WASTE TO ENERGY TECHNOLOGY FOR THE DESALINATION OF WATER: GAZA STRIP AS A CASE STUDY

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To all our families, friends and all who supported us

To our supervisor and great mentor, Dr. Abdelrahim Abusafa

We dedicate this work

ABSTRACT

This research aims to shed light on the most important problems faced by the world in this modern era. Municipal solid waste management and water shortages are notorious for being two of the main obstacles of development around the world. In a place that has been anguished by war and occupation for so long, such problems are an integrated part of the region that hinders the development process there. Gaza strip is such a place that suffers from the major drawbacks that occur from these problems.

This research has been conducted to review methods in which the aforementioned problems can be mitigated and possibly solved. Types and alternatives of waste to energy technologies, cogeneration plants and derived desalination units have been studied, while analyzing their variables and parameters accordingly. A comparison has been made as well, to find the most effective combination of these three components, which yields the highest efficiency of the overall project.

After determining a WtE technology to be followed, other components of the project were studied. An environmental review of the project was conducted in order to find the major environmental impacts of the project. Then, centralized and decentralized scenarios were compared on different parameters. Then, a timeline of the project is suggested for the flow of work of the project. Finally, a conclusion as well as recommendation for further studies have been made. After conducting the required calculations, it was found that centralized plants are generally 30% less costly than decentralized plants. Additionally, the IRR of the project was -5% and the levelized cost of water is 4NIS/m^3.

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1. CONSTRAINTS

In this research, many constraints came up that obstructed the flow of design. These constraints can be summarized as:

1.1. Technical Constraints:

1.1.1. Waste Collection:

- MSW collection will be focused on the main sanitary landfills in the city, eliminating random dumpsites due to difficulty in collecting and transporting waste from these sites.
- The inability to segregate waste during the process of collection, excluding glass, metals and other waste materials.

1.1.2. WtE/ Incineration:

- To ensure appropriate combustion, waste collected entering the incinerator must have a moisture content less than 50%, ash content to be less than 60%, and combustible solids should be more than 25% by weight.
- Incinerator unit must accommodate to the increasing volumes of waste over the years.
- The LCV must be, on average, at least 7 MJ/kg and never fall below 6 MJ/kg [1].

1.1.3. Desalination:

- Brine disposed after the desalination process must be utmost 70,000 ppm in salinity to avoid negative environmental impacts and enhance the system's performance.

1.2. Environmental Constraints:

- Complying with EQA laws and terms, measures must be taken to improve air pollution control (APC).
- Brine concentration should be within the acceptable levels to be disposed back in the sea.

2. INTRODUCTION

Since Earth is what we all have in common, preserving it should be our highest priority. Our modern world faces two major problems that are detrimental to the environment and future generations. Waste management, and water availability are the focus of development in most countries. These problems rise from various reasons such as population growth, urbanization and climate change.

With a continuous global population growth at an average rate of 1.08% per year, waste is an inevitable problem [2]. It is estimated that solid waste generated worldwide from urban areas will almost double in size from 1.3 to 2.2 billion tonnes/day by the year 2025 [3]. Solid waste management is a huge concern to many countries, both developed and developing ones alike. Disposal of waste, specifically municipal solid waste, and/or recycling it, can take lawmakers huge investments and a lot of effort to impose change.

The definition of municipal solid waste (MSW) typically ranges from waste arising from private households to that managed by or on behalf of local authorities from any source. MSW therefore includes a proportion of commercial, nonhazardous industrial waste and potentially also demolition waste and sewage sludge [4].

Factors that control MSW management are suitable areas, health concerns, environmental pollution, and economical constraints. These factors are extremely sensitive to the status of the country. Economic, political and social stability of the nation plays a huge role in managing solid waste, Figure 2.1 shows the most popular ways in waste disposal around the globe. As the figure demonstrates, around 33% of municipal waste is disposed in open dumps [5].

