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Comparison between Incineration and Landfill methods – Zahrit Al-Finjan Landfill

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Abstract

This project aims to study the whole process of Zahrit AL-Finjan landfill. Zahrit AL-Finjan landfill has been chosen in particular because of the large number of the received complaints about its bad conditions. It has a full capacity of wastes therefore; it was necessary to find an effective solution. The suggested solutions are two types of waste disposal methods which can be used in the landfill. The first solution is to apply the incineration process and the second one is to make a well-managed landfill to be a source of energy by burning methane. methane is being released with the emissions from landfills.

However, the economic and the environmental aspects are discussed in this study. Moreover, the calculations of incineration (economic calculations) have been done to get the results of the annual electrical energy production. The production is 271.2 GWh / year which costs $33.9 million annually and the value of Levelized Cost of Energy (LCOE) equals $ 0.13 / KWh. On the other hand, calculations of the landfill were also done to get the results of the annual electrical energy production. The production is 74.5 GWh / year which costs $3.8 million annually and the value of Levelized Cost of Energy (LCOE) equals $0.05 / KWh.

Environmentally, the amount of emissions released from the incineration have been calculated. The emissions of Nitrous oxide, Carbon dioxide and Methane were all calculated to get the total amount of CO_2 equivalent which is 856.48 Kg CO_2 eq / ton of waste, whereas, the amount of emissions released from the landfill have been calculated for carbon dioxide and methane to get the total amount of CO_2 equivalent which is 77.98 Kg CO_2 eq / ton of waste.

Chapter one:

Introduction

Solid Waste Management (SWM) is one of the major environmental hazards which the world is suffering from. In 2016, the world's cities generated 2.01 billion tons of solid waste. Waste generation per capita is 0.74 kilograms per day. With the rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tons in 2050. [1]

The major challenges on SWM are collection and disposal of waste. Waste collection process is affected by the per capita income rate in countries. Waste collection rates in high-income countries are near 100 %, In lower-middle-income countries, collection rates are about 51 %, and in low-income countries about 39 %.[1] Around the world, almost 40 percent of waste is disposed of in landfills, about 19 percent undergoes materials recovery through recycling and composting ,11 percent is treated through modern incineration and 33 percent of waste is still openly dumped.

At an international level, waste categories percentages are illustrated as shown in the figure bellow:

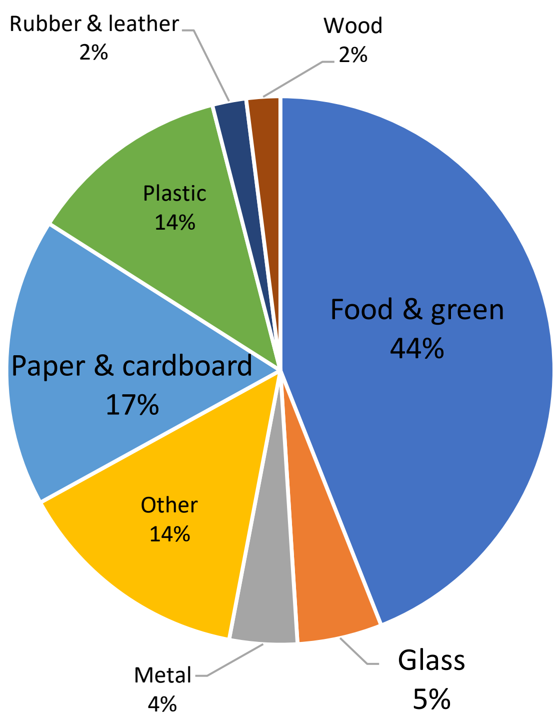

Figure 1: Global waste composition percent.[1]

There is no sufficient strategy in SWM in the undeveloped countries, which over 90% of waste is disposed in random dumps or openly burned which both ways will cause environmental hazards such as, pollution on the water, air and soil which will lead to health diseases, global climate change which contributes about 5% of global greenhouse gas emissions[1] and consequences on the renaissance of nations.

Duo to these hazards, people become aware of the importance of SWM, so municipals start to care about SWM processes, but these processes affect on municipal's budget (20-50%). In order to get the best results, municipal service requires integrated systems that are efficient, sustainable, and socially supported. [2, 3]

Municipal solid waste generation in the West Bank was increased sharply, as the waste generation rate is 2% per year[4], the total amount of solid waste will increase from 0.956 million tons in 2019 to 3.22 million tons in 2050 as shown in the figure below:

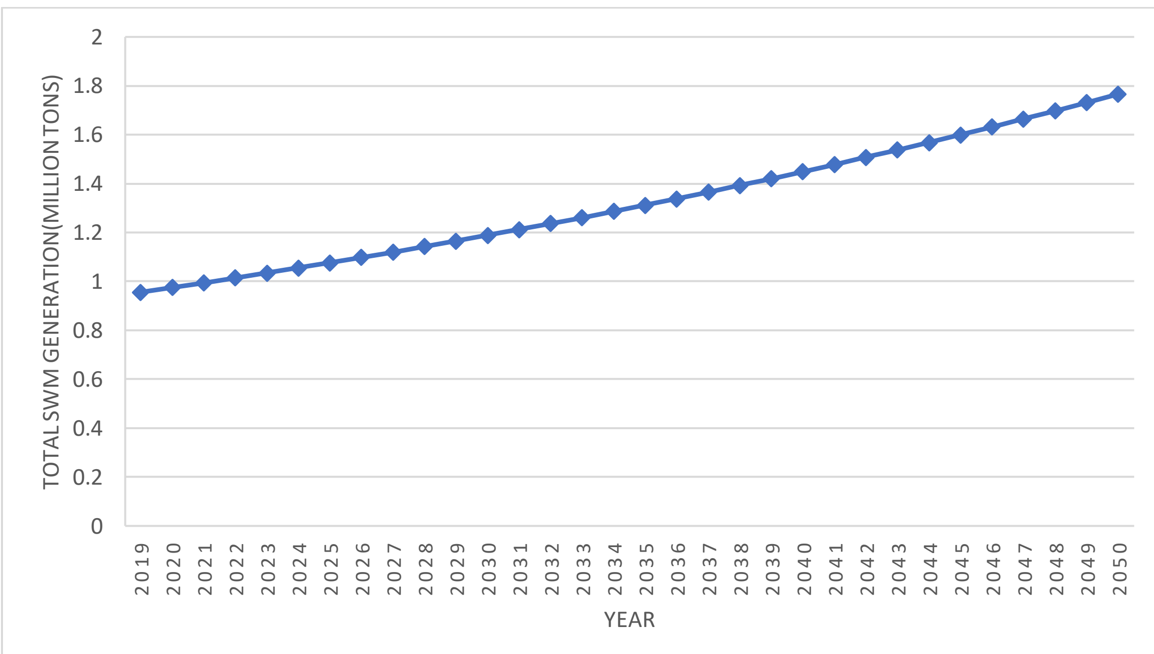

Figure 2:Municipal solid waste generation in West Bank.

Currently, SWM in Palestine is facing many challenges at different levels; legal, organizational, technical, and cultural levels, in addition to the complicated political situation resulting in limited access and control of Palestinian authorities and the poor public awareness on the importance of keeping the environment safe and clean. [5-7]

The major challenge on SWM is the political situation, SWM is suffering from the Israeli occupation terms and obstacles aimed to damage the Palestinian environment by imposing restrictions on the Palestinian institutions that are supposed to be the responsible of SWM since random dumpsites is under Israeli occupation control since it is in area C which is based on OSLO accords. OSLO accords divided the West Bank into three administrative divisions: Areas A, B and C. The distinct areas were given different statuses, according to their governance pending a final status accord: Area A is exclusively administered by the Palestinian Authority; Area B is administered by both the Palestinian Authority and the Israeli occupation; and Area C, which contains the Israeli occupation settlements, is administered by the Israeli occupation. So Palestinian institutions have no control on area C, that can cause a lot of environmental hazards such as pollution which can make the area unstable for living in.[8]

The map below shows OSLO accords and its divisions on the West Bank.

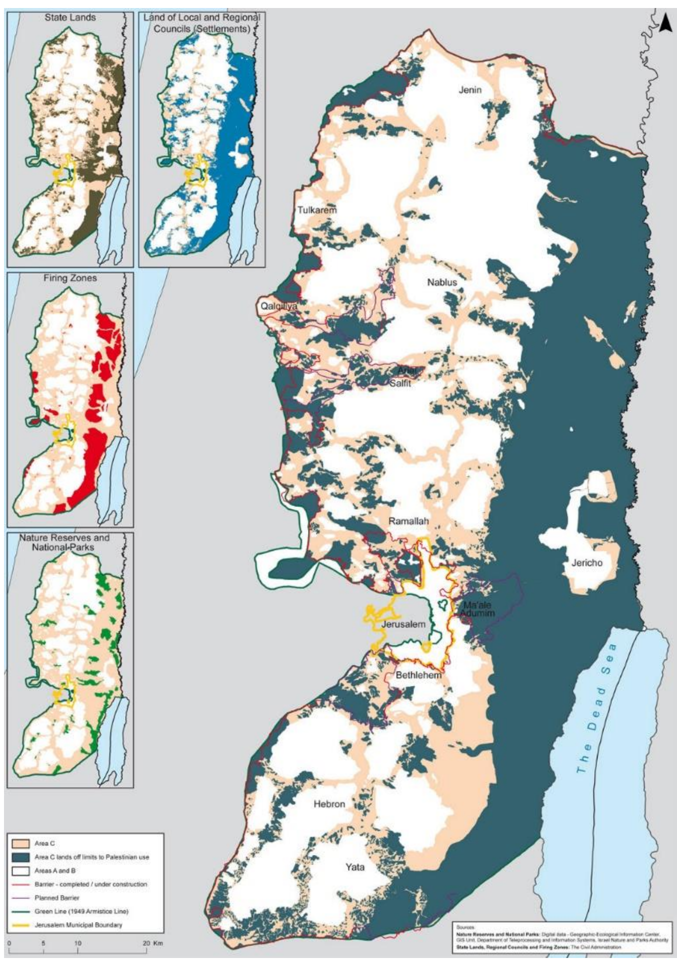

Figure 3:Palestine Map Based on OSOLO Accords. [9]

The West Bank has three main landfills distributed in three different areas to cover the whole area in the West Bank. The first landfill is called Al Menya, it is located in Hebron city, which serves the southern area of the West Bank. The second one is Jericho landfill which serves only Jericho city. The last one is Zahrit AL-Finjan it is located in Jenin, which serves the northern area of the West Bank. Waste is collected firstly from cities in specific areas called transfer station; to reduce the cost of transferring it to landfills, then it is transferred to the main landfills.[7]

