic (35–37 °C), and psychrophilic (20 °C), depending on the environment. This helps to lower the amount of external energy that is required to run the process (Wang et al., 2018). This process results in the production of biogas, which is typically made up of between 50 and 75% CH_4, 25 to 50% CO_2, and between 1 and 15% of other gases such as water vapor, NH_3, and H_2S. which is typically referred to as the digestate is the remaining exceedingly viscous semi-solid substance. It is possible to make use of the biogas by combusting it in order to create heat and electricity, particularly in Combined Heat and Power (CHP) engines. Alternatively, biogas might be employed in interior combustion engines, boilers, or kitchens. How biogas is ultimately used is what defines the amount of purification and removal of contaminants, primarily carbon dioxide, hydrogen sulfide, or water (Mustafi & Raine, 2008)(Rajaeifar et al., 2017).

Through a process called anaerobic digestion, the organic component of biodegradable MSW is broken down and converted into methane. Hydrolysis is the first step in treating MSW, in which the complex organic molecules, such as carbs, proteins, and lipids, are broken down into more soluble organic elements. After the organic compounds have been broken down by AD into acetic acid, H_2, and CO_2, the process moves on to fermentation. Finally, methanogenesis, the creation of methane, occurs. In Figure 4, we see the entire workflow from organic materials to methane (Kumar, A., & Samadder, S. R., 2017).

Figure 4

Stages in the anaerobic digestion process



Note: (Kumar, A., & Samadder, S. R., 2017).

Environmentally speaking, AD offers several benefits that make it a viable option for waste management in the long run. Studies have shown that AD increases biogas production, reduces waste through digestion, and improves waste management. Furthermore, as stated by (Arafat, H. A., Jijakli, K., & Ahsan, A. , 2015) and (Saxena, R. C., Adhikari, D. K., & Goyal, H. B., 2009), the production of power through AD in three weeks is expected to be two to four times greater than the recovery of electricity from landfilling in 6-7 years. According to another study done by (Murphy, J. D., & McKeogh, E. , 2004), one cubic meter of AD-produced biogas may provide 2 kWh of power at a conversion efficiency of 35%.

In general, when people talk about biogas, they are talking about the gas that is produced by anaerobic digestion systems. Biogas is a potential way of meeting the world's demand for energy while also delivering various advantages to the environment (Haberl et al., 2012)(Tambone et al., 2010)(Qi et al., 2005)(Zhao et al., 2016) As an illustration, the European Union policy estimates that at least 25% of all bioenergy can be derived from biogas (Jiang et al., 2011).In Italy, 3405 GW h of electricity was produced from biogas in 2011n(Holm-Nielsen et al., 2009) and in Germany, approximately 4000 agricultural biogas production units were operated on German farms at the end of 2008, which is beneficial for farmer living-environment (Weiland, 2010).

Landfilling

Landfills are among the management solutions available used in many cities around the world to interact with solid waste. According to (Eriksson et al., 2005), landfilling has frequently been identified as the lowest useful treatment option. Moreover, it was used as a reference case to emphasize this point. It is the only method for treating that can deal with mixed household waste, along with incineration. The primary constituents of landfill gas are methane (CH_4) and carbon dioxide (CO_2), with a substantial percentage of other components present in small concentrations such as ammonia, sulfide, and non-methane volatile organic compounds (VOCs) (Harrison, R. M., Hester, R. E., & Carroll, 1994).

The above management solution may impose expenses on the nearby areas in the form of noise, smells, soot, and health impacts. Besides this, improperly managed landfills may have a serious effect on groundwater quality and natural systems. (Lino, F. A. M., & Ismail, K. A. R. , 2018)Toxic gases from landfills have a significant impact on plant growth, animal life, and ecological processes (Danthurebandara et al., 2013). However, the methane gas released during the decomposition process can be recovered and used as a sustainable energy source. During this procedure, also known as landfill gas (LFG) recovery, the Methane gas that is released from the landfill is collected and then used in one of two ways: either as a fuel for the generation of power or heating and cooking. LFG recovery projects in the United States have the potential to create over 17 billion kilowatt-hours of electricity per year, which is sufficient to power over 1.5 million households, according to research conducted by the Environmental Protection Agency (EPA) (Wang, S., Ruan, Y., Zhou, W., Li, Z., Wu, J., & Liu, D. , 2018). Methane is released into the atmosphere during the anaerobic decomposition of organic matter found in MSW in landfills. Aerobic decomposition occurs first when MSW is dumped in a landfill, and during this time very little methane is produced. Typically, anaerobic conditions are formed in less than a year, and methanogens begin decomposing the waste and producing Methane (Du et al., 2017).

Incineration

Incineration is a popular method of waste treatment and disposal. It is meant to attack the various organic materials found in the waste (Gohlke, 2009). It operates at extremely high temperatures and is consequently known as the thermal treatment process. The disposal materials are converted into ash, flue gas, and a big quantity of heat generated throughly. Ash is usually generated by inorganic compounds, which can be converted to solid chunks (Liuzzo et al., 2007). This strategy just reduces waste size, it is not a full waste disposal method; and it is also attributed to fire hazards and the production of greenhouse gases (Ayilara et al., 2020).

Incineration is a major waste method of treatment since it can minimize waste mass by 70% and volume by 90% even while recovering energy from waste to produce electricity (Singh, R. P., Tyagi, V. V., Allen, T., Ibrahim, M. H., & Kothari, R., 2011). Monitored incineration methods for electrical power generation are comparable with many fossil-fuel-based power plants. A waste storage chamber, an incinerator, a vapor engine, a cleaner for flue gas, and an impurities filtration system seem to be typical components of a monitored incineration method for power generation (Ofori-Boateng, C., Lee, K. T., & Mensah, M. , 2013). However, as proposed in an article by (Kalyani & Pandey, 2014), over 90% of MSW created in India is carried to landfills, sometimes in the most unsanitary method. The Municipal Solid Waste Management (MSWM) landfilling operation is the most disorganized method.

Obtained from data analysis explored by (Pasek, A. D., Gultom, K. W., & Suwono, A. , 2013), it could be stated that MSW is used as a vapor power plant fuel without using extra fuel, even after recyclable parts were eliminated. On an as-received basis, waste with a moisture of 40% will contain a thermal value of 6500 kJ/kg or 1500 kcal/kg (Lower heating value). A simple WTE plant using waste with a moisture content of 40% can be constructed to generate 800 kW of electrical energy from 50 tonnes of waste each day or 2.04 kg/hr of waste.

(Bosmans, A., & Helsen, L., 2010) concluded that the waste feedstock is extensively mixed in the incineration process to ensure a far more consistent thermal efficiency, and then placed into a big hopper. Waste incineration, like most garbage treatments, aims to minimize the quantity and destructive qualities of waste while also trapping (and so concentrating) or discarding toxic materials. Incineration methods can however allow for the recovery of waste's energy, mineral, and/or chemical value.

However, as pointed out by (Mendes, M. R., Aramaki, T., & Hanaki, K. , 2004) in his study conducted in São Paulo City, the least environmental workload was described by incineration with ash in a landfill area. Because ash and slag contain primarily substances and very limited amounts of carbon, nitrogen, and sulfur, their own destruction to a dump site did not cause global warming, acid rain, or nutrient retention.

Composting

Traditional techniques like incineration and landfilling have evolved into environmental disservices due to their wasteful production of greenhouse gases and their exploitation of precious farmland. Composting, in contrast to conventional waste management practices, is increasingly being recognized for its environmental benefits (Zhang, L., & Sun, X., 2014). Composting has grown in popularity among waste disposal options due to its beneficial features such as waste hygiene, economic viability, and waste conversion to value-added products(Onwosi et al., 2017). This process is defined according to (Azim et al., 2018) as a natural mechanism that occurs in an aerobic environment (presence of O_2), with sufficient temperature and humidity. Composting efficiency is influenced by factors including turning frequency, heat, C/N ratio, moisture levels, oxygenation, electrical conductivity, pH, and size of the particles (Onwosi et al., 2017).

As for the decomposition process, they may undergo continuous transformations that have a major bearing on the ultimate products. During the thermophilic period, temperature swings have a significant impact on killing off disease-causing organisms, and the relationship between pH and microbial growth and ammonia emission is well-established. The C/N ratio is important for microbial development, and both aeration and MC have major effects on microbial growth and gas emission (Li, Z., Lu, H., Ren, L., & He, L. , 2013).

Materials containing both nitrogen and carbon have been converted into more sustainable organic compounds through composting by the sequential actions of various microbes, that also chemically look like humid molecules (Gajalakshmi, S., & Abbasi, S. A. , 2008).

$$\text{Fresh organic waste} + O_2 \xrightarrow[\text{metabolism}]{\text{Microbial}} \text{Stabilized organic material (compost)} + CO_2 + H_2O + \text{Heat} \quad ....(1)$$

Among the many environmental practices gaining popularity is composting. A respectable method of dealing with and making use of organic garbage. Composting, in the opinion of (Raut, M. P., William, S. P., Bhattacharyya, J. K., Chakrabarti, T., & Devotta, S. , 2008), facilitates the long-term management of huge volumes of organic wastes by repurposing organic substances into items with a variety of applications. When compared to the landfilling technique for waste disposal, composting aids in protecting underground water from pollution (Ayilara et al., 2020). There are benefits and drawbacks to using compost techniques as illustrated by (KOÇAK, E., & İKİZOĞLU, B., 2020). The open compost pile method has the advantages of being low-cost to implement, requiring little in the way of work, having an adaptable capacity, and taking up very little physical area. Lack of shelter from the elements (rain, sun, etc.) and a lengthy composting process are some of the drawbacks. However, composting is the most feasible method given the little means at the disposal of impoverished countries. Due to the significant proportion of biodegradable items, such as food waste, in the residential waste stream, diverting these products is crucial for achieving ambitious diversion goals (Lino, F. A. M., & Ismail, K. A. R. , 2018).

WTE Technologies Comparison

The techniques that were outlined above may be contrasted in regard to their outcome, the effects they have on the economy and environment, and the repercussions they have on people's health.(Kumar, A., & Samadder, S. R., 2017) evaluated many methods of energy regeneration, including combustion, gasification, AD, and methane gas recovery. They compared the financial, ecological, and health consequences of potential WTE technologies using case studies from both rich and remote areas. Based on their findings, AD and incineration are the most practical methods of managing solid waste in developing regions for either organic or blended MSW, while gasification is preferable for plastic, electrical devices, and wood residues, and landfilling is better for indeclinable wastes.

They have concluded that the optimum method for dealing with municipal garbage is largely determined by its unique features and chemical makeup. While WTE facilities are becoming increasingly common in developing nations, they still do not have the facilities, monitoring devices, and repair. Furthermore, the researchers affirm the possibility of MSW as a source of renewable electricity if WTE technologies are applied, which will lead to meeting energy needs, reducing dependence on traditional power sources, and addressing the concern of solid waste treatment.If regulators and investigators provide adequate funding and upgraded technology, WTE may be used to gain a better grasp of the state of the art in energy and waste management and to find solutions to the problems that have arisen.

(Lino & Ismail, 2018) conducted another analysis of WTE possibilities, and they discovered that incineration generates 35 times as much power as bio-digestion. As a bonus, recycling may provide a monthly profit of 201,439 US dollars or the equivalent of 1,120 Minimum National Salary.Prior work employed the life cycle assessment (LCA) technique to compare the effectiveness of burning and landfilling processes, but that study presupposed that the MSW in question had already been prepared for eventual disposal. Releases from the incineration facility, transfer of byproducts, landfill pollutants, and saved emissions owing to the WTE plan's replacement of energy and thermal locations were all included in the estimations (Assamoi, B., & Lawryshyn, Y., 2012). The findings support the use of incineration as an environmentally preferable alternative to landfilling for managing MSW. Specifically, burning generates more power than landfilling does. Since plastic has a high level of energy and is commonly found in MSW, incineration may use this to its strength by reducing the amount of trash that must be disposed of in landfills.

(Lino & Ismail, 2018) presented incineration and landfilling as two possibilities to oversee MSW in Brazil. Regarding the pollutants released into the environment came from the escape of biogas from the landfills and the burning to create electricity, they calculated a sum of 38.385 ktCO_2/year from landfilling and 92.929 ktCO_2/year from incineration (total value of MSW incineration and burning of supplemental fuel LPG).The most negative environmental impact is expected if all garbage is disposed of in landfills, according to research by (Mendes, M. R., Aramaki, T., & Hanaki, K. , 2004) which was partially mitigated by the inclusion of electricity production in landfills.

Similarly, it was discovered that incineration with eventual disposal of ash by landfilling causes the least environmental burden.For their part, (Cucchiella, F., D'Adamo, I., & Gastaldi, M., 2017) compared landfills to WTE facilities. Examining a case study that suggests a WTE plant in the Abruzzo area supplied data confirming that the technique is more acceptable and ecological than landfill without sacrificing recycling and reuse levels.

In addition, it was discovered that the mass burning of solid waste can produce the largest amount of electrical capacity when compared to mass burning with recycling and rejected derived fuel (RDF) with bio-methanation (Khobar, 2015). Additionally, they verify that 11.25 MW of power can be generated in Jeddah city, KSA, under the incineration scenario, and 180 MW of electricity may be generated under the incineration plus recycling scenario.

With regards to power production and GHG reduction, (Rajaeifar et al. (2017), the following technologies: AD, incineration, and pyrolysis-gasification. Using a life cycle assessment method, we assessed the theoretical and technological potentials of energy generation and reduction of GHG emissions. WTE technologies supply the benefits of efficient waste processing and sustainable power production that is also economically feasible, as evidenced by the information available from Iran.

examined the typical MSW procedures, forms, and volumes to look for opportunities to better use MSW. They looked at the possibility that MSW's energy output may guarantee Serbia's continued progress toward eco-friendliness and independence from foreign energy imports. Their research found that the past WTE procedures in Serbia had failed for several reasons, including a lack of solid laws and regulations and a shortage of economic and logistical management. However, the increase in energy consumption and the accompanying increases in cost have contributed to WTE's increased popularity for several other reasons as well.