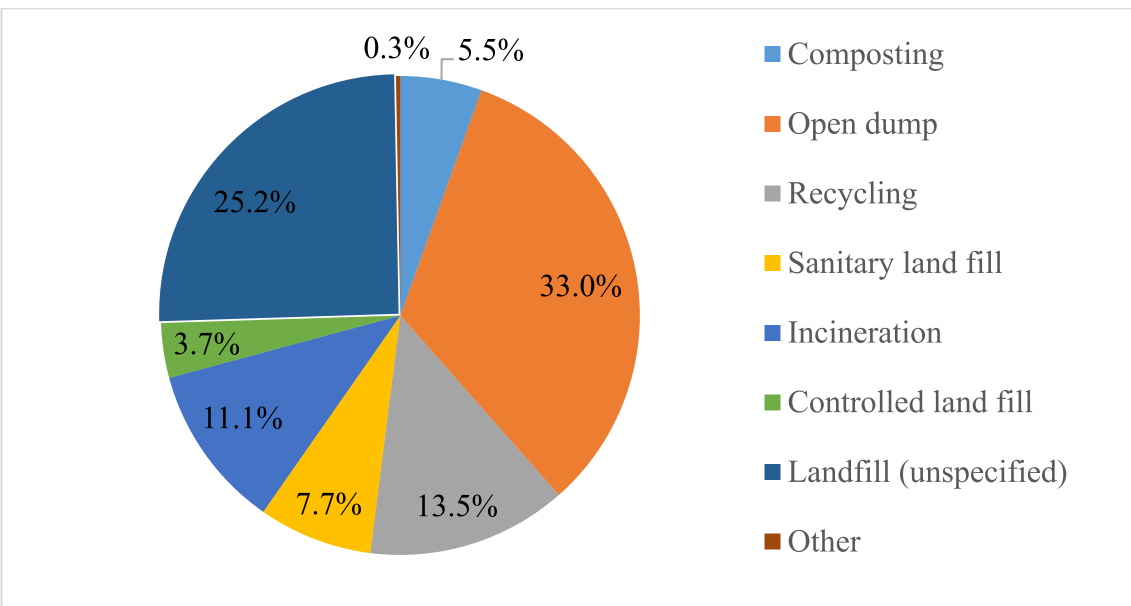


Figure 2.1: Most common ways in SWM worldwide

Ordinarily, waste generated worldwide averages at 0.74 kg/person but ranges widely, from 0.11 to 4.54 kilograms [5]. This can be seen clearly when comparing developed and developing nations. Volumes of waste generated and its composition is related directly to a country's gross domestic product (GDP) available which is not always static. Less developed countries tend to have higher proportions of biodegradable organic waste than more economically developed countries [6]. The composition of generated waste is extremely variable as a consequence of seasonal variation, lifestyle, demographic, geographic, and local legislation impacts [7]. Accordingly, effective solid waste management is expensive and often comprises 20-50% of municipal budget [3].

Most of the world's population growth will occur in developing countries, where water is already critically short and many of the residents are impoverished. Even today, over one billion people do not have access to safe and affordable drinking water and perhaps twice that many lack adequate sanitation services. Water sources in the world are very limited, in fact 1/3 of global water supply is maintained from snow melts [8].

Water scarcity in the world is one of the big issues experienced by countries with limited natural resources of water. Most of these countries have insufficient water supply to meet their agricultural, urban, industrial and social needs. Water scarcity or water stress can be measured by a scale of water stress index. Water stress index is typically defined as the relationship between total water use and water availability. The closer water use is to water supply, the more likely stress will occur in natural and human systems. This indicator has been used by the United Nations and others [9]. Most regions that suffer from water scarcity in the world are the Middle East and North Africa, as shown Figure 2.2 [10]. In the year 2025, over half of the world's population will suffer from water exhaustion [8].

Reasons for water stress vary from place to another. Generally speaking, most prevalent reasons are population growth, social and economic development, urbanization and climate change. However, human water consumption across the globe is known to be around 100L/person/day, as it is set by the United Nations, which must safe, acceptable and affordable water resources [11]. In regions where the climate is hot and dry, fresh water resources can be inadequate for the continuously growing demand. However, most of these regions are surrounded by the ocean. Therefore, people resort to ways of making seawater drinkable by desalination.