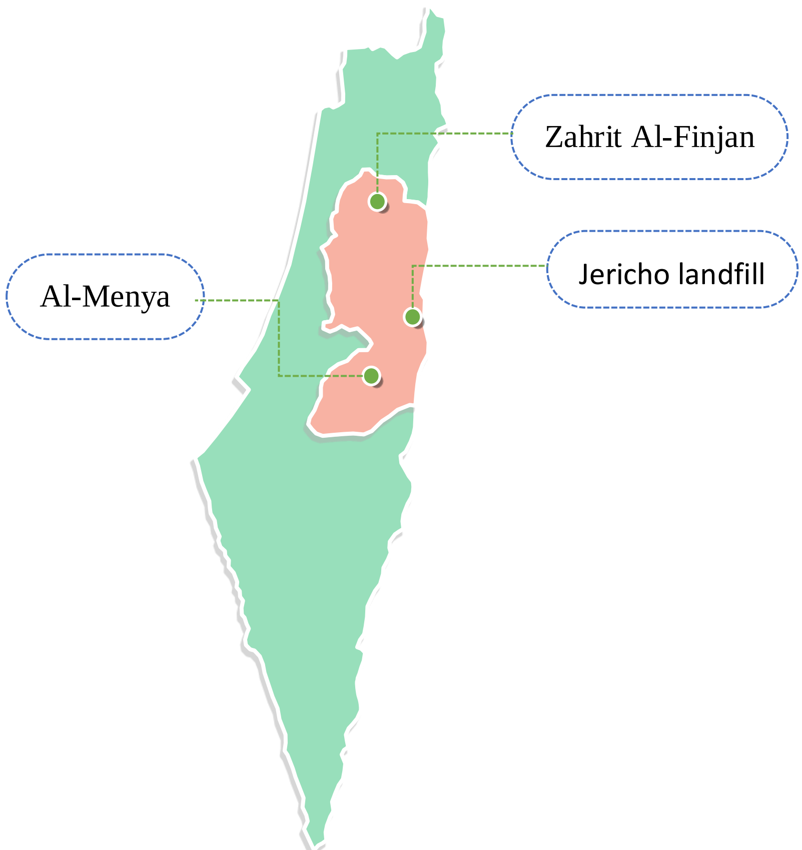

Figure 4: Locations of main Westbank landfills.

As we see above, Zahrit Al-Finjan landfill serves the northern area of the west bank and it’s the largest share of all landfills, the governorates that Zahrit Al-Finjan serves are illustrated in the table below:

Table 1: Governorates that Zahrit Al-Finjan serves[7].

Governorates	Transfer Station	Transferred Quantity (tons/day)	Transferring Distance (Km)	Total Cost (Nis/ton)	Cost Analysis (Nis/ton)
Jenin	-	290	-	-	-
Jenin JSC	Western Jenin	50	35	135	Collection: 75 Transfer: 30 Landfill fee: 30
Tubas JSC	Tubas	43	28	143	Collection: 95 Transfer: 17 Landfill fee: 30
Nablus Municipality	Al Sayrafi	180	40	140	Collection: 66 Transfer: 47 Landfill fee: 27
Tulkarem JSC	Tulkarem	132	30	165	Collection: 95 Transfer: 37 Landfill fee: 33
Qalqilya	Qalqilya	123	60	223	Collection:113 Transfer: 57 Landfill fee: 33
Ramallah Municipality	Ramallah	100	120	329	
Al Bireh Municipality	Al Bireh	100	80		
Jericho	Al Sayrafi	2.1	-	65	

There are 13 transfer stations in the West Bank. In the West Bank, municipal solid waste generation is estimated at 2622 tons/day (956030 tons/year), and the per capita generation rate is 0.91 kg/day[7]. Solid waste fractions in the West Bank illustrated in the figure below:

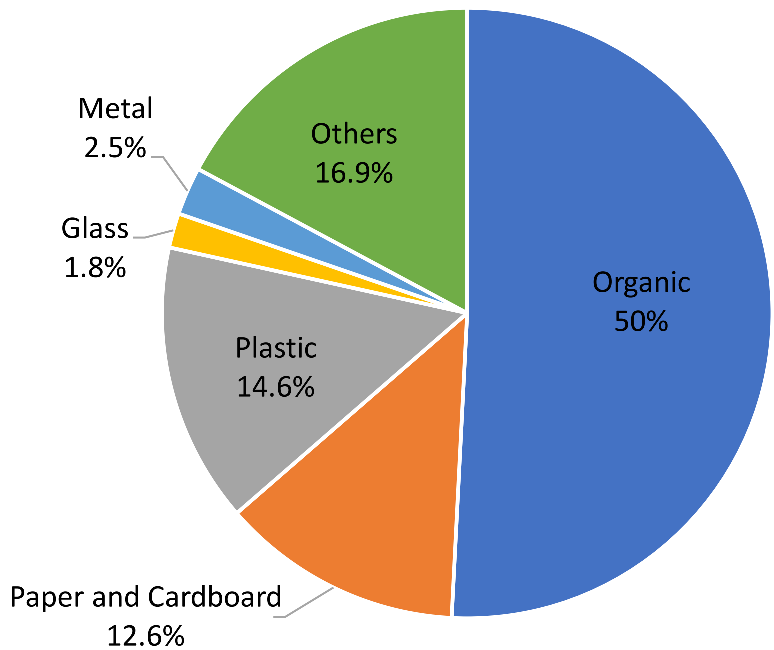

Figure 5: Solid waste fractions in the West Bank.[7]

Objectives

The main objective of the project is to find solutions for the problems that Zahrit AL-Finjan landfill suffers from. The proposed solutions are using the process of landfill and the process of incineration. In this project, an economic and environmental comparison has been made between landfill and incineration processes.