Overall, waste-to-energy integration with a waste management strategy and waste reduction achieved the best results. The technologies, benefits, and costs of WTE facilities were reviewed in an economic analysis of the WTE sector in China by Zhao et al. (2016). An ROI, NPV, IRR, and simulation all entailed the economic evaluation. Costs associated with WTE may be broken down into two categories: investment costs and operational costs. Operating expenses include things like raw goods, employee salaries and benefits, and repairs, as well as any added economic or environmental costs related to environmental control and management. Investment expenses include the price of all proper tools, devices, and construction works.

(Cucchiella et al., 2017), for example, conducted a study on the topic of the environmentally responsible operation of waste-to-energy plants. Over fifty percent of Italy's garbage ends up in landfills, and that's the primary issue. According to the authors, immediate measures are needed to ensure the proper environmental handling of trash, which has the potential to bring about positive outcomes for the environment and the economy. They suggested a nationwide waste management strategy to calculate the economic net present value of WTE plants, decide how much labor would be created, and examine the viability of WTE facilities in terms of greenhouse gas emissions. The authors proved that WTE techniques can achieve energy independence through the collection of electrical and thermal energy from waste in the same way as other RES can.

Furthermore, they emphasize the necessity of tight regulation to minimize unintended negative effects on public health and the environment from WTE facilities in comparison to older incinerators. To lessen the harmful impact on human health and cut down on CO_2 emissions from trash transportation, incineration stations should be placed near where garbage is generated.

Planning to complete a SWM processing and disposal project requires doing a SWOT analysis. The first thing decision-makers would do is look at the SWOT analysis to see if the goal is even possible. If the intended result cannot be accomplished, a new or revised objective must be selected, and the procedure must begin again from the beginning. To get the most out of a SWOT analysis and find a competitive edge, users need to ask and answer certain questions in order to generate useful data for each strategic fit (Aich, A., & Ghosh, S. K., 2016).

The value of SWOT lies in assessing the strategic positioning of the industrial cluster and helping in the approach to growing competitiveness, as highlighted by (Beloborodko, A., Romagnoli, F., Rosa, M., Disanto, C., Salimbeni, R., Karlsen, E. N., ... & Blumberga, D. , 2015) to the broad applications for which a SWOT analysis can be undertaken to assist in identifying and improving the system. The analysis may be used to help identify and improve the system. According to Pesonen & Horn, (2013), a SWOT analysis begins with a situational analysis to describe the internal (strengths and weaknesses) and external (opportunities and threats) aspects of business development, as well as the internal and external building management strategy of any project or organization.

It is impossible to say that a particular technology is sustainable in another location if it is only viable in one. Whether or not something is suitable is determined by several criteria, including the nature and quantity of the trash, the local climate, the environmental laws and regulations, the availability of human resources, and other similar considerations. According to Aich & Ghosh, (2016), selecting the most appropriate technology for the treatment and disposal of municipal solid waste depends on analyzing the SWOT (strengths, weaknesses, opportunities, and threats) of the external and internal factors of the waste treatment and disposal project. This is done in accordance with the technology that can be applied within the conditions and factors that have been mentioned. It is important to note that this is the case.

Chapter Two

Methodology

2.1 Research Methodology

This thesis employs an exploration methodology due to its uniqueness in Palestine. According to the aims and scope, there have been few studies published on waste-to-energy systems in Palestine, in addition nobody has examined the possibility of constructing or employing one of these methods. Also, the objective of this research is to discover and investigate new information based on energy scenarios, costs, and capacity in Palestine, as well as to gather and examine the energy and electricity laws and strategies for implementing renewable energy solutions. The researcher decided to do similar work regarding legislation and policies guiding waste management, energy production, and environmental conservation. The study's methodology comprises the gathering and assessment of both qualitative and quantitative information as well as SWOT analysis. Key informants from the Local Government, the Palestinian Authorities of Energy, the Joint Services Councils, Palestinian Electricity Regulation Council, and Palestinian Electricity Transmission Company, were interviewed using a semi-structured format as part of the qualitative approach. A quantitative method including MSW generation in the main states of the country, energy potential for each site, environmental assessment using suitable calculations, and economic evaluation will be analyzed using a quantitative research approach, as detailed below.

2.2 Collecting the Data

Data was gathered through a series of interviews with key participants and officers working in the relevant Palestinian government entities responsible for energy, environmental, and municipal solid waste management not to mention attaching the questions in the app. Among them are PENRA, JSCs, EQA, the Ministry of Local Governments, a few local governments, and the Public Energy Trading and Logistics Company (PETL). Furthermore, all national articles, studies, regulations, and strategies concerning waste management, energy consumption and capacity, and environmental safety policies were assessed. The Ministry of Local Government (MOLG) reports, the Palestinian Central Bureau of Statistics (PCBS) reports, the Ministry of Local Government (MOLG) reports, and the Japan International Cooperation Agency (JICA) reports were the primary sources of information used to build this perspective. In order to better understand the practices used to examine the information and to spot patterns, it was decided to investigate regional and global science publications and articles.

2.3 Criteria for Analysis

The assessment of the information was primarily quantitative. Each scenario's technical, economic, and ecological details will be determined with the help of suitable equations as part of the quantitative approach.In order to carry out the technical analysis, the data gathered concerning the rates of MSW generation and the availability of power source in the West Bank was subjected to spatial analysis.The West Bank was subdivided based on the states of the country, as MSW generation and disposal are categorized by these administrative divisions.

2.3.1 MSW Composition and Energy Content

The available electrical power of the rubbish is initially calculated through finding out the energy content (En) for waste that expressed as En (MJ/kg) as the facility's fuel. Around 1200 tons of waste is thrown away daily in Zahrat Al-Finjan landfill, according to information about waste management from JSCs in the areas of the West Bank and Gaza (Yoshida, M., & Muferreh, S. A. , 2019). The energy composition of each waste fraction varies; however, Figure 1 indicates that all MWS created by various municipalities and disposed of in landfills include the unchanged waste components. Table 1 shows this.

Table 1

MSW features in Palestine

Fraction	MSW%	En (MJ/kg)
Paper	12.6	16
Organic	50	4
Plastics	14.6	3
Glasses	1.8	0
Metal	2.5	0
Fabrics	18.5	19

Note: (Abu Muferreh, 2019)

2.3.2 Power output potential evaluation for WTE technologies:

The possibility of the Landfill Gas to Energy which denoted as (LFGtE) technology, which gained from rubbish through the anaerobic breakdown, heavily dependent on the methane production capacity of the garbage dumped in landfill. Factors of methane production include waste degradability, temperature, amount of oxygen, and moisture (Cai et al., 2014). Thus, it must employ a model for evaluating the potential electrical energy generated from the methane created.

In the absence of a landfill gas collecting system, LFG models were initially developed to predict the potential for emissions from landfills and to determine the potential for methane production. The amount of methane gas that will be released during the project was predicted using the widely used model LandGEM-v302. Methane production rates are calculated in terms of either volume [m^3] per year or cubic meters [m^3] per minute or mass [Mg/year] using a first-order decaying equation. Land GEM was developed in the United States for compliance with local and federal regulations, although it was additionally employed for simulating LFG collection in both countries. To estimate how much methane will be produced, it uses the following first-order exponential equation (United States Environmental Protection Agency (US EPA), 2005):

$$QCH4 \;=\; \sum_{t=1}^{n} \sum_{j=0.1}^{1} k\; L0\; \frac{Mi}{10} \left(e^{-ktij}\right) \qquad (2)$$

Where:

- QCH_4 = greatest estimated ratio of CH_4 generation.
- i =time increase equal to 1 year.
- n = (calculation year) – (first year of rubbish approval).
- j = 0.1-year time growing.
- k = CH_4 creation value (1/yr).
- L_0 = possible CH_4 production size (m^3 /ton).
- Mi = the quantity of rubbish that was placed in ith year (tons).
- tij = age of the jth portion of the waste mass Mi in the ith year (decimal years).

The software formula is for determining the creation of methane for a specific year based on the total amount of rubbish that has been disposed of up until that point in time.

- Measuring the on-site constants that affect biogas production.

Although the amount of MSW dumped has a significant impact on the amount of methane produced, the first-order decay equation's fixed parameters k and L_0 also play a significant role. For this, interviews with the dump's general manager were conducted, and the landfill site was inspected so that details concerning the landfill's characterization and future MSW management could be gleaned.

- The CH_4 production level constant (k).

Used to describe the ratio of waste decomposition into gas. At low values of k, methane production is constrained since only a negligible part of the remaining waste decomposes annually to produce LFG. More garbage decays and turns into LFG every year when k is greater than one. More methane is being formed accordingly. The rate at which organic materials decomposes and the total amount of water in the garbage (derived from annual average rainfall) are the two most influential factors in determining the k value (Yao, Z., Xiong, J., Yu, S., Su, W., Wu, W., Tang, J., & Wu, D. , 2020). As shown by equation (3)

$$K = (10^{-5} \times annual\ preciption\ (mm) \times 3.2) + 0.01 \qquad (3)$$

- The possibility of CH_4 production capacity (L_0).

Provides the probable amount of CH_4 gas created by decomposing one measured ton (Mg) of garbage. Almost everything is conditional on the nature of the garbage at hand. The greater the cellulose content in the garbage, the greater the quantity of L0. While sites in extremely dry regions may never produce all the methane, they're capable of, L0 is generally accepted to be unrelated to moisture overhead a certain threshold. In addition, L0 modifies the yearly landfill gas emissions, which are determined by, among other things, the parameters used to compute L0 considering shifting waste composition.:(Krause, M. J., Chickering, G. W., & Townsend, T. G., 2016)

$$L_0 = \frac{MCF \times DOC \times DOCf \times F \times \frac{16}{12} \times 1000}{0.7140} \qquad (4)$$

Where MCF a parameter for modification of CH_4, DOC is the decomposable carbon (C), f is a fraction for the methane in biogas and DOC_f is the fraction of decomposable carbon integrated, in addition to that, 16.0/12.0 is the methane to carbon massratio; 1 thousand is the transition from megagrams to kilograms, and (0.7140) is the density for CH_4 gas (kg/m^3).

The formulas and equations that are utilized in this study to compute the factors and parameters were described in appendix c.

After putting in the simulation's input information, which includes data about the landfill spot like the amount of trash dumped there each year, (MSW). Also, a starting and stopping year were made up to the landfill, which will be managed by using new technology to turn the covered biogas into electricity. For this reason, you can figure out how much potential electrical energy $Ep_{(LFRE)}$ you could get from landfill gas by using equation (1), which figures out how much biogas will be made at the estimated year because of all the trash that has been thrown away through it. To begin, the quantity of captured methane gas (Q_R) could be measured through multiplying the produced biogas by efficiency of the collection system (▪ collection system), as indicated in this equation:

$$Q_R = Q_{CH4} \times \eta_{\text{collection system}} \quad (5)$$

Then, the electrical energy produced from the biogas can be attained through the following formula (Gonçalves et al., 2018):

$$Ep = Q_R \times 10 \times \eta overall(LFGE)(5) \quad (6)$$

However, number ten in the equation is the transforming parameter from one m^3 of methane into one kWh and ▪ $_{overall(LFGtE)}$ is the total efficiencies that will be used in the LFGtE plant.

2.4 Electricity production by the incineration technique

In the present scenario, only electrical energy (Eele) kWh/day was considered. To evaluate the daily generation of electricity, determine the (En) of the MSW as indicated in equation (6). After that computing potential electricity (Ep) that produced from the incineration facility with 22% electrical facility efficiency (▪ overall), Also, the quantity of waste that isdropped off annually in tons. By equation (7) provides potential electrical energy in kWh which can be attained.

$$En = \sum_{fraction=1}^{f} En\ fraction \times MSW\ percentage \qquad (7)$$

$$Ep(incineration) = \frac{Qmsw \times \frac{1000\ kg}{ton} \times En \times \eta\ overall(incineration)}{EleCconv} \qquad (8)$$

$EleConv$ is the factor of conversion from mega joules to kilowatt hour, ▪ overall (incineration) is the overall efficiencies which will be employed for incineration technology.

2.5 Electrical energy generation using anaerobic digestion

In the biological process, oxygen is removed from the environment in order to create conditions that are favorable for bacteria to convert organic matter into methane. The biological processes involved are, at their core, identical to those involved in the formation of landfill gas; the only difference is that this process takes place in industrially well-controlled settings. The residual sludge, known as digestate, is converted into compost by an aerobic process so that it can be used in agriculture.

The first step is collecting and preparing the feedstock, which can be anything from agricultural waste, food waste, sewage sludge, or energy crops. To prepare the feedstock for AD, it is routinely treated to eliminate pollutants and provide the ideal environment. After the feedstock has been processed, it is placed in an anaerobic digester, which is a hermetically sealed, oxygen-free container. The digester fosters an atmosphere where anaerobic bacteria can accomplish their work of decomposing organic materials.

Through a series of metabolic events, the bacteria degrade the feedstock to generate biogas. Collecting and Storing Biogas: The digester is used to collect the biogas that is created during the process of anaerobic digestion. Methane (CH_4) makes up most of its composition (25-75%) and carbon dioxide (25-55%) with trace amounts of other gases being present(Augusto et al., 2013). In most cases, the biogas will be cleaned to get rid of pollutants such as moisture, hydrogen sulfide, and other contaminants. After being cleaned, the biogas is placed in gas containers or tanks in preparation for subsequent utilization.

Biogas is burned in an engine or gas turbine to generate mechanical energy, which is then converted into electricity. A generator is used to transform this mechanical energy into electrical energy. Energy efficiency is maximized since the heat produced during burning can be collected and utilized for heating or other reasons. When an anaerobic digestion plant generates more electricity than it needs, that extra power can either be used to power the plant itself or sent back into the grid for broader distribution and consumption. Upgrading biogas to natural gas quality and injecting it into the natural gas system opens further applications for the fuel. Anaerobic digestion results in a by-product called digestate, which is processed further. It's possible to extract liquid and solid components from the digestate. While the liquid fraction can be further processed or utilized for irrigation, the solid fraction can be put to good use as a nutrient-rich fertilizer for crops.