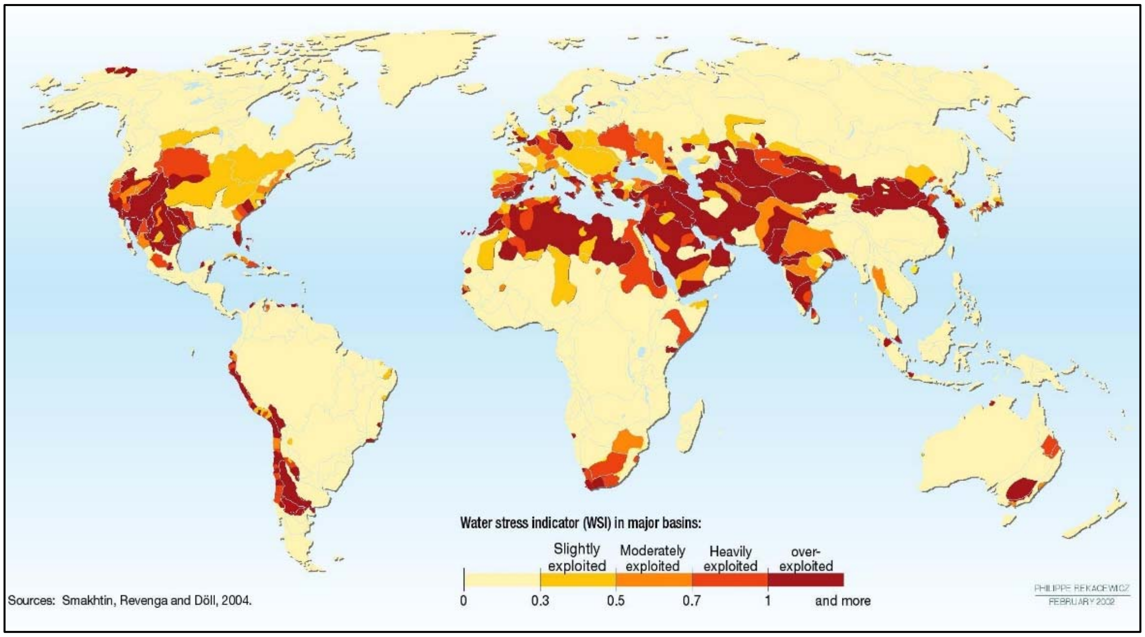


Figure 2.2.2: Water stress index in the world

Gaza strip, or simply Gaza, is a self-governing Palestinian territory on the eastern coast of the Mediterranean Sea, with a total area of 365 km² and an estimated population of 1.816 million people in 2014 [12] Consequently, Gaza strip is the most densely populated city in the world [13]. With it also being in the midst of constant conflicts, Gaza became very susceptible to shortages in water and energy resources, as well as a continuous increase in municipal waste production due to high population growth rates.

2.1. Problem Statement

This research will focus on the two major aforementioned problems, including municipal solid waste management and water accessibility in Gaza strip.

Municipal solid waste is the most popular type of waste in Gaza. In fact, collectively around 1330 tonnes of waste is produced daily. With only 12% of this waste is collected by joint services councils, waste is extremely ill-managed. This leaves the strip with various random dumpsites, and landfills overflowing with waste [14].

Water is also one of the biggest problems faced by Gaza. Restricted water supply and continuous demand growth, makes Gaza highly water stressed. 96% of the total water demand in Gaza is supplied from groundwater wells through 247 well in the strip, while the remaining 4% is supplied from the national water company of "Israel" (Mekorot) [15]. These water sources are extremely variable to natural occurrences and political status of the city. Even so, 97% of the groundwater supply is not drinkable, according to WHO recommended standards. Three of domestic water supplies in Gaza are ground water from coastal aquifers, desalinated water from using brackish and seawater as feed, and rain water from harvesting wells. Therefore, only around 11% of families in Gaza consume clean water daily, with an average of 60L/day/person [16].