The economic aspect was by finding the value of Levelized Cost of Energy (LCOE) by calculating the amount of energy produced, the whole costs of project during the year and the amount of annual electric energy.

The environmental aspect was by finding the amount of emissions released including Nitrous oxide, Carbon dioxide and Methane, then by calculating and comparing the value of CO_2 equivalent for each one of them.

Scope of work

The project includes the study of the whole process from the beginning of its implementation until the final calculation and production of the amount of energy and the amount of emissions released.

Chapter two:

Literature review

Incineration

History of Incineration

In the 1890s the burning of garbage in cremators started in America. Initially incinerators were used merely to reduce waste volume. By the 1920s, incineration had been a common waste disposal method. Now, most are waste-to - energy facilities that also generate useful products including heat, steam and electricity using the combustion process. In 2006, United States Environmental Protection Agency (EPA) estimated that by some form of energy recovery incineration nearly 13 per cent of municipal solid waste was managed. Despite their long history, the use of incinerators remains controversial because of concerns like the release of gaseous contaminants. Despite the use of pollution control systems, ash sections that may contain trace amounts of heavy metals, dioxins or other substances are still concerned[10].

Definition of Incineration

Incineration is the treatment of waste material by combustion of organic substances present in the waste materials. It converts the waste material into heat, flue gas and ash which are released into the atmosphere without any further use treatment. High-percentage heat can be used to generate electrical power. Flue gases contain traces of nitrogen, carbon dioxide and sulfur dioxide, each of them is better used when optimally used. incineration reduces the solid mass of organic wastes by 80–85 percent and volume by 95–96 percent which is commendable[11].

Municipal solid waste (MSW) incineration plants tend to be among the most expensive solid waste management options and require highly qualified personnel and careful maintenance[12].

Pros of Incineration

Incineration is an effective means of reducing the volume of waste and landfill space demand. Incineration plants can be located close to the center of waste generation, so the waste wouldn't have to be driven for hundreds of miles and this would reduce the cost of waste transportation[13].

Incineration reduces the need for landfills, so the world doesn't have to look for new zones for landfills. Incineration plants generate energy from waste, this energy can be used to generate electricity or heat. It can be used to supply power to the needs of those living nearby. Also, incineration doesn't add any toxic elements to the groundwater, as landfills do[14].

Impact of incineration

Incineration is an expensive process, the cost of building the infrastructure is considerable, the cost of operating incineration facilities is also significant. Incinerators need a big staff to keep running. Smoke is produced by incinerators, the chimney smoke contains nitrogen oxide, particulate matter, heavy metals, acid gases and carcinogen dioxin. Fear of toxic pollution is one of the main reasons why incineration projects tend to stall[14].

Incineration encourages more waste production because incinerators require large quantities of waste to keep fires burning and local authorities can opt for incineration through recycling and waste reduction programs[13].

Incineration process

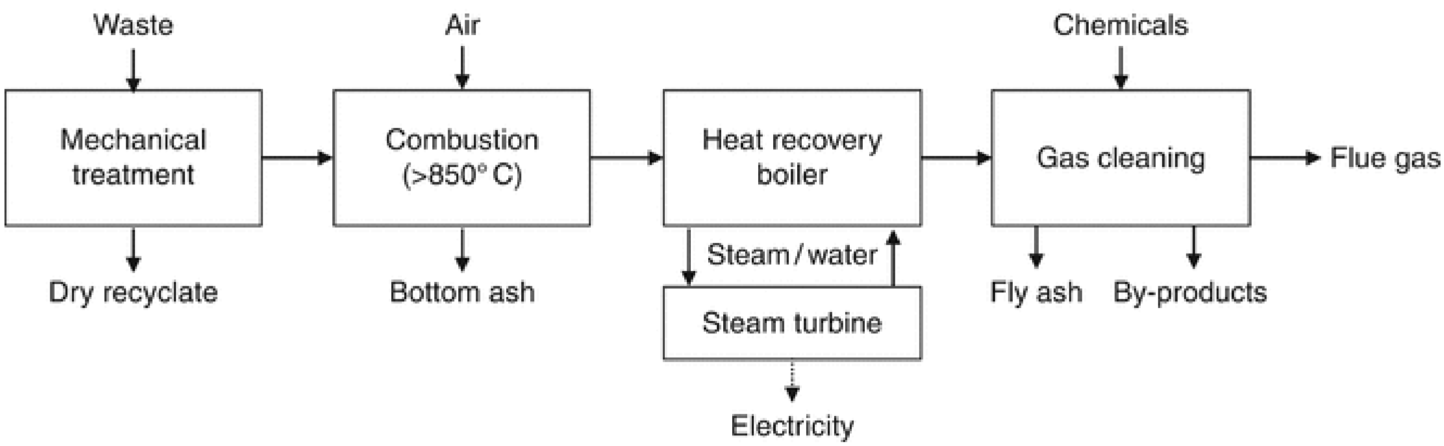

Figure 6: Block diagram of Incineration process[15].