For this study, it is expected that the input will consist of organic municipal garbage that has been collected separately. Because of this, the process is simplified, and it will increase the likelihood that the compost will be able to be sold. This relationship to the installation of separate collections could, on the other hand, result in a period of five years being required for implementation.Like landfill gas, biogas can be converted into energy.

Energy Generation: Using anaerobic digestion (AD) technology, 600 tons of organic waste a day are transformed into biogas, and the biogas that is produced from this process is then used in a subsequent step to produce energy. When put through an AD conversion system, one ton of RDF waste can produce 992 kWh of power, in addition, the research that has been done indicates that the AD plant has an efficiency of 36% in terms of the creation of electrical power (International Renewable Energy Agency, 2015).

This thesis assumes that the entered waste will contain organic materials that has been collected. This simplifies the technique and makes sure that the compost can be sold steadily. An amount of organic waste weighing 1 ton produces 70 m^2 of biogas, including 60% methane. (Bank, 2018) Biogas can be transformed into electricity with the same process as landfill gas.

The following Equation is for the energy produced (kWh) using anaerobic digestion process (Abanades et al., 2022):

$$E\ (kWh)\ =\ Biogas\ Production\ Rate\ (m^3/h)\ x\ En\ of\ Biogas\ (kWh/m^3) \qquad (9)$$

Where:

- Biogas Production Rate (m^3/h): the rate at which biogas is generated by anaerobic digestion. It depends on many factors such as the amount of waste, digester mass, temperature, and time.
- En: is the energy Content of Biogas (kWh/m^3): The energy content depends on the CH_4 content of the biogas, which can change. An approximation is that 1 m^3 of biogas can contain around 20-25 kWh of energy.

2.6 Estimating the Economic Impact

The feasibility of investing to fund a high-budget work is determined through the application of financial variables like the levelized cost of electricity (LCOE), which is used to calculate the cost in dollars per kilowatt-hour of generated electrical energy Eele (kWh/day), followed by the net present value (NPV), that is utilized to analyze the profits of the project according to the disparity between both. Additionally, internal rate of return (IRR) calculations is utilized to determine the approximate highest profitability percentage of an investment's prospective return on investment.

Simple Payback Period (SPP) calculations were also performed, that means the time it needs to collect the cost of a particular financing. Equations (10) - (13) were made using these economic aspects (Blank & Tarquin, 2018).

$$LCOE = \frac{\sum_{n=1}^{N} \frac{In+Fn+OMn}{(1+i)^n}}{\sum_{n=1}^{N} \frac{Eele}{(1+i)^n}} \qquad (10)$$

$$NPV = \sum_{n=1}^{N} \frac{Rt-(In+Fn+OMn)}{(1+i)^n} \qquad (11)$$

$$NPV = 0 = \frac{Cn}{(1+i)^n} \qquad (12)$$

$$Spp = n-1+\frac{CNCF\ n-1}{NCF\ n} \qquad (13)$$

Where, in is the initial investment value, Fn is the plant fuel cost, OMn is the operational and maintenance cost, I is the discount rate, n is the number of time periods, Cn is the plant cash flows at year n, CNCF is the cumulated net cash flow, NCF is the net cash flow.

2.7 Revenues

The planned facility generates revenue (Revt) in a couple of ways. The first one is Revele, which is the money made by selling the electricity that is generated every day (in kilowatt-hours, or kWh/day). By transforming daily production into yearly and employing feed-in tariff parameter ($/kWh), that is 0.40 ILS/kWh and 0.1171 $/kWh (Tayeh et al., 2021), we may derive yearly electricity earnings in $ from annual electrical energy per year, as indicated in equation (15). The second form of revenue is called Revfee, and it comes from payments made by municipalities on gate fees. These payments are made for every ton of MSW that is dumped off and handled in a landfill at a rate of $1 per ton ($/ton). Applying formula (15), one might determine how much money is made annually from gate fees for MSW, where QMWSn is the quantity of MSW in tons that are eliminated every year.

$$Rev\ ele = \sum_{n=1}^{N} Eele \times feed\ in\ tariff\ \times 365 \qquad (14)$$

$$Revfee = \sum_{n=1}^{N} Qmsw\ \times gate\ fee \qquad (15)$$

$$Revtotal = Revele + Revfee \qquad (16)$$

2.8 SWOT Analysis

In this work, the procedures that need to be taken to carry out a full SWOT analysis to compare incineration, anaerobic digestion, and landfills as techniques for producing energy are developed according to (David, 2011)IPCC. The SWOT analysis is a beneficial framework that enables a methodical examination of the strengths, weaknesses, opportunities, and threats that relate to each alternative. It serves as an acronym for "strengths, weaknesses, opportunities, and threats." In the first step of the process, a comprehensive literature review is carried out to gather appropriate data on the efficiency, benefits, and drawbacks of landfilling, incinerating, and anaerobic digesting with regard to the production of power. In addition, interviews were carried out with industry professionals, experts, and stakeholders in order to acquire an understanding of the wide range of experiences and points of view that are associated with these diverse techniques of energy production.

The advantages of each approach are then broken down and analyzed in the following step. These may include energy efficiency, waste reduction, resource recovery, and interoperability with the infrastructure that is already in place. At the same time, the constraints of each method are assessed, considering factors such as emissions, land needs, public perception, and operational restrictions.

After then, the focus of the research shifts to determining the opportunities and risks associated with the three methods of producing energy; anaerobic digestion, incineration, and landfills in order to dispose of waste. Opportunities may present themselves as a result of shifting policies and regulations, developments in technology, growing consumer demand for renewable energy sources, and the possibility of forming partnerships with businesses operating in other sectors. On the other side, dangers may occur as a result of difficulties such as more stringent environmental rules, opposition from the general public, cost competition, and concerns surrounding the long-term viability of the project.

Both qualitative and quantitative research approaches are utilized in the process of data collection for the analysis. Quantitative data can be acquired through metrics on energy output, analyses of waste composition, and cost assessments; qualitative data, on the other hand, can be derived from the opinions of experts, case studies, and documented experiences. After that, the data is thoroughly analyzed, and the found factors are placed into the relevant SWOT categories.

In the final step of this analysis, the SWOT profiles of incineration, anaerobic digestion, and landfills as energy production technologies are contrasted. This comparison enables a full understanding of the relative benefits and drawbacks of each strategy by contrasting them side by side. The most important conclusions and repercussions that may be drawn from the SWOT analysis are outlined here, providing insightful support for the subsequent conclusions and recommendations that are presented in the thesis.

2.8.1 Formulation of SWOT Analysis Questions

In the following paragraphs, the major research questions that were developed for each approach in order to carry out the focus group meeting will be given and detailed.

Question 1: What are the advantages of using this method?

The first question focuses on determining the primary advantages that are offered by each solution (AD, landfilling, and incinerating). To be more specific, the participants can be asked questions such as:

- Is it possible for the process to reduce the amount of garbage?
- Is it possible for the process to recover energy from the waste products?
- Will the technique be able to lower the emissions of greenhouse gases?

Question 2: What are the constraints? The purpose of this question is to discover any potential flaws in the approach. During the meeting of the focus group, the participants were asked to share their thoughts on a variety of issues, such as the following:

- What are the costs?
- Does it contribute to the pollution of the air and the disruption of the areas that are close to the project?
- Which potential health dangers are the most serious ones to consider?

Question 3: What are the opportunities? The purpose of this inquiry is to gather information on the potential opportunities that the method may encounter in the outside world in the future. The question can be understood better by considering some of the questions that are given below:

- Which possible benefits of the project do you consider to be the most important?
- Will there be an increase in energy autonomy?
- Will the initiative result in an increase in available work positions?
- Is there a chance that environmental sustainability may improve?

Question 4: What potential dangers could arise if the process were to be carried out as planned? This inquiry investigates the potential risks that would arise from the implementation of the strategy. Questions along these lines include:

- What are the most significant external issues that will have a detrimental impact on the project?
- Will the applicable authorities, environmental rules, and environmental policies oppose the proposal?
- How is this trash removal method compared to others currently on the market?
- Will the process contribute to the contamination of the air?
- Will there be an effect on the local community as well as the environment that surrounds it?

Chapter Three

Results and Discussion

3.1 Spatial Analysis

Zahrat Al-Finjan Landfill Site

The landfill that was chosen for the study is called Zahrat AL Finjan, and it is situated in the north of Palestine in Jenin city. However, the weather in Jenin is classified asmoderate, including an annual normal precipitation of around 468.21 mm/ year with an expected yearly total precipitation of 508.5 mm/year in 2022. In addition, the average temperature throughout the year is approximately 20.8 degrees Celsius. Although the landfill has a total area of 250 donum, only roughly 140 donum were used up throughout the filling process, which began in 2007.

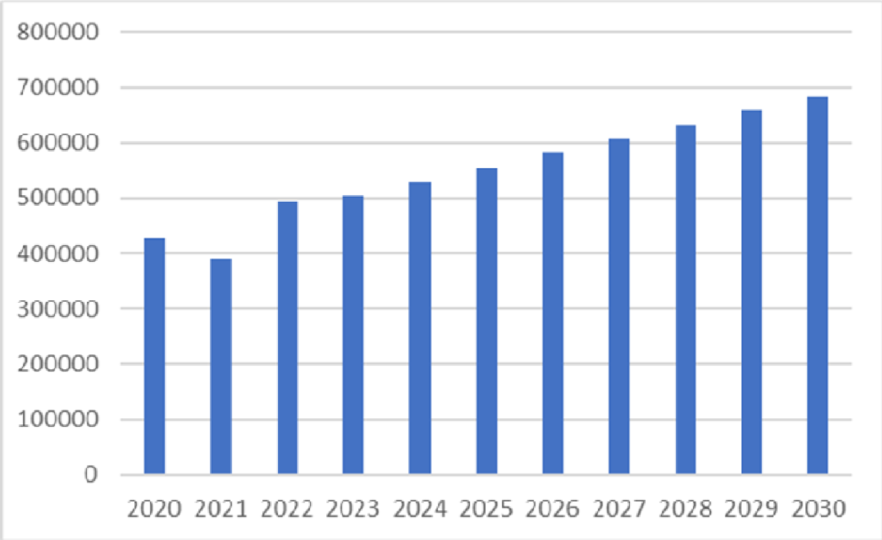
The landfill is still in service today. In addition, the landfill consists of four cells, each of which has an average lifespan of thirteen years and is utilized for the disposal of municipal solid waste that has been acquired.approximately 1200 tons of municipal solid waste are collected each day and taken to the Zahrat Al Finjan landfill, that falls below the management of the JSC. Since 2019, this landfill has been operating on a rate that is more than 88% of its capacity. Currently, the method of operating the landfill that is being utilized is landfilling without any form of gas recovery.

According to the collected data from Zahrat Al-Finjan landfill reports, the amount of waste that arrived at this landfill reached 495,433.81 tons in the year 2022. As for the current functioning circumstances of landfills, the Zahrat Al-Finjan dump is either close to being overloaded or is already full. There is no denying the impending environmental and health crises in the West Bank governorates. Difficult social limitations by local inhabitants in the nearness ofcities and communities, as well as the findings of MOLG research, suggest that there is no opportunity of expansion or updating the present landfills. The PA and Israeli`s occupation government tangled political position has also pushed this national challenge down the list of priorities. In area C, there will be several Israeli restrictions on constructing additional landfills, even though this is the best suited location because of its lower concentration of people.

The enormous quantity of waste that is produced can become an obstacle if it is not processed or dumped incorrectly. When that occurs, it will hurt the surrounding ecosystem. Every year, there is a rise in the total number of people. As a direct result of this, the volume of waste that is produced will continue to rise. It is possible that by the year 2030, the produced quantity is expected to reach 684000 tons of waste. As can be seen in Figure 5, it has become essential for us to identify an approach that is effective in processing waste in order to realize our primary objective of decreasing the amount of waste that is produced. Encouraging reasons like a shortage of energy supplies and a scarcity of plans that may assist the West Bank's inner economies can be potential advantages of creating the WTE facility and creating electricity from it, thus decreasing dependency on Israeli imported energy. Other potential motivating factors include an absence of programs that might help the Palestinian Authority's efforts to negotiate a permanent status with Israel.

Figure 5

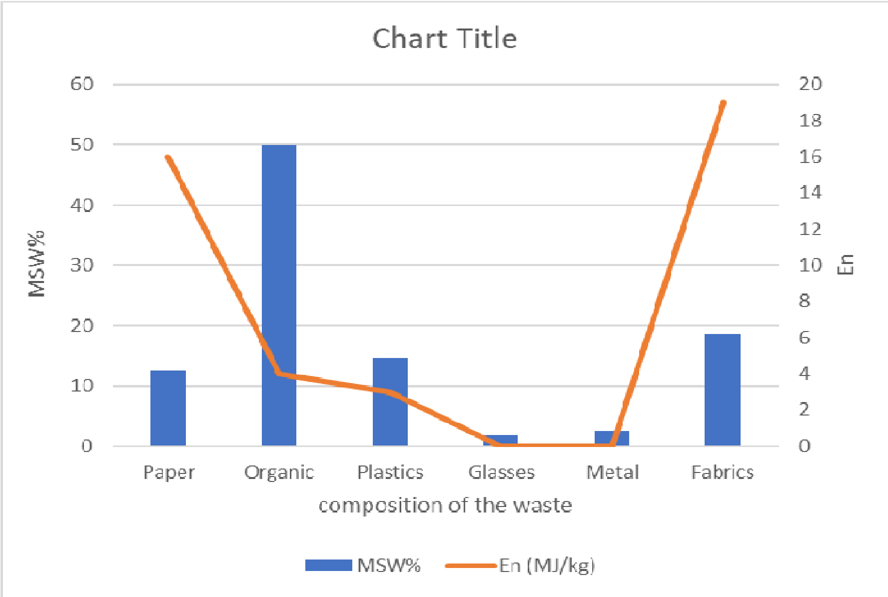
The evaluated annual MSW progress in the West Bank (ton/year) between 2020 and 2030



In fact, the kinds of trash a nation makes could show how developed it is. In advanced nations, there are greater amounts of non-organic fractions than organic fractions. This means that industrial garbage makes up a lot of waste. In comparison, because industrial production is lower in developing countries, they tend to have a lot of MSW that comes from natural sources. Still, other things, like the weather, the speed of growth, the availability of energy, and the way people live, influence how waste is made. So, changing the types of waste and the total calorific value of waste affects each energy content and the likelihood of making electricity. Figure 6 shows the West Bank MSW parts and how much energy they have.