2.2. Objectives

This research aims to shed light on the impacts the two previously mentioned problems existing in Gaza strip, and proposing few solutions, such as:

- Benefits of incineration of waste will be demonstrated, as well as ways of increasing the calorific value of waste will be proposed.
- Help in providing drinkable water access for Gaza strip citizens, and minimize the effects of water scarcity in the region.
- Optimize the MSF desalination unit to maximize output.
- Conduct an economic feasibility to visualize the revenues and determine the costs of products accordingly.
- Determine best suitable site to setup the project on to be centralized around the inputs and outputs of the project.

3. METHODOLOGY

3.1. Background of the problem

Our modern era faces two major problems that are, unfortunately in continuous and exponential growth. These problems are mainly concerned with waste management and water scarcity. As mentioned in previous chapters, all countries worldwide are subjected to these problems. However, it differs massively between countries the ways in which these problems are handled. Developed and first world countries usually have better grip on the matter of their problems, resources and expertise. This in turn, helps a lot in managing their issues in an optimal and efficient way. Developing countries, on the other hand, don't usually have an overall understanding of their problems. This could be due to political, social or economic disturbances. Moreover, resources in these countries are not necessarily always inadequate, rather official control over them could be extremely restricted. This, as expected causes limited to no properly addressed solutions to the problems on hand. An example to this, as discussed previously, is the situation in Gaza strip in the Palestinian territories.

Gaza strip is described by many people and humanitarians across the world, as the world's largest open-air prison [17]. With more than fifty years of occupation and ten years of blockade, Gaza strip is currently suffering from an unbearable living situation. In fact, it has been estimated by the UN that by the year 2020, Gaza will be "unlivable" if the blockade continues. With mismanagement of municipal solid waste, and extreme water scarcity, Gaza sure is in immense distress. Therefore, efforts and future investments should be completely targeted towards improvements in Gaza, which will benefit the strip and its citizens as a priority.

3.2. Suggested solutions

For the municipal solid waste problem getting rid of it can be really challenging, especially when land availability is quite limited. Thus, the option of building larger landfills to accommodate for the growing production of MSW is not possible. Another option could be by converting this waste to energy, and it can be achieved by incineration for instance. By using incineration as a WtE process, it can be applied to most components in the MSW produced which significantly reduces sorting and separating expenses and efforts. Additionally, incineration has been historically used as a way for MSW management. Therefore, the know-how technologies as well as the workplace experience can be easily gathered and applied. Furthermore, newer applications in incineration can be environmentally harmless if executed properly. In fact, modern incineration plants in today's world, do not have to be constructed in remote areas anymore due to complete closure of the plant, and stack gas treatment. A good example to this, is a new plant under construction in Denmark that will be built only 4km outside from the city center. The plant will deal with 400,000 tonnes of waste per year, and can generate up to 2 MWh of heat and 0.7MWh of electricity per tonne [18].

This makes WtE options by incineration applicable to many countries, and can benefit many people and stakeholders as shown in Figure 3.1 below [19].

Figure 3.1.1: Relevant stakeholders of WtE plants

Moreover, incineration through WtE plants produces very large amounts of thermal energy that has multiple uses to it. The production of large amounts of thermal energy, really does open the doorway to many options to apply. One of these options is a desalination plant. Through water desalination, the second problem of water shortage can be mitigated or even solved. By directing the thermal energy produced previously through a desalination unit. Desalination can be categorized as thermal and membrane technologies. Choosing a desalination technology depends on various parameters, such as raw and product water qualities, sources of energy used and their relative costs, location and size of the plant, environmental requirements, capacity and the know-how technology [20]. The appropriate kind of desalination plant is then chosen according to these criteria.

4. RESULTS AND DISCUSSION

4.1. Incinerator requirements

A simple calculation has been done for a brief assessment of feasibility of waste as a source of energy, its calorific value, moisture content, combustible solids and ashes percentages. These parameters are important indicators for designing incinerators and mapping out the constraints of this project.