Firstly, solid waste which is located in a land site taken to be sent to the combustion process, then performed in incinerators. The gas produced from the combustion process at a temperature around 900^o Celsius to 1000^o Celsius is sent to a heat exchanger for steam production to be then used in a thermal cycle for energy production. Out of the exchanger, at a temperature around 200^o Celsius to 250^o Celsius, the gas is then sent to the gas cleaning line to abate the polluting substances (dust, acid gas, etc.), and is discharged from the chimney into the atmosphere. Energy recovery is performed in a thermal cycle, usually with turbine and condenser to maximize the production of electric energy[16].

Incineration residue

The incineration process produces different solid and liquid residual materials, as well as gaseous effluents. About one-fourth of the wasted mass remains as solids on a wet basis, residue volume corresponds to one-tenth of the initial volume of waste.

The residues of incineration process are[16]:

- Bottom ash which is consisting mainly of coarse non-combustible materials and unburned organic matter accumulated in cooling tank at the outlet of the combustion chamber.
- Fly ash, the fine particulate matter still in the flue gases downstream of the heat recovery units, is removed before any further treatment of the gaseous effluents. The amount of fly ash produced by incinerator is about 1–3 percent of the waste input mass on a wet basis.
- Boiler and economizer ash, which represent the coarse fraction of the particulate carried over by the flue gases from the combustion chamber and collected at the heat recovery section.

Treatment of flue gases

Incineration process generates large volumes of flue gases. these gases consist of ash, heavy metals, and a variety of organic and inorganic compounds. The pollutants are present as particles (dust) and gases such as HCl, HF, and SO_2, these pollutants can be removed through advanced and costly chemical treatment technologies[16].

Landfill

History of landfill

Disposal of waste materials in landfill sites has its origins in Crete in 3000 B.C where waste was placed in pits in the soil. In 1979, United States Environmental Protection Agency (EPA) developed the first set of criteria for sanitary landfills that included standards for locating new landfills and operational standards for existing landfills to reduce disease vectors and increase protection of surface and groundwater. However, in the US and Europe waste was primarily disposed of by dumping within cities until the 1800s when the link was identified between poor environmental conditions and disease. It is worth noting that although the term landfill implies filling a hole with waste (landfilling), it is also used to refer to sites constructed by disposing of waste on the ground and covering it such sites have often been used for land reclamation, i.e. raising land above the river or coastal floodplains[17].

Landfills have developed from open polluting dumps to modern highly engineered facilities with sophisticated control measures and monitoring routines. However, in spite of all new approaches and technological advancement the landfill still is a long-lasting accumulation of waste in the environment. Much of current landfill design and technology has been introduced as a reaction to problems encountered at actual landfills[18].

Definition of landfill

Landfilling is the most common waste disposal method throughout the world. In a global warming (GW) context, the landfill is a complex unit because so many aspects must be included when counting greenhouse gases (GHGs). Methane is a major emission from landfills caused by degradation of organic matter, but methane may also be converted prior to discharge or recovered and used for energy purposes thereby potentially off-setting energy based on fossil fuels. Within the foreseeable future, for example, 100 years, not all biogenic carbon in a landfill will be released, and bound biogenic carbon may be considered a sink of carbon and the landfill should potentially be credited for this. Landfilling technologies have developed dramatically during the last few decades, although this development has not yet been implemented in all parts of the world. Landfills range from dumps to highly engineered facilities as bioreactor landfills, flushing-bioreactor landfills and semi-aerobic landfills. The engineered landfills may have a range of landfill gas utilization and control systems leading to dramatically reduced emissions of methane and recovery of energy[19].

Pros of landfills

Landfills Are a Source of Energy; As the trash and waste begin to break down, landfill gas -a mix of carbon dioxide and methane- is created. While this can be harmful to the ozone layer and produce air pollutants, modern landfills have found ways to harness that and not allow it to be freely dispersed. Also Landfills provide an area of dumping of non-recyclable material (for example, non-recyclable or a contaminated piece of plastic), or for recycling waste, which can be expensively installed depending on the technology used. Well managed landfills provide a quick way for developing or poorer countries to dispose of their waste in a safer and more healthy way – compared to recycling which may be more complex and expensive. Further to that, data on land available for landfill space in several countries shows there is enough space into the short to mid-term future. landfills can be used for other purposes such as temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). Landfills can have fewer fixed or ongoing costs than recycling or resource recovery, and incineration[20].

Impact of landfills

It can be hard to find new sites for landfill sometimes – you have to assess transport costs to get the waste to the landfill site, bushfire risk, flooding risk from nearby rivers and water sources, suitability of the soil, impact on the surrounding area. Landfills can produce greenhouse gases such as methane and carbon dioxide from decomposing organic waste, this contributes to climate change. Also, landfills can produce leachate which is a toxic substance when rain washes through hazardous materials, or materials with toxic chemicals in the landfill, so soil and water pollution and contamination can occur if leachate breaches the landfill lining, and gets into groundwater, or surrounding rivers, streams and other water sources. The problem with dumping in landfills is that you aren't re-using resources (assuming the waste just sits there) – this is a problem in terms of resource depletion and sustainability. Virgin materials have to be used to make new products, which means more mining or more manufacturing and depletion of resources[20]. So, reduce, re-use, recycle and recover materials should be looked to before dumping in landfills.