Figure 6

Fractions of MSW and energy content (En) in the West Bank area



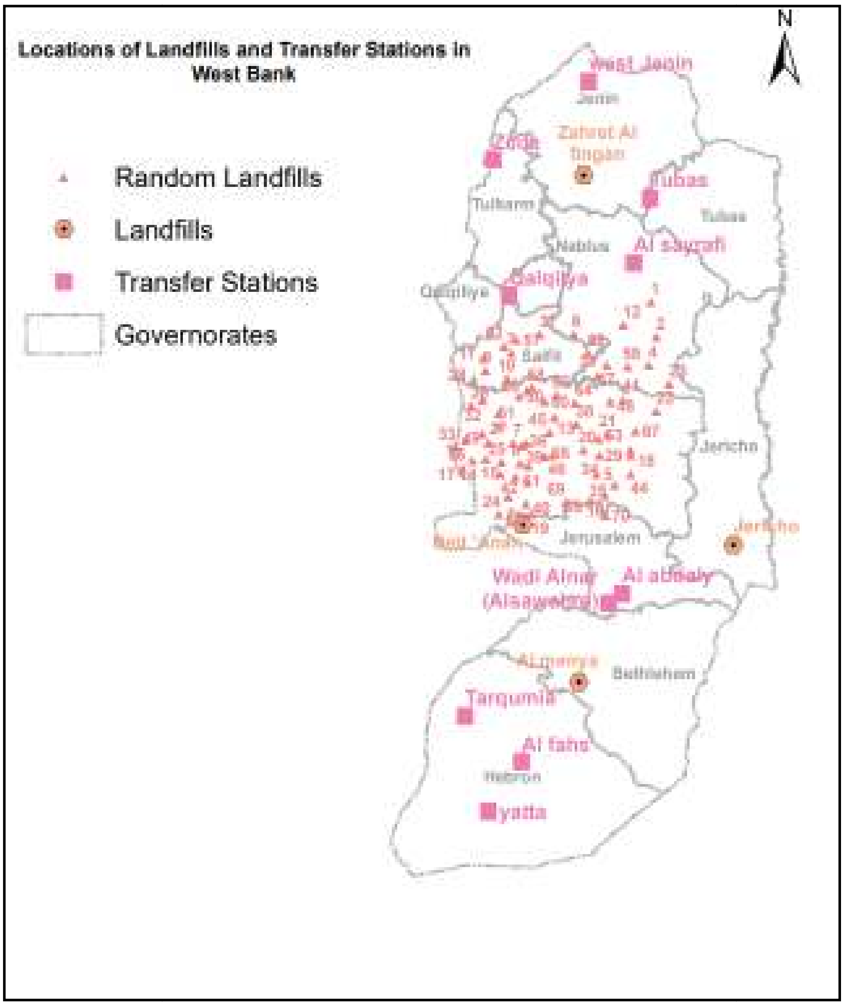
To return to the present operational circumstances of landfills, Zahrat Al-Finjan dump is quite close to reaching its capability. In the next several years, it is unavoidable that the governorates in the West Bank will be confronted with significant challenges related to both the environment and public health. Based on studies conducted by MOLG, it has been determined that there is no potential for expanding or modernizing the existing landfills. This is due to the social limits that are imposed by the local inhabitants who live in the vicinity of residential areas.

Calculating the energy content in MSW in Palestinian territory using a weighted average yield of 11.9 MJ accessible per kilograms of MSW, corresponding to compositions and calorific value of MSW fraction that provided in Table (1). While in contrast to other fossil energy sources, like diesel fuel, which has nearly 37 MJ/L, this calorific value is particularly important. To put this in electrical conditions, that every kWh includes 3.6 MJ, diesel involves 11 kWh/L, also Palestinian MSW contains 3.12 kWh/kg MSW.

A spatial analysis that offers a concise description of the present MSW descriptive data is displayed by Figure (7). It is plain to see that the Ramallah governorate transports garbage over a significant distance to the Zahrat Al-Finjan dumpsite, which serves as its disposal facility. The Israeli control is the primary cause of that situation. Since Israel has not permitted the projected dumping site to open close to Ramallah as of this moment and according to MOLG's predictions and prior involvement with same problems, it is anticipated that the scenario will remain unchanged over the next few years.

Figure 7

Location of Landfills and Transfer Stations and Random Dumpsites in West Bank



Note:https://molg.pna.ps/ar/categories/ /2127/Shared-Urban-Database/1)

Zahrat Al-Finjan runs at roughly 88% of its optimum size, and there is no way of increasing its capacity as a result of defense from local citizens and other technological and the accessibility of land limitations; this circumstance places a great deal of social stress on the PA.

According to spatial analysis, the southern part of the West Bank is unlikely to experience dumping site overflow issues; the Al-Menya landfill has only been used at 9% of its intended capacity so far, so it is going to have a lot of space for use in the southern governorates. Despite this 9% usage, it is important to remember that the project is still in its early stages and will not be completed for another 5 to 8 years.

In the middle and northern regions, each accessible location is either overcrowded or is going to be rapidly overcrowded, with minimal potential for constructing another dumping place due to a lack of land. A shortage, inadequate PA control in regions B and C, and political difficulties among the PA and Israeli administration, especially since considering Israeli settlements on the West Bank, which are problematic for both parties. In keeping with the MOLG statements, always the PA tried to construct an additional location, and the Israeli government required it to help its settlements alongside Palestinian towns and villages, which the PA refused because it wants all settlements removed and considers them illegal under international legislation.It's also important to note that moving some of the municipal solid waste from the northern and middle regions to the Al-Menya site isn't feasible because of the system's high operating costs and the inadequacy of the transportation infrastructure linking the two areas.

All West Bank transfer stations were also considered in the spatial study; these facilities serve a pivotal role in regulating transported amounts, keeping transfer expenses in the PA's means by moving large, concentrated loads. The significance of transfer stations is going to rise significantly once sorting and recycling are included.It is apparent that, in addition to disparities in costs between governorates, there is also an obvious variation in the average rate of municipal solid waste creation per capita among governorates. In 2022, the daily consumption of rubbish in the West Bank was 1 kg/capita/day.

Specifically, the researcher used a spatial analysis of waste production, populations, and existing dump locations for better understanding. The current MSW descriptive statistics are graphically represented by spatial analysis. It’s clear that the governorate of Ramallah transports wastes a considerable distance to the landfill in Zahrat Al-Finjan. Why? Primarily because of Israel's occupation. According to MOLG prediction and knowledge with same situations, as well as the fact that Israel has thus far refused to agree to the proposed landfill neighboring Ramallah to work, the current impasse is projected to persist for the foreseeable future.

The Israeli government's conditional agreement to function their settlements alongside with the Palestinian + communities, as stated in the MOLG declarations, is unacceptable to the PA because it is part of its demand for the removal of all settlements, which it views as illegal under international law. It's also important to note that moving some of the municipal solid waste (MSW) from the northern and middle governorates to the Al-Menya site isn't feasible because of the system's high operating costs, as well as the distance involved, Israeli checkpoints, and inadequate transportation connecting infrastructure.

Table 2

MSW descriptive data governorates spatial analysis

#	Item	JSC										
		Jenin	tubas	Nablus	Tulkarm	Qalqilia	Salfit	Jericho	Ramallah	Bethlehem	Hebron	Jerusalem
1	Population	325271	63114	400012	191873	116454	78380	51410	340475	225020	743121	451584
2	Daily collected amount [ton]	286	39	93	166	105	66	55	232	130	370	169
3	Daily generated waste/person [kg/capita. Day]	1.00	0.71	0.55	1.10	0.95	0.83	1.08	0.91	0.77	0.98	1.00

The cost economic study for the existing MSW management system in the West Bank reveals that collection, transfer, and disposal are the primary terms. Municipalities are responsible for collection in major towns, local governments in rural areas, and UNRWA in the camps for refugees. MSW is subsequently transported to transport stations or straight to a landfill.Tipping fees must be. delivered for each ton of MSW that is moved to a landfill.

3.2 Assessment of the energy and financial potential of WTE technologies

This part illustrates the primary objective of the study, which is to choose among the suggested WTE technologies and implement them at the Zahrat Al-Finjan landfill in the Palestinian West Bank to regulate the region's MSW. Each WTE technique, from LFGtE's methane production to incineration's energy content to compost, indicates how capacity is reliant on as well as how the composition of MSW serves an important part in the utilized WTE system.

Table 3

Coefficients that examined in evaluating various WTE systems

Assumptions for WTE technique	
Feed-in tariff [$/kWh]	0.1161
Gate fees [$/ton]	8
Facility lifetime in years [n]	30
(MARR)	13%

Note: (Bank, 2018)

As shown in Table 3, the target feed-in tariff for the facility is 0.1161 $/kWh, which determines the selling price of electricity generated by the plant. In addition, gate fees are a clear supplementary source of income for a facility that benefits from getting waste from JSCs, as is occurring in the landfill area. Furthermore, a minimum attractive rate of return is a revenue percentage that contributed to the original investment in the work within the lifetime of the facility while conducting the economic evaluation.

3.2.1 An Assessment of LFGtE's Energy and Financial Potential

This study area is dedicated to determining the feasibility of setting up a landfill capturing system and utilizing the methane gas CH_4 created through the biodegradation of organic material when the process of anaerobic digestion which takes place within the landfill so it can generate electricity. It's also important to note that the analysis relied on several assumptions that will be stated. Table number 4 illustrating the main constants for LFGtE technology`s economic analysis.

Table 4

constants for LFGtE technology's economic assessment

Character	Constants
Debt percentage	50%
Debt reduction	5%
Debt payment period	5
collection system η	80%
plant η	33%

Pproviding the relevant inputs information to the software to consider the annually produced LFG, the Land GEM model gave a forecast quantity of CH_4 emission for (2024-2054) as the facility's lifetime anticipated. Expected levels of methane gas (CH_4) and generated electricity are shown in Figure 8.

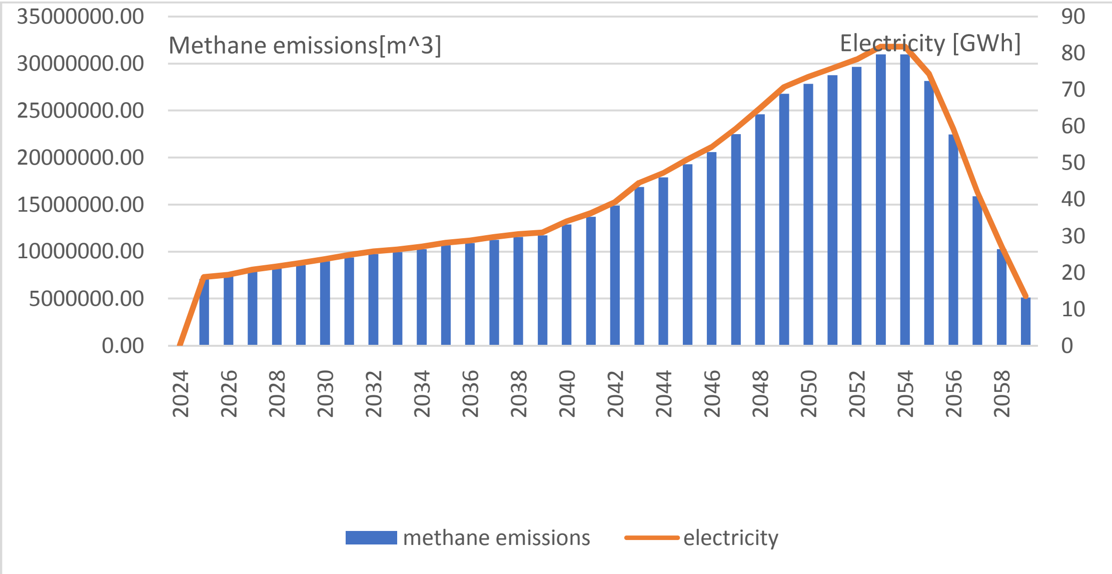
Methane recovery assessment

As was noted before, the Land GEM model was utilized to make projections regarding the amount of methane that was created at the location. even though the software supplies default numbers for both L_0 and k, and this could be influenced by if the input information insufficient for k and L_0 determined during the study corresponding to the site characteristics consisting of the waste type, the amount of moisture (predicted from the yearly average precipitation), as well as the climate in order to give a more precise analysis. By using the equations number 2 and 3, the results of these calculations had been around 0.016/year, and 94 m^3 /Mg, correspondingly.

The software supposes that the measured amount of CH_4 in 2024, that is the first year of working of the facility, will not be obtained through that year. A year after, the methane in the facility is around 7,105,000 m^3, so this year is considered the first year that can produce electrical energy. After sixteen years of function, the CH_4 gas equals 11,707,045 m^3,demonstrating that the output is extensively expanding. In 2053, when the facility has finished its life process at a rate of 30,975,207 m^3. In 2054, thehighest point of CH_4 production evaluated to be 30,965,341.27 m^3, and then the production reduces exponentially after the landfill shutdown affected by the declining of the quantity of the waste in the site.Around a 15-year span, the landfill will require investment cost of $18 million. Studying cumulative operating and investment cash flow for the initial year, shows a negative amount of $ - 620,000.00. This landfill will take around 402,000 tons of waste yearly, yielding a 18,615 MWh of electricity. The yearly energy revenue, calculated at $ 1,986,220 with a sales price of $0.1067 per KW, is supplemented by a gate fee set at $.5 per ton . This fees needed to achieve zero cumulative cashflow in 15 years.