In general, the combustion efficiency of an incinerator is about 80%, where it is controlled by excess air and temperature of combustion. In practice however, about 65–80% of the energy content of the organic matter can be recovered as heat energy, which can be utilized for direct thermal applications, such as desalination plant [21].

The simplest way of characterizing waste as a fuel of MSW incinerator is to determine (based on wet waste) the moisture content, ‘W’ (typically 15–35% when drying at 105 ◦C), and the (inorganic) ash content, ‘A’ (typically 10–25% after ignition at for example 550 ◦C) and then to calculate the combustible (organic) solids, ‘C’, as the difference between the dry solids and the ash content (typically 40–65 %). Knowing these characteristics, Tanner’s diagram can be used to examine whether or not the waste can be combusted without auxiliary fuel. If the data are located within the shaded area (W < 50 %, A < 60 %, C > 25 %), this indicates that the combusting process does not need any auxiliary fuel, as shown in Figure 5.1 [4].

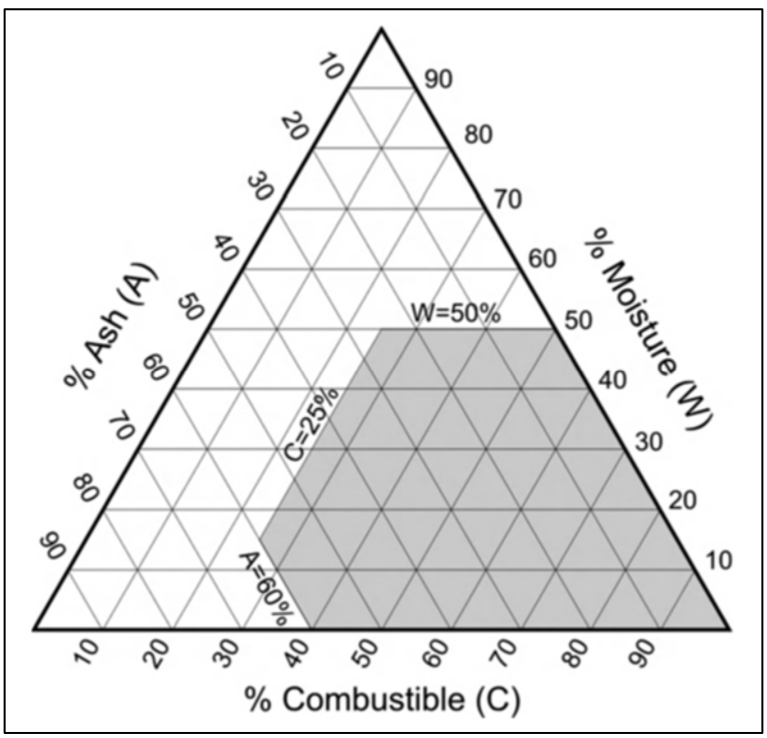


Figure 4.1: Tanner's diagram for waste characteristics

4.2. Material fractions and net calorific value

The following Table 5.1 shows the average percentage of moisture content, solids, ashes and combustible solids for each component of MSW, and material fractions of waste in Gaza strip. This is after excluding metals, glass and other wastes like rock, sand, dirt, ceramics, plaster and bones [7].

Table 4.1: Material fractions and net average calorific value of waste

Heating value calculation		Fraction basis				Heating Values	
Material fractions in wet waste	% of waste	Moisture W (%)	Solids TS (%)	Ash A (%)	Comb. Solids C (%)	H.H.V. (kJ/ kg)	L.H.V. (kJ/ kg)
Food and organic waste	52	66	34	13.3	20.7	17 000	1912
Plastics	13	29	71	7.8	63.2	33 000	20 144
Paper and cardboard	11	47	53	5.6	47.4	16 000	6440
Weighted average	76	56.9	43	11.3	31.8		**5686**

4.3. Quality enhancement of MSW

Through these calculations, the heating value of waste in Gaza Strip was found to be about 5686 kJ. But, by referring to previous research, the lowest average lower heating value (L.H.V.) was 6000 kJ for a combusting process without an auxiliary fuel. Therefore, a method of enhancement calorific value has to be done, to achieve complete combustion in appropriately.