Sequence of landfill[21]

Working Landfill

-Daily Cover:

At the end of each working period, waste is covered with six to twelve inches of soil or other approved material. Daily cover reduces odors, keeps litter from scattering and helps deter scavengers.

- Waste:

As waste arrives, it is compacted in layers within a small area to reduce the volume consumed within the landfill. This practice also helps to reduce odors, keeps litter from scattering and deters scavengers.

Leachate Collection System

- Leachate Collection Layer:

A layer of sand or gravel or a thick plastic mesh called a geonet collects leachate and allows it to drain by gravity to the leachate collection pipe system.

- Filter Geotextile:

A geotextile fabric, similar in appearance to felt, may be located on top of the leachate collection pipe system to provide separation of solid particles from liquid. This prevents clogging of the pipe system.

- Leachate Collection Pipe System:

Perforated pipes, surrounded by a bed of gravel, transport collected leachate to specially designed low points called sumps. Pumps, located within the sumps, automatically remove the leachate from the landfill and transport it to the leachate management facilities for treatment or another proper method of disposal.

Composite Liner System

- Geomembrane:

A thick plastic layer forms a liner that prevents leachate from leaving the landfill and entering the environment. This geomembrane is typically constructed of a special type of plastic called high-density polyethylene or HDPE. HDPE is tough, impermeable and extremely resistant to attack by the compounds that might be in the leachate. This layer also helps to prevent the escape of landfill gas.

- Compacted Clay:

It is located directly below the geomembrane and forms an additional barrier to prevent leachate from leaving the landfill and entering the environment. This layer also helps to prevent the escape of landfill gas.

- Prepared Subgrade:

The native soils beneath the landfill are prepared as needed prior to beginning landfill construction.

Residue of landfill

An undesirable phenomenon related to the operation of landfills is the production of landfill leachate. This is a liquid waste that flows out of the landfill body after exceeding the sorption capacity of the deposited material and contains components that leak out of the waste. Landfill leachates are a complex mixture of organic and inorganic substances. The chemical composition depends mainly on the type and composition of the waste deposited, but also on the age of the landfill. The amount of leachate produced depends mainly on the method of compaction of the waste layers and on climatic conditions. The simplest option is once again recirculation to the landfill body after reducing the original volume of the leachate, which can present various constraints in the form of high salinity, the presence of toxic substances, and the possibility of disrupting the production of landfill gas and the activity of microorganisms in the landfill body[22].

Treatment of leachate

Landfill leachate treatment is a major engineering challenge due to the high and variable concentrations of dissolved solids, dissolved and colloidal organics, heavy metals and xenobiotic organics. On-site leachate treatment is an alternative to the increasing costs associated with hauling leachate to a local wastewater treatment plant. These treatment facilities are designed to fulfill the specific needs of individual landfill sites and allow discharge to a sanitary sewer or water body without any hauling or disposal costs. Technologies for landfill leachate treatment include biological treatment, physical/chemical treatment and “emerging” technologies such as reverse osmosis (RO) and evaporation. The choice of technology depends largely upon characteristics of the leachate, discharge limitations, and site constraints[23].

Biological leachate treatment is a proven technology for organics and ammonia removal in young and mature leachate. The anoxic/aerobic processes achieve nitrification and denitrification and reduce the oxygen demand for landfill leachate treatment[24].

The Intergovernmental Panel on Climate Change (IPCC):

The IPCC provides regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

Created in 1988 by the World Meteorological Organization(WMO) and the United Nations Environment Programme (UNEP), the objective of the IPCC is to provide governments at all levels with scientific information that they can use to develop climate policies. IPCC reports are also a key input into international climate change negotiations.

The IPCC is an organization of governments that are members of the United Nations or WMO. The IPCC currently has 195 members. Thousands of people from all over the world contribute to the work of the IPCC. For the assessment reports, IPCC scientists volunteer their time to assess the thousands of scientific papers published each year to provide a comprehensive summary of what is known about the drivers of climate change, its impacts and future risks, and how adaptation and mitigation can reduce those risks.

An open and transparent review by experts and governments around the world is an essential part of the IPCC process, to ensure an objective and complete assessment and to reflect a diverse range of views and expertise. Through its assessments, the IPCC identifies the strength of scientific agreement in different areas and indicates where further research is needed. The IPCC does not conduct its own research.

Table 2: Default dry matter content, DOC content, total carbon content and fossil carbon fraction of different MSW components[25].

MSW component	Dry matter content in % of wet weight	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range	Default	Range	Default	Range
Paper / cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden & Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber & Leather	84	39	39	47	47	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal	100	-	-	-	-	NA	NA	NA	NA
Glass	100	-	-	-	-	NA	NA	NA	NA
Other , inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

CO_2 emission estimate based on the MSW composition[25]:

$$CO_2 \text{ emissions} = MSW.\sum(\,WFj\ \cdot dmj\ \cdot CFj\ \cdot FCFj\ \cdot OFj\,)\ \frac{44}{12}$$

CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr.

MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr.

WF_j = fraction of waste type/material of component j in the MSW (as wet weight incinerated or open burned).

dm_j = dry matter content in the component j of the MSW incinerated or open-burned, (fraction).