Figure 8

Predicted methane and electricity using LANDGEM model



The effectiveness of the collecting system was evaluated to be around 80%, but the normal efficiency can range anywhere from 55 to 95 percent, as stated by the EPA for LandGEM modeling (United States Environmental Protection Agency (Alexander, A., Burklin, C., & Singleton, A. , 2005). In addition to this, it is estimated that the entire plant efficiency is 33% (Dace, E., Blumberga, D., Kuplais, G., Bozko, L., Khabdullina, Z., & Khabdullin, A. , 2015).

Estimating Electrical Energy Recovered

The quantity of methane detected (which in turn is dependent on the efficiency of the collecting equipment) determines how much electricity the plant can produce.Furthermore, 1m^3 of CH_4 might be converted into kWh. The total quantity of potential electrical energy is also affected by the efficiency of every device employed to produce energy at the location, including engines and turbines.

In Figure (8), electricity growths with growing amount of generated CH_4 upward to the ending of landfill created MSW. According to this, in 2054, the CH_4 production reaches its highest degree of LFG creation, wherever the possible electricity is around 81 GWh.Differently, electrical energy would decline to 70 GWh in 2063 when the landfill finishes placing MSW, and rubbish decomposition is stopped consequently.

3.2.2 Considerations on the power and financial viability of incineration method

To conduct and explore economic analysis, this study uses Zahrat Al-Finjan landfill's WTE combustion facility as a case study.As was previously noted, the recycling procedure wouldn't take place on the plant, and the trash is going to be handled outside the facility. Since recycling yields no income, only electricity sales and tipping fees will be considered in the economic analysis of the plant. The subsequent assumptions in table 5 were also employed in the economic evaluation of the proposed WTE combustion facility.

Table 5

Assumptions for incineration WTE financial assessment

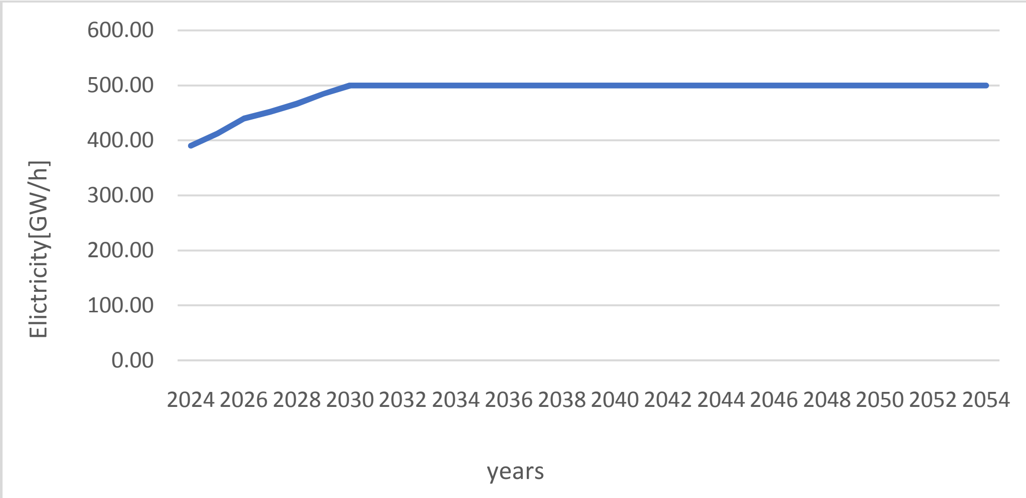
Assumptions	
Debt rate	70%
Debt reduction ratio	6%
Years for debt	10
facility efficiency η	23%
Evaluates according to the system	
facility space [t/day]	1200
Energy content [MJ/kg]	11.91
Total Eele [GWh/year]	499.601

Note: (Tayeh et al., 2021)

Based on these assumptions, a financial investigation was conducted. The plant's space is an independent factor. However, additional outputs are dependent on it, and any variation in facility capacity could lead to a difference in several sensitive elements containing the starting investment, energy content, and the generated electrical power.

Figure 9

Electricity Generated from Incineration



Obtaining a particular quantity of produced MSW is created by holding a stable amount of generated electricity every year, that can be proved by Figure 9. Incineration plants are vital for waste management and sustainable energy production. One plant with a capacity of 1200 tons generates around 350 GWh/year of electricity. This highlights the plant's ability to handle a substantial volume of waste and showcases its significant energy generation potential. Producing such a large amount of electricity is noteworthy when considering the alternative sources required to generate an equivalent output. Moreover, incineration plants contribute to environmental sustainability by reducing the volume of waste and mitigating greenhouse gas emissions. The electricity produced can be considered 'green' and aids in minimizing the reliance on fossil fuel-based power sources. These plants incorporate advanced technologies, such as waste sorting systems and flue gas treatment processes, which enhance efficiency and environmental performance. Evaluating the economic viability of the plant further emphasizes the long-term sustainability of waste-to-energy initiatives.

3.2.3 Considerations on the energy and financial viability of digestion method

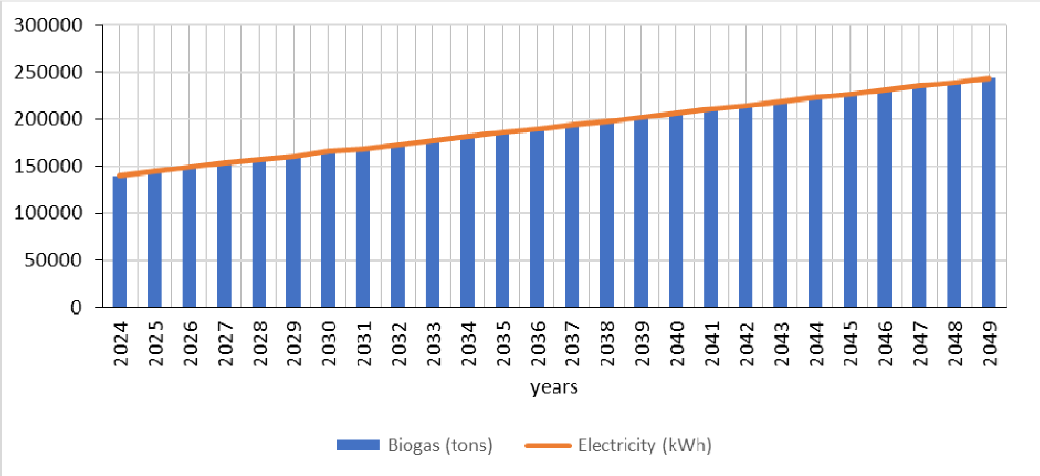
The calculations of methane and biogas production from the AD process provide valuable insights into the renewable energy potential of organic waste management as shown in figure (10). The estimated amounts of biogas and methane generated during AD demonstrate the feasibility of harnessing this process for energy generation. The methane conversion factor, specific to the composition of organic waste, played a crucial role in determining the proportion of methane within the biogas. By understanding the methane content, we can better comprehend the environmental implications of AD, as methane is a potent greenhouse gas. The calculated biogas production highlights the potential for renewable energy production, which could contribute to reducing reliance on non-renewable energy sources. These findings emphasize the importance of implementing AD initiatives as a sustainable waste management practice that simultaneously promotes renewable energy generation and mitigates greenhouse gas emissions.

Organic waste constitutes 50% of the amount of waste that reaches the Zahrat al-Finjan landfill. Accordingly, the amount of methane and biogas produced annually was calculated.Over a 25-year time, a waste-to-energy technology with initial investment cost of $90,000,000. The net cash flow before financing is positive at $9,400,000, but when looking in the cumulative operating and investment cash flow, the overall financial image shows a negative value of -$7,200,000.This project includes processing 200,000 tons of waste every year, resulting in the creation of 23,000 MWh of electricity. The annual energy revenue is $2,454,100 considering 0.1067$ sales price per KW . however, to attain zero cumulative cashflow in 15 years we study gate fee at 90$ where prices of separate collection are involved and that will donate extensively to the revenue at $19,000,000.

To maintain the project, there's an economic cash flow of $82,800,000, showing that financing has acted a crucial role in supporting the strategies. Notwithstanding the negative net cash flow after funding, the project might be financially feasible in the long term, and it's crucial to reflect factors such as the project's lifespan, future profits, and operative efficiencies for a full assessment. Figure 10 shows the continuous increase in the amount of biogas annually.

Figure 10

Annual biogas production and electricity



The discussed anaerobic digestion (AD) plant, with a capacity of 1200 tons and 50% organic waste, has the potential to generate approximately 40 GWh of electricity. This capacity indicates its ability to handle a significant volume of waste, particularly organic waste materials. By efficiently converting organic waste into biogas through AD, the plant contributes to waste management while simultaneously producing renewable energy. The estimated electricity generation relies on factors such as the biogas composition, power generation efficiency, and overall energy content. The electricity generated not only reduces reliance on fossil fuel-based sources but also mitigates greenhouse gas emissions.

3.3 Comparability between LFGtE, AD, and incineration WTE systems

The methods that take place are determined by several criteria, including the content of the waste, the local legislation, the infrastructure, and the preferences of the community. When all these factors are taken into consideration, WTE facilities appear as a realistic choice that strikes a balance between the creation of energy, the reduction of waste, and the possible economic rewards.

Table 6

Comparison between AD, LFGtE and incineration WTE plant

	LFGtE	Incineration	Digestion
Plant capacity and initial investment			
Plant capacity[tons/day]	1200	1200	600
Initial investment [$]	18,000,000.00	110,000,000.00	90,000,000.00
Electricitygenerated			
potential Eele [GWh/year]	18.62	200	23
Profitability			
NPV [$]	1,341,944.52	21,553,186.41	19,352,715.81
LCOE[$/kWh] Only investment	0.0947	0.0796	0.4311
LCOE[$/kWh] Investment + O&M	0.1027	0.1612	0.7528
IRR [%]	11%	10%	12%
SPB [year]	7	8	15

In 2018 a feasibility study in waste to energy possibilities for the West Bank, Palestine was conducted by Mr. Hans Breukelman, evaluating the ability and costs of electricity from gas at the Zahrat al Finjan landfill place in Jenin. The report is complete and covers all relevant sides of the chances on this site. (Bank, 2018)So, based on this feasibility and the data provided by Engineer Muhammad Al-Saadi, who is responsible for the landfill, the values of the Initial Investment and the Operational Cost were provided and used in the equations to obtain the rest of the economic values shown in table 6.

Landfill is the most basic waste management method, where waste is disposed of in designated areas. The initial investment cost for a landfill is $18,000,000.00, which is the lowest among the three methods. Landfills produce electricity by capturing and using the methane gas generated from the decomposition of organic materials. The potential electricity which gets generated from the landfill is around 18.62 GWh/year. Also, it is important to note that landfill sites have restricted capacity and will increase environmental problems like emissions of methane and contamination of the water in the ground. Nonetheless, incineration process is a waste treatment that includes burning waste at intensive heat. It is a more improved technique compared to landfill. The capital cost for incineration is clearly bigger at $110,000,000.00. Waste incineration plants commonly employ the heat that formed from burning rubbish to create steam, which leads turbines to produce power. incineration offers a superior capacity for electricity production of up to 200 GWh/year. It is a successful way to minimize waste and recover energy, even though it can also increase environmental challenges such as atmospheric pollution and the release of toxic gases.

Digestion, additionally known as anaerobic digestion, is a biological method that breaks down organic materials without oxygen, making biogas (methane and carbon dioxide). The initial capital cost for this process is $90,000,000.00. Biogas can be utilized to generate electricity by combustion or transformed into biomethane for insertion into the natural gas grid. The electricity generation potential of this method is about 23 GWh/year which is low compared to incineration but is higher than landfill. It provides additional advantages such as forming nutrient-rich digestate that can be used as fertilizer and lowering greenhouse gas flows.

In addition to initial investment and potential power generation, additional parameters such as net present value (NPV), levelized cost of electricity (LCOE), internal rate of return (IRR), and simple payback period (SPP) are analyzed in this study. This study's findings will help fill in some of the blanks regarding the cost-effectiveness and impact on the environment of waste-to-energy technologies.

- **Net Present Value (NPV)**

The NPV metric provides insights into the economic profitability of the waste-to-energy methods. Incineration exhibits the highest NPV of $21,553,186.41, indicating its potential for generating substantial returns. Digestion follows closely with an NPV of $19,352,715.81, while landfill shows a more modest NPV of $1,341,944.52.

- **Levelized Cost of Electricity (LCOE)**

LCOE analysis considers both the investment-only and investment plus operation and maintenance costs. Landfill demonstrates the lowest LCOE, indicating its cost-effectiveness in electricity generation. Incineration's LCOE falls between landfill and digestion. However, digestion exhibits the highest LCOE due to its higher initial investment cost and relatively lower potential electricity generation.

- **Internal Rate of Return (IRR)**

IRR provides insights into the financial attractiveness of the waste-to-energy methods. Digestion shows the highest IRR at 12%, followed by landfill at 11%, and incineration at 10%. The higher IRR for digestion suggests its potential for generating superior returns on investment.

- **Simple Payback Period (SPP)**

Landfill presents the shortest SPP at 7 years, followed by incineration at 8 years, and digestion at 15 years. The shorter SPP for landfill indicates a quicker recovery of the initial investment, enhancing its economic feasibility.

3.4 SWOT Analysis for Incineration, Landfilling, and Anaerobic Digestion

The steps for conducting a SWOT analysis to compare landfill, incineration, and anaerobic digestion as methods for energy production are outlined. A SWOT analysis is a model by which the strengths, weaknesses, opportunities, and threats related to each option can be evaluated. The strengths and weaknesses which are internal factors are defined for each process, considering elements such as efficiency, ecological consequences, cost, and expandability. Next, the opportunities and threats which are external factors presented by each approach, such as government systems, technological developments, market requirements, and acceptance of society, are explored. Related information was gathered through a literature review and interviews to confirm the analysis. The information is then analyzed, and the identified agents are classified into appropriate SWOT classes. The SWOT model of each technique is compared, and the main outcomes and consequences are outlined. Accordingly, a complete understanding of the various power generation methods can be realized, enabling for adequate conclusions and recommendations to be made in the thesis.