In this case, several options were suggested to achieve the desired calorific value:

- Pre-heating of organic waste to a higher tempreture to decrease the percentage of moisture by evaporating its water content. This increases the heat content of waste, but, a sub-stream of heat should be diverted which means lower output heat of the incinerator.
- Co-firing of waste using pulverized coal (PC) by inserting controlled amounts of coal to raise the calorific value for suitable combustion. This raises another question of economic feasability and availability of the auxiliary fuel.
- Seggregation process of waste to extract components that affect the heating content, and only use waste of higher heating content. This increases the capital cost of the project and the operating and maintenance costs.
- Choosing another technology other than incineration, such as composting, gasification or pyrolysis.

However, and since one of the main objectives of this project was the reduction of the volume of MSW, this excludes seggregation process of waste, where choosing another technology other than direct incineration is unlikely because it has the maximum volume reduction percentage of 90%, more than the rest of WtE technologies. This leaves the option to co-firing waste with pulverized coal which is selected in this project, due to its efficiency, easy application, and controlled upon the quality of MSW.

4.4. Nominal estimation of products

In this study, the co-firing ration taken is 1:4 coal to MSW based on current waste incineration facility in China [22], and using a sub-bituminous coal with average heat content of 20 MJ/kg, from a simple calculation the resulted net calorific value is **8.5488 MJ/kg**

Referring to previous research, an output of only heat with an average L.H.V. of 8.55 kJ/kg of MSW, (using interpolation) is to produce 1.9 MWh/t of heat, where the overall efficiency of the system can be obtained as:

$$8550\ MJ/ton\ waste \Longrightarrow 1.9\ MWh/t\ heat$$

$$heat\ heat = \frac{1.9MWh}{t} \times \frac{3.6MJ}{MWh} = \frac{6.84MJ}{t}$$

$$combustion\ efficiency = \frac{output}{input} = \frac{6.84\ MJ/t}{8.55\ MJ/t} = 80\%$$

In the case of considering all sanitary landfills to be utilized by the incineration plant, the total amount of waste is 1300 tonnes per day, which means the output energy is:

$$heat \Longrightarrow 1.9\ MWh/t \times 1300\ t/day = 2{,}470\ \mathrm{M}Wh/day$$

As the proposed desalination technology is Multi stage flash (MSF), the following calculation is to find the amount of daily desalinated water produced by heat from the incineration plant and electricity to run the whole plant sectors. Assuming that the required steam and electricity are 14 kWh/m^3 and 4 kWh/m^3 respectively, the output potable water is:

$$desalination\ plant\ output = 2{,}470\ MWh/day \div 14\ kWh/m^3\ = 176{,}428\ m^3/day$$

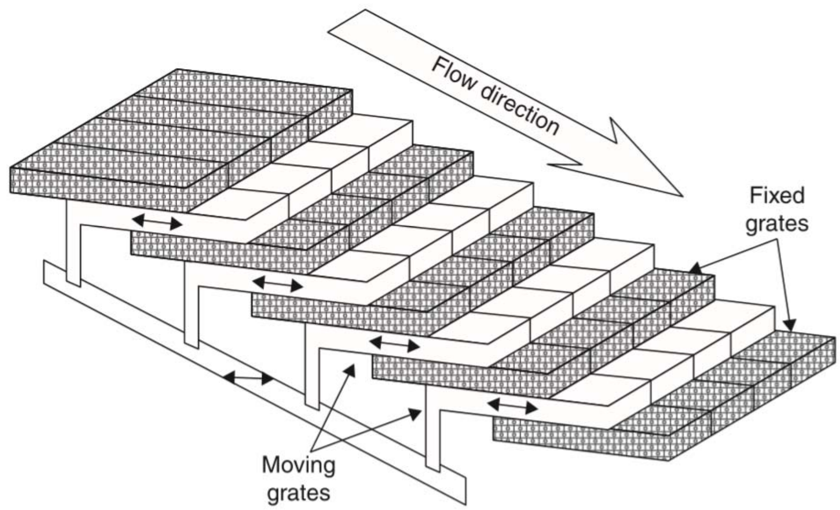
$$required\ electricity\ for\ plant = 4\ kWh/m^3 \times 176{,}428\ m^3/day = 706\ MWh/day$$