CF_j = fraction of carbon in the dry matter (i.e., carbon content) of component j .

FCF_j = fraction of fossil carbon in the total carbon of component j.

OF_j = oxidation factor, (fraction).

44/12 = conversion factor from C to $CO_{2.}$

with: Σj (WFj) =1.

j = component of the MSW incinerated/open-burned.

CH_4 & N_2O emission estimate based on the total amount of waste combusted[25]:

$$CH_4\ \ /\ N_2O \text{ emission} = \sum(IW_j.\,EF_j)\,.\,10^{-6}$$

CH_4 Emissions = CH_4 emissions in inventory year, Gg/yr.

IW_j = amount of solid waste of type *i* incinerated or open-burned, Gg/yr.

EF_j = aggregate CH_4 emission factor, kg CH_4/Gg of waste.

10^{-6} = conversion factor from kilogram to gigagram.

j = category or type of waste incinerated/open-burned.

Chapter three:

Calculations

Incineration Levelized Cost Of Energy [LCOE]

$$\mathrm{LCOE} = \frac{\text{Annual cost}}{\text{Annual electrical energy production}}$$

$$\text{Annual electrical energy production } [E_{ele}] = \frac{Q_{MSW} \times \frac{1000\text{kg}}{\text{ton}} \times \text{En} \times \eta_{ele}}{\text{EleConv}}$$

Table 3: Electrical energy production from incineration parameters values.

Q MSW	1200 ton/day [7]
Energy content [En]	11.49 Mj/Kg [26]
Efficiency	19.4 % [27]
Elect. Conv.	3.6 Mj/KWh

$$\text{Annual electrical energy production} = 271202300\ \text{KWh/year}$$

$$\text{Annual cost} = \text{Annual worth} + \text{Running cost} + \text{Operating \& Maintenance cost}$$

Table 4: Annual cost parameters values of incineration.

Investment	$216000000
O & M	$1350000/year
Running cost	$8760000/year

With taking 25 year as the lifetime and interest rate 10%

Using Excel to estimate the annual worth:

$$\text{Annual worth} = \$23796303.59$$

So:

$$\text{Annual cost} = \$33906303.59$$

$$\mathrm{LCOE} = \$0.13/\text{KWh}$$

Incineration Emissions

CO2 emission:

Based on this equation:

$$CO_2 \text{ emissions} = \text{MSW}.\Sigma\left(\text{WFj} \cdot \text{dmj} \cdot \text{CFj} \cdot \text{FCFj} \cdot \text{OFj}\right)\frac{44}{12}$$

Table 5: CO_2 emissions parameters values.

Composition	WFj	dmj	CFj	FCFj	OFj	Σj(WFj*dmj*CFj*FCFj*Ofj)
Paper & paper board	0.126	0.9	0.46	0.01	1	0.00052
Food	0.5	0.4	0.38	-	1	0.07600
Plastics	0.146	1	0.75	1	1	0.10950
Metals	0.025	1	-	-	1	0.02500
Glass	0.018	1	-	-	1	0.01800
Other inert waste	0.169	0.9	0.03	1	1	0.00456
						0.23358

$$\text{Q MSW} = 1200 \ \text{ton/day} = 438 \ \text{Gg/year}$$

So:

$$CO_2 \text{ emissions} = 375.13 \text{ Gg } CO_2/\text{year}$$

CH_4 emission:

$$CH_4\text{emission} = \sum\left(IW_j . EF_j\right) . 10^{-6}$$

Table 6:CH_4 emissions parameters values.

Composition	Wfi	Q MSW [ton/day]	Q MSW [ton/year]	IW j	EF j [Kg CH4/ton of waste]	CH4 emission
Paper & paper board	0.126	1200	438000	55188	0.188	10375.344
Food	0.5	1200	438000	219000	0.188	41172
Plastics	0.146	1200	438000	63948	0.188	12022.224
Metals	0.025	1200	438000	10950	0.188	2058.6
Glass	0.018	1200	438000	7884	0.188	1482.192
Other inert waste	0.169	1200	438000	74022	0.188	13916.136
						81026.496

$$\mathrm{CH_4 emission} = 0.081026\, Kg\ CH_4/year$$

According to IPCC, the methane emission rates were converted to CO_2eq using a Global Warming Potential (GWP) factor of 21[28]:

$$\mathrm{CH_4 emission} = 1.706\, Kg\ CO_2\ eq/year$$

N_2O emission:

$$\mathrm{N_2O\ emission} = \sum(\mathrm{IW_j}.\mathrm{EF_j}).10^{-6}$$

Table 7:N_2O emissions parameters values.