3.4.1 SWOT Analysis for incineration

Table 7

SWOT analysis for the incineration method

Internal factors	External factors
Strength	Opportunities
• S1: lowering the waste in the landfill. • S2: producing renewable energy. • S3: create work and motivate economic growth in the local region. • S4: effective waste management system.	• O1: Development of Advanced Technologies. • O2: Integration with Renewable Energy Sources. • O3: Expansion of Waste-to-Energy Programs. • O4: Public informing and Acceptance. • O5: generate steam for industrial processes.
Weaknesses	Threats
• W1: Air pollution. • W2: incineration is at the bottom of waste reduction hierarchy. • W3: High initial investment and operating costs. • W4: Social and environmental justice concerns. • W5:Limited Applicability. • W6:High water consumption. • W7:Absorption of generated electricity by the grid.	• T1: disagreement of environmental agencies. • T2: competitiveness with recycling. • T3: Social and environmental justice concerns. • T4: Political situation.

Transformation of waste to energy by incineration method can have many essential advantages for Palestine. this includes:

S1:Incineration method could be a main support to avoid landfills from being overfilled by lowering the quantity of waste created.By converting garbage into electricity, incineration technology helps landfills last longer and cuts down on the need for additional disposal sites.

S2: The incineration method could generate renewable energy in the form of both electricity and heat. This might be very helpful for Palestine, which now imports a lot of fossil fuels to meet its energy needs. Adopting garbage incineration methods to generate electricity could help Palestine become more energy independent.

S3:Jobs and economic growth are two benefits that can result from incineration. Developing new commercial and employment opportunities: The incineration technology can create new jobs and cash for waste management and energy businesses. Palestine's high unemployment rate and struggling economy make this a pressing problem. Palestine can improve its economy, reduce its waste, and reduce its energy use all at once by investing in incineration technology.

S4: Efficient waste management system: Palestine has an effective waste management system that collects, transports, and disposes of garbage quickly and effectively. Since waste-to-energy incineration must constantly burn through waste to produce energy, this efficiency is crucial. Implementing waste-to-energy incineration is facilitated by a well-oiled waste management system. As a result, incineration plants can count on a steady stream of waste to burn, increasing their efficiency and the amount of energy they can produce.

Weaknesses

Converting waste to energy through incineration technology can provide many potential benefits for Palestine, however, there are also several weaknesses and potential concerns associated with this approach. Some of these weaknesses and concerns include:

W1: Air pollution: Components of particulate matter, nitrogen oxides, and Sulphur dioxide, are among the air pollutants that can result from incineration procedures. There is a possibility that these contaminants are putting locals at risk for respiratory disorders, cardiovascular diseases, and cancer. This is a particularly pressing issue in the Palestinian area due to the high population density and the proximity of many Palestinian settlements near potential incineration sites.

W2: In the hierarchy for the reduction of waste, the recovery of energy through incineration is the very last option, coming after the more environmentally friendly practices of reducing, reusing, and recycling. If the development of incinerator technology is favored, there is a risk that other waste management technologies that are more environmentally friendly may be ignored.

W3: Costs both upfront and ongoing might be high, as building incineration equipment and keeping it up to date can be an expensive endeavor. Because of this, Palestine, which has few financial resources, may have difficulties financing and maintaining such technology over the long run, which can provide a challenge for the country.

W4:Issues of social and ecological justice: there are social and environmental justice concerns because low-income and disadvantaged individuals tend to live near incineration facilities. Because of this, there is a greater chance that incineration technology will exacerbate existing social and ecological disparities in Palestine.

W5:Limited Applicability: Incineration may not be suitable for all types of waste, such as hazardous waste, which requires specialized treatment.

W6:Incineration practices frequently require quantities of water for a number of functions, involving ash controlling and emissions instruction.

W7: The electrical grid takes a restricted capability for both absorption and distribution of electricity. A significant quantity of electricity produced by a waste-to-energy plant might surpass the capacity of the power grid, leading to in grid instability.

Opportunities

O1:progress of improved Technologies:investment in research and development will lead to the development of incineration technologies that are more effective and environmentally friendly.

O2:Integration with RE Sources: There is an opportunity to incorporate incineration with renewable energy sources like solar and wind power to produce a sustainable and reliable energy system.

O3:Expansion of Waste-to-Energy Programs: There is an opportunity to extend waste-to-energy programs globally, especially in developing countries where waste management is a major problem.

O4:Public informing and Acceptance: it is possible to educate the public about the benefits of incineration as a waste management method. This can increase approval and help for the advancement of waste-to-energy systems.

O5: Incineration can also be employed to produce steam for industrial processes, such as cement and paper production, providing additional profits.

Threats

The conversion of waste to energy through incineration technology in Palestine also poses several threats and challenges, including:

T1: Opposition of environmental groups: Environmentalists are likely to oppose incineration as a waste disposal method due to the potential for toxic substances to be discharged into the air and water. Some may argue that the risks to health of people and the nature posed by incineration are very great for justifying the process.

T2: Competition with recycling: Financial incentives for recycling and other forms of trash reduction may be weakened by incineration technology. It can impede efforts to create a more sustainable circular economy.

T3: Social and environmental justice concerns: When incinerators are in already complainant neighborhoods, that can make ecological, social and economic issues much terrible.

T4: Political situation: The politicalcircumstance in Palestine is complicated, which may lead to difficulty to implement incineration as a process of waste disposal and management. The PA is trying to reduce the garbage condition in the West Bank, which has contributed to an increased accumulation of waste and an absence of proper disposal facilities.

3.4.2 SWOT Analysis for the Landfilling Method

Table 8

SWOT Analysis for the Landfilling Method

Internal factors	External factors
Strength	Opportunities
• S1: easy and cost-effective method. • S2: Reducing the amount of waste. • S3: Generating renewable energy. • S4:Reduced Methane Emissions. • S5: Can be used to safely contain and isolate hazardous materials. • S6: Enhancing energy security.	• O1: Increasing demand for renewable energy. • O2: Government incentives and funding for sustainable energy projects. • O3: Development of new technologies to improve energy production efficiency. • O4: Diversifying the energy mix. • O5: Investment in Landfill Gas Collection Infrastructure • O6: Creating local jobs.
Weaknesses	Threats
• W1: Environmental impacts. • W2: Limited efficiency. • W3: Limited lifespan. • W4: Limited waste reduction.	• T1: Competition from other renewable energy sources • T2: Health risks. • T3: Environmental pollution. • T4: Social and political opposition. • T5: Limited waste reduction. • T6: weather Change. • T7: Availability of land

S1: Landfilling is a relatively simple and cost-effective method of waste disposal.Contrasting it with other waste disposal methods such as incineration or digestion, landfilling needs lower infrastructure and technical complexity.

S2: Reducing the amount of waste: Landfilling waste for energy can decrease the volume of waste in landfills, which can help expand the lifespan of existing landfill sites.

S3: Generating renewable energy: Landfill gas is made when waste breaks down, and it can be gathered and utilized to create electricity or heat. This can supply us with a source of energy that doesn't come from fossil fuels.

S4: Decrease Methane Emissions: Landfills can reduce CH_4 emissions bycatching and using landfill gas. Methane is a powerful greenhouse gas, due to this capturing and using the landfill gas can help reduce the environmental effect of waste management.

S5: Can be utilized to safely isolate hazardous materials. Hazardous waste needs treatment and disposal ways to make sure that it does not raise adanger to individual health and the environment. Landfills that receive hazardous materialsshould conform with aggressive rules and safety considerations to avoid hazardous materials from escaping into the external environment.

S6: Enhancing energy security: The utilization of landfills as a source of energy can provide improved energy security through raising the diversity of usable energy sources and declining dependence on energy that is imported.

Weaknesses

W1: Environmental impacts: Landfillsmay lead critical damage to the natural system anywhere near them because of many factors such as leakage of waste into water sources,atmospheric pollution, and greenhouse gas emissions. In locations like Palestine, where landfill area is at a premium, theseoutcomes are probably to be magnified.

W2: Limited efficiency:unluckily, landfill gas catching technique is still not perfect, so few of the methane and other gases may still be dismissed. Also, elements such as moisture content and temperature can significantly influence the total amount of gas generated by a landfill.

W3: Limited lifespan: To avoid environmental pollution, landfills need to be closed and controlled long after they havereached their intended target. There might be future expenses and obligations as a result.

W4: Limited waste reduction: The usage of waste in landfills as fuel has noconsiderable effect on waste output. This demonstrates that even with recycling and composting, extra waste managementscales may be needed to reduce waste generation.

Opportunities

O1: Increasing the need for renewable energy.

O2: Government motivations andfinancial support for sustainable energy projects.

O3: Development of new technologies to improve energy efficiency.

O4: Diversifying the energy mix: The utilization of landfill gas, which is ashape of RE, could be an efficient method to improvecurrent energy sources in PA and contributing to the country's activities to diversify its energy mix.

O5:Investment in Landfill Gas Collection facilities:There is an opportunity to invest in facilities to capture and use landfill gas for energy generation. This can support torise the quantity of energy produced from landfill gas anddecrease greenhouse gas emissions.

O6: Creating local jobs: Using waste as an energy source will create many new job opportunities in fields such as waste management, power production, and maintenance.

Threats

T1:competitiveness from other renewable energy sources.

T2: Environmental pollution: The pollution of soil and groundwater, air pollution, and greenhouse gases emissions are among the potential negative consequences that landfills have on the surrounding systems.

T3: Health risks: Landfills can produce odors which can put the people living nearby at risk of increasing health issues. In addition, gas from landfills could be explosive and presents a possible risk to social safety.

T4: Social and political opposition: because of the opposition, land use problems, and political agents, finding asuitable location for a landfill can be complicated. This can make it challenging toplace adequate landfills for waste-to-energy transformation in Palestine.

T5: Limited waste reduction: the usage of landfill waste for electricity does not reduce waste production. This shows that more waste management estimates, such as recycling and composting, may be required tominimize total waste generation.

T6: weather Change: Climate change can be a threat to the efficacy of landfill gas capture and utilization as an energy productionapproach, as changes in temperature could influence the rate and structure of landfill gas production.

3.4.3 SWOT analysis for the anaerobic digestion method

Table 9

SWOT analysis for the anaerobic digestion method

Internal factors	External factors
Strength	Opportunities
• S1: Renewable Energy Source. • S2: Waste Management Solution • S3: Potential for Local Energy Production • S4: Economic Opportunities	• O1: Environmental benefits. • O2: Community Engagement. • O3: Energy Security and Diversification. • O4: Policy Support. • O5: Agricultural Sector Integration.
Weaknesses	Threats
• W1: Land Constraints. • W2:Infrastructure Requirements. • W3:Feedstock Availability. • W4:Waste Segregation.	• T1: Technological and Operational Risks. • T2:Market Factors. • T3: Public perception: Concerns about odor, insects, and other potential consequences. • T4: Alternative waste management technologies, such as recycling and incineration, may become more prevalent and cost-effective, reducing the market for composting services. • T5: Difficulties in separating and handling certain types of waste.

Strengths

S1: Renewable Energy Source: Biogas can be produced from organic materials, such ascrop scrap, animal, and food waste, through anaerobic digestion, which is a form of RE technique. It provides an energy choice that is sustainable and environmentally friendly.

S2: Waste Management Solution: Converting organic waste into useful energy by AD helps address matters that emerge with waste management. This, in turn, lower the adverse effects of waste disposal on the surrounding environment.

S3: Potential for Local Energy Production: Anaerobic digestion makes it feasible to create energynationally, which lowers our reliance on energy sources that come from external sources.

S4: Economic Opportunities: Both construction and maintenance of anaerobic digestion plans have the possibility to create jobs.Moreover, there is an opportunity to produce additional income streams by selling by-products such as biogas or organic fertilizers.

Weaknesses

W1:Land Constraints: The exploration for practical sites for AD facilities in densely populated areas of Palestine may be difficult by the scarcity of available land. municipalities regulations, community disagreement, and land use arguments may confound location selection.

W2: Infrastructure Requirements: AD facilities require professional infrastructure, including digesters, storage containers, and gas utilization systems. In order to install the basic infrastructure, it may be essential to make initial investments and to have expertise that is not easily accessible.

W3: Feedstock Availability: There is aprobability that theefficiency and dependability of the process can be negatively affected if the accessibility and uniformity of the organic materials feedstock for AD changes. It can becomplicated to maintain a stable and reliable supply of raw materials.

W4:Waste Segregation.

Opportunities

O1: Environmental benefits: The application of anaerobic digestion canactivate local economicadvancement. It can provide job opportunities in the construction, operation and maintenance of biogas facilities.Additionally, the generated biogas can be utilized for on-site power generation or sold to the grid, giving potential revenue.

O2: Community Engagement:Promoting anaerobic digestion projects can include public participation andcollaboration.Inviting local farmers, waste managementinstitutions, and relevant parties can encourage a sense of property and construct partnerships tohandle waste management and energy challengestogether.

O3: Energy Security and Diversification: investment in AD cancontribute to energy security and variation by reducingreliance on imported fossil.

O4: Policy Support: Government regulations and motivations that advance RE and waste management could provide an enabling environment for AD projects. Supportive regulations and financial incentives can support investment and enable projectgrowth.

O5: Agricultural Sector Integration: The agricultural field in Palestine generate a large quantity of organic rubbish that can be utilized for AD. The integration of AD systems with agricultural actions can give farmers extra revenue and enhance their sustainableexercises.

Threats

T1: Technological and Operational Risks: for the purpose of having a smooth and reliable operation, AD systems need a high degree of technological skills and right management. Both the performance and viability of initiatives can be negatively affected by inefficient operational methods or technical issues.

T2: Market Factors:There is a possibility that Palestine does not have a developed market for biogas or organic fertilizers that are produced through anaerobic digestion. The economic viability of projects may be affected in some way by the demand for these items in addition to the prices set for them.

T3: Public perception:Concerns about smell, insects, and other potential consequences.

T4: substitute waste management techniques, like recycling and incineration, might become more general and cost-effective, lowering the market for composting services.

T5: Difficulties in separating and treating specific types of waste: A key requirement for effective AD is a uniform and homogeneousstarting material. In practice, waste streams in Palestine contain various materials, like plastics, metals, and non-biodegradable materials, which are hard to separate from organic waste.This can create difficulties regarding waste sorting and pre-processing, as well as influencing performance of AD systems.

3.4.4 Strategies according to SWOT analysis

Landfilling

1. Investing in landfill gas recovery systems in order to catch and use CH_4 emissions.
2. Develop waste sorting and recycling processes to minimize the amount of waste entering landfills.
3. Conduct modern landfill management technologies to decrease environmental impacts.

Incineration

1. Invest in developed incineration technologies to enhance energy efficiency and reduce emissions.
2. Develop integrated waste-to-energy systems, such as combined heat and power (CHP) plants, to maximize energy recovery.
3. Join in transparent communication with the public and stakeholders to address problems and ensure compliance with emissions standards.

Anaerobic Digestion

1. Encourage awareness and provide training courses to develop technical expertise in AD implementation and operation.
2. Set up a partnership with the agricultural and food sectors to ensure a reliable supply of organic waste feedstock.
3. Advocate for supportive policies and financial incentives to enhance the financial viability of AD projects.

In the discussion section, the results of the SWOT analysis conducted to compare landfill, incineration, and AD as methods for energy production are presented. The analysis revealed distinct strengths associated with each approach. Landfilling demonstrated the advantage of established infrastructure and waste disposal capacity, while incineration showcased its ability to generate electricity consistently and efficiently. AD, on the other hand, exhibited strengths in terms of organic waste diversion, soil enrichment, and greenhouse gas emissions reduction.

However, weaknesses were also identified. Landfilling posed challenges in terms of limited landfill space, potential groundwater contamination, and the release of methane, a potent greenhouse gas. Incineration raised concerns regarding air pollution and the disposal of incineration ash. AD, although environmentally friendly, was found to have limitations in terms of scale and energy generation potential.

Opportunities emerged from the analysis, indicating favorable conditions for each method. Landfilling could benefit from advanced landfill gas capture and utilization technologies, plus the combination of RE systems on-site. Incineration could explore advancements in emission control technologies and the utilization of waste heat for district heating. AD could tap into the growing demand for organic products and explore innovative methods for energy recovery from anaerobic digestion processes.

Threats identified during the analysis included tightening environmental regulations, public concerns about air pollution and waste management practices, and the economic viability of each method. It is crucial to address these threats through continuous research and development, public engagement, and the adoption of sustainable waste management practices.

The results of this SWOT analysis provide a complete understanding of landfilling, incineration, and AD as methods of energy generation. Based on the strengths, weaknesses, opportunities, and threats that have been indicated, there is no single method that can be examined as a universal solution. Alternatively, a collaboration of these methods, tailored to the waste composition,country situation, and available resources, might give the most sustainable and efficienttechnique. Additional research and technological progresses are essential to maximize the strengths and mitigate the weaknesses of each method, while addressing the evolving environmental and societal difficulties of waste-to-energy.

Chapter Four

Conclusion and Recommendation

This study has presented a complete analysis of waste-to-energy techniques in Palestine, concentrating on landfill, incineration, and anaerobic digestion. The study included both environmental and economic assessments, along with a SWOT analysis for every method. By inspecting these portions, significant understandings have been gained, supplying a base for advancing a managerial framework for waste-to-energy in Palestine, particularly in the case of Zahrat Al-Finjan landfill. Waste is positioned in landfills, the simplest form of waste management. Of the three options, the landfill has the least initial investment cost, at about $18,000,000.00. By gathering and burning the methane gas released through the breakdown of organic waste, landfills can become a source of renewable energy.

Landfills can produce 18.62 GWh of power every year. The capacity of landfills is limited, and there are environmental consequences associated with them, such as methane emissions and groundwater contamination. Incineration, on the other hand, is an approach of waste dealing that requires the controlled combustion of waste at very high temperatures. Contrasting landfills, this technique is advanced. The incinerator startup costs are much greater, at $110,000.00,000.00. Generally, the steam formed by the incineration process is utilized to power turbines and produce electricity. The possibility for electricity generation by incineration is around 200 GWh annually. Although this technique is useful for recycling and reusing energy, it has the possibility to cause contamination and destructive emissions.

Anaerobic digestion, or digestion, is a biological process that decomposes organic waste materials without the usage of oxygen. This process has consequences in the production of biogas (methane and carbon dioxide).Digestive system setup and maintenance would require an investment of around $90,000,000. It is viable to transform biogas into biomethane and then inject it into the natural gas grid, or it can be burned to produce power. In comparison to incineration and landfill, digestion's potential electricity generation is 23 GWh/year. In addition to lowering GHG emissions, it also generates nutrient-rich digestate that can be utilized as fertilizer.

The SWOT analysis has offered a full insight of the strengths, weaknesses, opportunities, and threats correlated with each WtE practice. These insights are necessary for decision-makers to improve effective strategies and mitigate possible challenges.According to this analysis, strategies can be created for each waste management method. For landfilling, spending in landfill gas recovery techniques and improving waste sorting and recycling systems are suggested. Additionally, applying advanced landfill management practices can minimize environmental effects. For incineration, investment in developed technologies, advancing waste-to-energy systems, and keeping transparent communication with society are critical. As for AD, reinforcement awareness, building partnerships for organic waste resource, and advocating for supportive policies and economic incentives are key strategies. Based on the result, a managerial framework for `waste-to-energy in Palestine can be advanced. This frame must consider the specific condition of Zahrat Al-Finjan landfill and contain factors such as environmental effects, economic feasibility, community approval, and policyindications. It should target to enhance energy generation, minimize environmental impacts, and confirm economic sustainability.

The findings emphasize the importance of studying both environmental and economic aspects when creating decisions regarding waste management and energy production. By integrating the proposed managerial framework, policymakers, and waste management consultants can work on sustainable waste management procedures and advance the move to a greener and more energy-efficient future in Palestine. Considering Palestine's unique condition, WTE facilities appear as a favorable solution for electricity production. WTE facilities successfully merge waste reduction with energy recovery, proposing lowered greenhouse gas emissions. While WTE facilities involve higher initial capital costs, they show potential long-term economic profits by the sale of electricity created from waste.

Recommendations for Palestine include

1. Conducting feasibility studies to assess the suitability and viability of WTE facilities in different regions of Palestine, considering waste composition, population density, and energy demands.
2. Collaborating with international partners and organizations to access financial support and expertise in implementing WTE technologies tailored to Palestine's specific waste management needs.
3. Developing comprehensive waste management policies and regulations that promote the adoption of environmentally friendly methods like composting and WTE facilities while discouraging landfilling and incineration without proper emission controls.
4. Investing in public awareness campaigns and educational initiatives to promote waste reduction, segregation, and the importance of sustainable waste management practices among citizens, businesses, and local communities.

List of Abbreviations

Abbreviation	Meaning
AD	Anaerobic Digestion
CHP	Combined Heat and Power
EPA	Environmental Protection Agency
En	Energy content
EQA	Environment Quality Authority
GHG	Greenhouse gases
GW	Gega Watt
IRR	Internal Rate of Return
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Corporation Agency
JSC	Joint Service Council
Kg	Kilogram
kWh	Kilo Watt Hour
LCA	Life Cycle Assessment
LFG	Landfill Gas
LFGtE	Landfill gas to energy
LCOE	Levelized cost of electricity
MARR	Minimum Attractive Rate of Return
MJ	Mega Joule
MOLG	Ministry of Local Governance
MSW	Municipal Solid Waste
NPV	Net Present Value
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics
PENRA	Palestinian Energy and Natural Resources Authority
PETL	Palestinian Electricity Transmission Ltd.
RDF	rejected derived fuel
RES	Renewable Energy Sources
Rev	revenues

Abbreviation	Meaning
SPP	Simple Payback Period
SWOT	Strength, weaknesses, opportunities, and threats.
SW	Solid Waste
VOCs	volatile organic compounds
UNRWA	United Nations Relief and Works Agency

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Appendices

Appendix A

Landfill Gas Extraction _ FI

Yeas	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Received tonnage of waste (tons /yr)	-	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00
production of MW (MWh /yr)	-	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00	18,615.00
Annual Energy Revenue ($)	-	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50	1,986,220.50
Gatefee revenues ($)		201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00	201,000.00
Inflows																
Total Inflows ($)	-	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50	2,187,220.50
Out Flows																
Investment Cost ($)	4,000,000.00	3,000,000.00	3,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00		-	-	-	-
Total Operating Expenditures ($)	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00
Net CashFlow before Financing ($)	(4,300,000.00)	(1,112,779.50)	(1,112,779.50)	887,220.50	887,220.50	887,220.50	887,220.50	887,220.50	887,220.50	887,220.50	887,220.50	1,887,220.50	1,887,220.50	1,887,220.50	1,887,220.50	1,887,220.50
Cum ,operating /investments of ($)	(4,300,000.00)	(5,412,779.50)	(2,225,559.00)	(225,559.00)	1,774,441.00	1,774,441.00	1,774,441.00	1,774,441.00	1,774,441.00	1,774,441.00	1,774,441.00	2,774,441.00	3,774,441.00	3,774,441.00	3,774,441.00	3,774,441.00
Financial cashflow ($)	3,680,000.00	1,840,000.00	1,080,000.00	(680,000.00)	(680,000.00)	(680,000.00)	240,000.00	160,000.00	160,000.00	160,000.00	160,000.00	(760,000.00)	(760,000.00)	(1,680,000.00)	160,000.00	-
Net Cash Flow after Financing ($)	(620,000.00)	727,220.50	(32,779.50)	207,220.50	207,220.50	207,220.50	1,127,220.50	1,047,220.50	1,047,220.50	1,047,220.50	1,047,220.50	1,127,220.50	1,127,220.50	207,220.50	2,047,220.50	1,887,220.50
Cumulative total cashflow ($)	(620,000.00)	107,220.50	374,441.00	(465,559.00)	(385,559.00)	(305,559.00)	694,441.00	1,614,441.00	1,614,441.00	1,614,441.00	1,614,441.00	1,694,441.00	1,774,441.00	934,441.00	1,934,441.00	3,774,441.00
NPV ($)	(620,000.00)	673,352.31	(28,103.14)	164,498.31	152,313.25	141,030.79	710,340.12	611,043.10	565,780.65	523,870.97	485,065.72	483,445.55	447,634.77	76,194.55	696,998.82	594,930.61
Loan for investments ($)	4,000,000.00	3,000,000.00	3,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	-	-	-	-	-
Other Loans ($)		1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00			
Total loans ($)	4,000,000.00	4,000,000.00	4,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	1,000,000.00	1,000,000.00	-	-	-
loan investments repayments ($)	-	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	2,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00		
loan Other repayments ($)		-	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00		
Total Loan Payment ($)		(2,000,000.00)	(3,000,000.00)	(3,000,000.00)	(3,000,000.00)	(3,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	-	-
Remaining loan ($)	4,000,000.00	2,000,000.00	(1,000,000.00)	(4,000,000.00)	(4,000,000.00)	(4,000,000.00)	(3,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(2,000,000.00)	(3,000,000.00)	(3,000,000.00)	(4,000,000.00)	(2,000,000.00)	
interest (8%)	(320,000.00)	(160,000.00)	80,000.00	320,000.00	320,000.00	320,000.00	240,000.00	160,000.00	160,000.00	160,000.00	160,000.00	240,000.00	240,000.00	320,000.00	160,000.00	-

Appendix B

Equations for landfill technology

The following section describes the selected equations that are used to calculate the parameters described above:

- Correction Factor for Methane (MCF).

Provides the potential amount of methane gas produced by decomposing one metric ton (Mg) of garbage. Almost everything is conditional on the nature of the garbage at hand. While sites in extremely arid regions may never produce all the methane, they're capable of, L0 is generally accepted to be independent of moisture above a certain threshold. Finding L0 also affects annual landfill gas emissions, which are calculated by Rafew & Rafizul (2023), because different waste compositions require different sets of parameters.

Default MCF values for site conditions factor.

Landfill type	MCF value
Managed sites	1
Unmanaged, deep sites (≥5m)	0.8
Unmanaged, shallow sites (<5m)	0.4
Unspecified SWDS – default value	0.6

- Degradable Organic Carbon (DOC).

The DOC content is expressed by equation (4) and is essential in the calculation of the methane generation, which depends on the composition of the waste and varies from city to city (Thompson, S., Sawyer, J., Bonam, R., & Valdivia, J. E., 2009).

$$DOC = 0.40(A) + 0.17(B) + 0.15(C) + 0.30(D)$$

Where default values for DOC related to A, B, C, and D are presented in Table:

Default DOC values for major waste streams.

Waste stream	DOC (by weight) in wet SW
Paper and textiles [A]	40%
Garden and park waste, and other non-food waste [B]	17%
Food waste [C]	15%
Wood and straw waste [D]	30%

- Fraction of Degradable Organic Carbon assimilated (DOCf).

DOCf (fraction of degradable organic carbon that assimilated). This parameter is the portion of the DOC that is converted into biogas. The default value used by the IPCC 2006 Guidelines is 0.50 (Rafew & Rafizul, 2023). However, this factor can range from 0.42 to 0.98 at 10 C▪ or 50 C▪, respectively.

- Fraction of CH_4 in the biogas (f).

The fraction of methane in the gas is the volume fraction of produced methane. LFG in the main anaerobic phase contains a composition of mainly CH_4, CO_2, and many trace components, which pose less than 1% of volume. Usually, the 15 fractions of methane are assumed to be 50% from the produced biogas with 50% of the CO_2 fraction (Rafew & Rafizul, 2023).