Composition	Wfi	Q MSW [ton/day]	Q MSW [ton/year]	IW j	EF j [Kg N2O/ton of waste]	N2O emission
Paper & paper board	0.126	1200	438000	55188	0.068	3752.784
Food	0.5	1200	438000	219000	0.068	14892
Plastics	0.146	1200	438000	63948	0.068	4348.464
Metals	0.025	1200	438000	10950	0.068	744.6
Glass	0.018	1200	438000	7884	0.068	536.112
Other inert waste	0.169	1200	438000	74022	0.068	5033.496
						29307.456

$$\mathrm{N_2O\ emission} = 0.029307\, Kg\ \mathrm{N_2O}/year$$

According to IPCC, the methane emission rates were converted to CO_2eq using a Global Warming Potential (GWP) factor of 310[28]:

$$\mathrm{N_2O\ emission} = 9.085\, Kg\ CO_2\ eq/year$$

$$\text{Total emissions of Incineration process} = 375136942.6\ \mathrm{Kg\ CO_2\ eq/year}$$

$$\text{Total emissions of Incineration process} = 856.48\ \mathrm{Kg\ CO_2\ eq\ /ton\ of\ waste}$$

Landfill Levelized Cost Of Energy [LCOE]

$$\mathrm{LCOE} = \frac{\text{Annual cost}}{\text{Annual electrical energy production}}$$

$$\text{Annual electrical energy production } [E_{ele}] = \frac{Q_{methane} \times En \times \eta_{ele}}{EleConv}$$

Table 8: Electrical energy production from methane parameters values.

$Q_{Methane}$	1.927×10^{7} m^3/year
Energy content of methane [En]	39.8 Mj/ m^3 [29]
Efficiency	35 %
Elect. Conv.	3.6 Mj/KWh

$$\text{Annual electrical energy production} = 74564194 \text{ KWh/year}$$

$$\text{Annual cost} = \text{Annual worth} + \text{Running cost}$$

Table 9: Annual cost parameters values of landfill.

Investment	$33600000
Running cost	$336000/year

Using Excel to estimate the annual worth:

$$\text{Annual worth} = \$3483974.1$$

So:

$$\text{Annual cost} = \$3819974.1$$

$$\mathrm{LCOE} = \$0.05/\mathrm{KWh}$$

Landfill Emissions

We found the total landfill gases emissions using LandGem, all results are illustrated below:

Table 10: LandGem results of landfill emission.

year	Waste Accepted	Waste-In-Place	Total landfill gas	Methane	Carbon dioxide	NMOC
	ton / year	ton	ton / year	ton / year	ton / year	ton/ year
2007	755000	0	0	0	0	0
2008	770100	755000	3738	998.4	2739	6.437
2009	785502	1525100	7476	1997	5479	12.88
2010	801212.04	2310602	11220	2996	8221	19.32
2011	817236.2808	3111814	14960	3996	10960	25.77
2012	833581.0064	3929050	18710	4998	13710	32.22
2013	850252.6265	4762631	22470	6001	16470	38.69
2014	867257.6791	5612884	26230	7007	19220	45.17
2015	884602.8327	6480142	30010	8015	21990	51.67
2016	902294.8893	7364744	33790	9026	24760	58.19
2017	920340.7871	8267039	37590	10040	27550	64.37
2018	938747.6028	9187380	41400	11060	30340	71.3
2019	957522.5549	10126128	45230	12080	33150	77.89
2020	976673.006	11083650	49070	13110	35960	84.51
2021	996206.4661	12060323	52940	14140	38800	91.16
2022	1016130.595	13056530	56820	15180	41640	97.85
2023	1036453.207	14072660	60730	16220	44500	104.6

In 2021, the total landfill gas emissions equal to 52940 ton.

The Methane emission equal to 14140 ton

The CO2 emission equal to 38800 ton

Burning 1 Kg of CH_4 produces 2.75 Kg of CO_2 [30]

So, burning methane to produce energy will produce 38885000 Kg of CO_2

The total amount of CO_2 emission produce is 77685000 Kg/year

$$\text{CO}_2\text{ emission per ton of waste} = \frac{\text{Annual CO}_2\text{ emission}}{\text{Annual waste produced}}$$

$$\text{CO}_2\text{ emission per ton of waste} = 77.98\text{ Kg CO}_2/\text{ton of waste}$$

Chapter four:

Conclusion and recommendations

After studying the current situation of Zahrit AL-Finjan landfill which is located in Jenin and it serves the northern area of the West Bank, found that Zahrit AL-Finjan landfill worthwhile to find a treatment solution due to its bad conditions. Make a new landfill process as a source of energy and make a recovery for the released methane and the incineration process were the suggested solutions to be applied in Zahrit AL-Finjan landfill from an economic and environmental aspects. The economic results of incineration and landfill**,** have been done to get the results of the annual electrical energy production with 271.2 GWh / year by incineration process and 74.5 GWh/year by landfill process, annual cost which equals $33.9 million by incineration process and equals $3.8 million by landfill process and the value of Levelized Cost of Energy (LCOE) equals $0.13/KWh by incineration process and $0.05/KWh by landfill process. For the environmental aspect of incineration, the total amount of CO_2 equivalent which equals 856.48 Kg CO_2 eq / ton of waste, and 77.98 Kg CO_2 / ton of waste by landfill process.

After getting the results, incineration process is recommended to be applied due to two main reasons. Firstly, incineration process doesn't need to change its place and location especially under the circumstance we live in; because there are no options to choose the landfill and no available areas. Secondly, there is a deficit in the electricity sector in Palestine, therefore the electrical energy production by the incineration process is much higher than the electrical energy production by the landfill process. At the long term, this will indicate that there is electricity from a fixed source, unlike landfill which needs to be replaced and transferred every now and then therefore its generators and equipment need to be transferred too. Also, these need a new investment so it is difficult to be applied. Levelized Cost of Energy (LCOE) by incineration equals $0.13/KWh and it is lower than the cost of electricity that The Electricity Distribution Company buys from Israel.

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