Appendix C

Direct Incineration _ FI

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
received tonnage of waste tons /yr	-	-	-	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00
production of MW MWh /yr	-	-	-	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00
Annual Energy Revenue($)	-	-	-	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00
Inflows($)																
Total Inflows ($)	-	-	-	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00
Out Flows($)																
Investment Cost($)	50,000,000.00	50,000,000.00	10,000,000.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Operating Expenditures($)	3,000,000.00	3,000,000.00	3,000,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00
Net CashFlow before Financing($)	(53,000,000.00)	(53,000,000.00)	(13,000,000.00)	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00
Cum ,operating /investments of ($)	(53,000,000.00)	(106,000,000.00)	(119,000,000.00)	(102,680,000.00)	(86,360,000.00)	(70,040,000.00)	(53,720,000.00)	(37,400,000.00)	(21,080,000.00)	(4,760,000.00)	11,560,000.00	27,880,000.00	44,200,000.00	60,520,000.00	76,840,000.00	93,160,000.00
Financial cashflow ($)	60,000,000.00	50,400,000.00	18,000,000.00	(25,800,000.00)	(24,600,000.00)	(23,400,000.00)	(22,200,000.00)	(21,000,000.00)	(19,800,000.00)	(18,600,000.00)	(17,400,000.00)	(16,200,000.00)	(15,000,000.00)	-	-	-
Net Cash Flow after Financing($)	7,000,000.00	(2,600,000.00)	5,000,000.00	(9,480,000.00)	(8,280,000.00)	(7,080,000.00)	(5,880,000.00)	(4,680,000.00)	(3,480,000.00)	(2,280,000.00)	(1,080,000.00)	120,000.00	1,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00
Cumulative total cashflow	7,000,000.00	4,400,000.00	9,400,000.00	(80,000.00)	(8,360,000.00)	(15,440,000.00)	(21,320,000.00)	(26,000,000.00)	(29,480,000.00)	(31,760,000.00)	(32,840,000.00)	(32,720,000.00)	(31,400,000.00)	(15,080,000.00)	1,240,000.00	17,560,000.00
NPV($)	7,000,000.00	(2,407,407.41)	4,286,694.10	(7,525,529.64)	(6,086,047.18)	(4,818,529.03)	(3,705,397.41)	(2,730,735.05)	(1,880,135.72)	(1,140,567.65)	(500,248.97)	51,465.94	524,190.16	6,000,830.13	5,556,324.20	5,144,744.63
Loan for investments ($)	60,000,000.00	60,000,000.00	30,000,000.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Total loans ($)	60,000,000.00	60,000,000.00	30,000,000.00		-	-	-	-	-	-	-	-	-	-	-	-
loan repayments ($)	-	-	-	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00	15,000,000.00			-
Remaining loan ($)	60,000,000.00	120,000,000.00	150,000,000.00	135,000,000.00	120,000,000.00	105,000,000.00	90,000,000.00	75,000,000.00	60,000,000.00	45,000,000.00	30,000,000.00	15,000,000.00			-	-
interest (8%)	-	9,600,000.00	12,000,000.00	10,800,000.00	9,600,000.00	8,400,000.00	7,200,000.00	6,000,000.00	4,800,000.00	3,600,000.00	2,400,000.00	1,200,000.00			-	-
sum of costs ($)	53,000,000.00	53,000,000.00	13,000,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00
discounted cash out ($)	53,000,000.00	49,074,074.07	11,145,404.66	3,985,037.85	3,689,849.86	3,416,527.65	3,163,451.53	2,929,121.78	2,712,149.80	2,511,249.81	2,325,231.31	2,152,991.95	1,993,511.07	1,845,843.58	1,709,114.43	1,582,513.36

2040	2041	2042	2043	2044	2045
402,000.00	402,000.00	402,000.00	402,000.00	402,000.00	402,000.00
200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00
21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00
21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00	21,340,000.00
-	-	-	-	-	-
5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00
16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00
109,480,000.00	125,800,000.00	125,800,000.00	125,800,000.00	125,800,000.00	125,800,000.00
-	-	-	-	-	-
16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00	16,320,000.00
33,880,000.00	50,200,000.00	66,520,000.00	82,840,000.00	99,160,000.00	115,480,000.00
4,763,652.43	4,410,789.29	4,084,064.16	3,781,540.88	3,501,426.74	3,242,061.80
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00	5,020,000.00
1,465,290.15	1,356,750.14	1,256,250.13	1,163,194.56	1,077,032.00	997,251.85

Appendix D

Anaerobic Bio digestion _ FI

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Received tonnage of waste tons /yr	-	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00
/yr	-	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00
Annual Energy Revenue($)	-	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00
Gatefee revenues ($)		19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19000000.00	19000000.00	19000000.00	19000000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00
Inflows($)	23000000.00															
Total Inflows ($)	-	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21454100.00	21454100.00	21454100.00	21454100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00
Out Flows																
Investment Cost ($)	90,000,000.00			-	-	-	-	-	-	-	-	-	-	-	-	-
Total Operating Expenditures($)		9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00
Net CashFlow before Financing($)	-90000000.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12054100.00	12054100.00	12054100.00	12054100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00
Cum ,operating /investments of($)	-90000000.00	(77,945,900.00)	(65,891,800.00)	(53,837,700.00)	-41783600.00	-29729500.00	-17675400.00	(5,621,300.00)	6,432,800.00	18486900.00	30541000.00	42,595,100.00	54,649,200.00	66,703,300.00	78,757,400.00	90,811,500.00
Financial cashflow ($)	82,800,000.00	(4,440,000.00)	(5,784,000.00)	(7,032,000.00)	(8,184,000.00)	(9,240,000.00)	-22200000.00	-22104000.00	-20808000.00	-19512000.00	-18216000.00	(8,640,000.00)	(6,960,000.00)	(5,376,000.00)	(3,888,000.00)	(2,496,000.00)
Net Cash Flow after Financing($)	(7,200,000.00)	7,614,100.00	6,270,100.00	5,022,100.00	3,870,100.00	2,814,100.00	-10145900.00	-10049900.00	(8,753,900.00)	(7,457,900.00)	(6,161,900.00)	3,414,100.00	5,094,100.00	6,678,100.00	8,166,100.00	9,558,100.00
($)	(7,200,000.00)	414,100.00	6,684,200.00	11,706,300.00	15,576,400.00	18,390,500.00	8,244,600.00	(1,805,300.00)	(10,559,200.00)	(18,017,100.00)	(24,179,000.00)	(20,764,900.00)	(15,670,800.00)	(8,992,700.00)	(826,600.00)	8,731,500.00
NPV($)	(7,200,000.00)	7,050,092.59	5,375,600.14	3,986,704.90	2,844,639.03	1,915,229.17	(6,393,638.02)	(5,864,020.12)	(4,729,459.79)	(3,730,806.77)	(2,854,151.95)	1,464,248.97	2,022,937.20	2,455,523.51	2,780,238.91	3,013,111.74
Loan for investments ($)	90,000,000.00			-	-	-	-	-	-	-	-	-	-	-	-	-
Other Loans ($)		12,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00									
Total loans ($)	90,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00	12,000,000.00	-	-	-	-	-	-	-	-	-	-
repayments ($)	-	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00	9,000,000.00					
loan Other repayments ($)			1,200,000.00	2,400,000.00	3,600,000.00	4,800,000.00	6,000,000.00	7,200,000.00	7,200,000.00	7,200,000.00	7,200,000.00	7,200,000.00	6,000,000.00	4,800,000.00	3,600,000.00	2,400,000.00
Total Loan Payment($)		(9,000,000.00)	(10,200,000.00)	(11,400,000.00)	(12,600,000.00)	(13,800,000.00)	(15,000,000.00)	(16,200,000.00)	(16,200,000.00)	(16,200,000.00)	(16,200,000.00)	(7,200,000.00)	(6,000,000.00)	(4,800,000.00)	(3,600,000.00)	(2,400,000.00)
Remaining loan ($)	90,000,000.00	93,000,000.00	94,800,000.00	95,400,000.00	94,800,000.00	93,000,000.00	90,000,000.00	73,800,000.00	57,600,000.00	41,400,000.00	25,200,000.00	18,000,000.00	12,000,000.00	7,200,000.00	3,600,000.00	1,200,000.00
interest (8%)	(7,200,000.00)	(7,440,000.00)	(7,584,000.00)	(7,632,000.00)	(7,584,000.00)	(7,440,000.00)	(7,200,000.00)	(5,904,000.00)	(4,608,000.00)	(3,312,000.00)	(2,016,000.00)	(1,440,000.00)	(960,000.00)	(576,000.00)	(288,000.00)	(96,000.00)

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00	200,000.00
23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00	23,000.00
2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00	2,454,100.00
19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00	19,000,000.00
21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00	21,454,100.00
-	-	-	-	-	-	-	-	-	-
9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00	9,400,000.00
12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00
102,865,600.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00	114,919,700.00
(1,200,000.00)	-	-	-	-	-	-	-	-	-
10,854,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00	12,054,100.00
19,585,600.00	31,639,700.00	43,693,800.00	55,747,900.00	67,802,000.00	79,856,100.00	79,856,100.00	79,856,100.00	79,856,100.00	79,856,100.00
3,168,208.32	3,257,848.97	3,016,526.82	2,793,080.39	2,586,185.55	2,394,616.25	2,394,616.25	2,394,616.25	2,394,616.25	2,394,616.25
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
1,200,000.00									
(1,200,000.00)									
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Equations for landfill technology

The fraction of methane in the gas is the volume fraction of produced methane. LFG in the main anaerobic phase contains a composition of mainly CH_4, CO_2, and many trace components,

جامعة النّجاح الوطنيّة

كلية الدراسات العليا

تطويرإطار إداري لتحويل النفايات إلى طاقة في فلسطين: دراسة حالة لمكب زهرات الفنجان

إعداد

سارة فواز محمد حمزة

إشراف

د. محمد السيد

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قدمت هذه الرسالة استكمالاً لمتطلبات الحصول على درجة الماجستير في الإدارة الهندسية، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس – فلسطين.

2023

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الملخص

بسبب النمو السكاني العالمي وتحسين مستويات المعيشة، هناك دفعة لمصادر الطاقة المتجددة المتنوعة. أحد الخيارات هو استخدام النفايات لتوليد الطاقة. تعتمد الأراضي الفلسطينية المحتلة بشكل كبير على الكهرباء المستوردة، وتواجه مشاكل بسبب عدم كفاية إدارة النفايات ووفرة النفايات البلدية. تتناول هذه الدراسة الضفة الغربية، وتحديداً مكب زهرات الفنجان في جنين (سعة 88٪). ويهدف إلى تقييم الآثار البيئية والاقتصادية لطرق تحويل النفايات إلى طاقة، مع التركيز على دفن النفايات، والحرق، والهضم اللاهوائي. يخضع كل نهج لتحليل (SWOT) لتحديد نقاط القوة والضعف والفرص والتهديدات. تبدأ هذه الدراسة بتحليل أدبي شامل لإدارة النفايات واحتياجات الطاقة في فلسطين. ثم يفحص طرق تحويل النفايات إلى طاقة. تتم مقارنة مصاريف الاستثمار الأولية وتوليد الكهرباء المحتمل والآثار البيئية بين الأساليب الثلاثة. تم جمع البيانات من خلال سلسلة من المقابلات شبه المنظمة مع المشاركين الرئيسيين والمسؤولين العاملين في الهيئات الحكومية الفلسطينية ذات الصلة والمسؤولة عن الطاقة والبيئة وإدارة النفايات الصلبة البلدية. ومن بينها سلطة الطاقة والموارد الطبيعية، ومجلس الخدمات المشتركة، وسلطة جودة البيئة، ووزارة الحكم المحلي، والشركة العامة لتجارة الطاقة والخدمات اللوجستية.

يأخذ التحليل الاقتصادي في الاعتبار العوامل الرئيسية مثل الاستثمار الأولي، صافي القيمة الحالية، التكلفة المعيارية للكهرباء، معدل العائد الداخلي، وفترة الاسترداد البسيطة. يستخدم التحليل البيانات المقدمة لكل طريقة من طرق تحويل النفايات إلى طاقة لتقييم جدواها الاقتصادية. تظهر النتائج ضرورة

وجود إطار إداري لتحويل النفايات إلى طاقة في فلسطين. يقارن تحليل القيمة المعيارية للكهرباء تكاليف الاستثمار والتشغيل لأساليب توليد الكهرباء. المكب هو الأقل تكلفة يليه الحرق ثم الهضم. يعتبر مكب النفايات أكثر فعالية من حيث التكلفة بسبب انخفاض النفقات. تكاليف الهضم أكثر بسبب الاستثمار وانخفاض إمكانات الكهرباء. يوضح تحليل معدل العائد الداخلي أن الهضم لديه أعلى عائد محتمل، ثم طمر النفايات، والحرق بعائد أقل قليلاً. يصنف تحليل فترة الاسترداد المكب أولاً في وقت الاسترداد، ثم الحرق، والهضم أخيرًا، مما يشير إلى استرداد أسرع للتكلفة. تولد مدافن النفايات 18.62 جيجاوات ساعة من الكهرباء سنويًا ولكنها تواجه مشكلات مثل انبعاثات الميثان والمساحة المحدودة. يتضمن الحرق حرق النفايات بدرجة حرارة عالية، مما يوفر نهجًا حديثًا بتكاليف بدء تشغيل تبلغ 110 مليون دولار. ينتج 200 جيجاوات/ ساعة من الكهرباء السنوية عبر المحركات التي تعمل بالبخار. يعالج الهضم اللاهوائي النفايات العضوية بدون أكسجين، مما ينتج عنه غاز حيوي. تركيب وصيانة هذا النظام يكلف 90 مليون دولار. ينتج الهضم 23 جيجاوات / ساعة من الكهرباء، ويقلل من الانبعاثات، وينتج هضمًا غنيًا بالأسمدة.

الكلمات المفتاحية: الطمر، مكب زهرة الفنجان، القيمة الحالية الصافية، الحرق، تحويل النفايات إلى طاقة، تحليل SWOT، الهضم اللاهوائي.