The result of combusting 1300 tonnes per day of waste generates roughly around 176 thousand cubic meters of water daily, regardless of fluctuations in production of waste and its quality and electricity that depend on the demand on water and electricity during day and night.

4.5. Moving grate incineration technology

By far the dominant WTE technology is combustion on a moving grate, either inclined or horizontal. An estimated 80% of the global WTE industry uses this method because of its simplicity and reliability. The solid wastes are unloaded from the collection trucks into a concrete bunker, which can hold a week's feedstock or more. In cases where the WTE plant is some distance away from the collection points, waste transfer stations are used where the collection trucks (2–5 tons capacity) unload and the MSW is then loaded onto larger trucks (20– 25 tons) for transport to the WTE facility [23].

The basic difference between the various technologies is the means by which the waste is transported through the furnace during the combustion process. The primary purpose of the grate is to convey the waste automatically from the ram feeder to the residue discharge point. A second purpose is to tumble the waste to ensure that all of the waste is exposed to the combustion air and that complete combustion occurs. Grates can use a reciprocating motion, rotary drum, rollers or other means to move the waste through the furnace.



4.6. Proposed Location for project

As the proposed plant is for the incineration of MSW and the desalination of seawater, the location of the project have to be near the MSW aggregation and to the coast where the access of seawater is found, costs increased in the form of transporting of waste, fresh water, seawater and brine if the location is far from the above parameters, the following Figure 5.2 shows the location of the main sanitary landfills in Gaza strip.

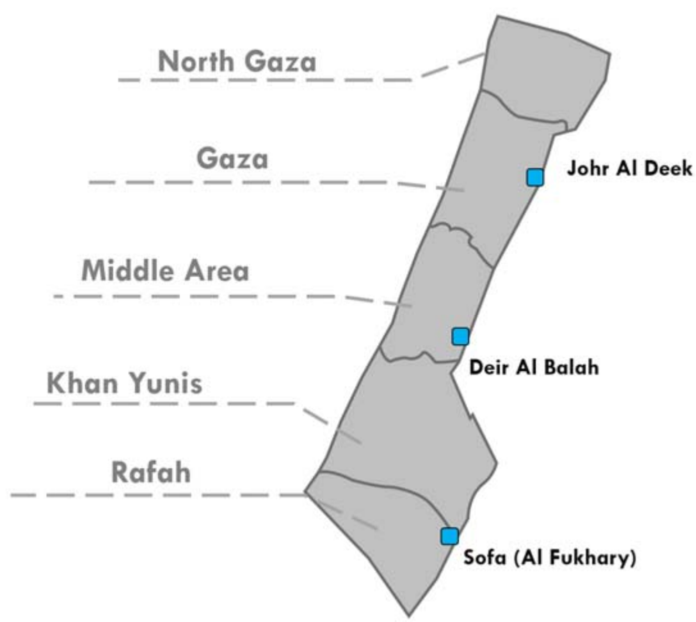


Figure 4.2: Three main sanitary landfills in Gaza Strip

The sanitary landfills are handling 1300 tonne/day of MSW and the rest of waste dumped in random and insanitary dumpsites and landfills, as the project seek to accommodate the daily amounts of waste produced, the project recommended to be near the major landfills, but from the desalination unit view, it is far away of the coast of Gaza strip, that is to say that the waste transportation trucks must be diverted toward the new locations of proposed plants to be in the coast near to the seawater, the proposed locations are in the following Figure 5.3.

Figure 4.3: Proposed locations to the project

4.7. Scenario Study

The diagram below shows the two scenarios identified and evaluated in this study:

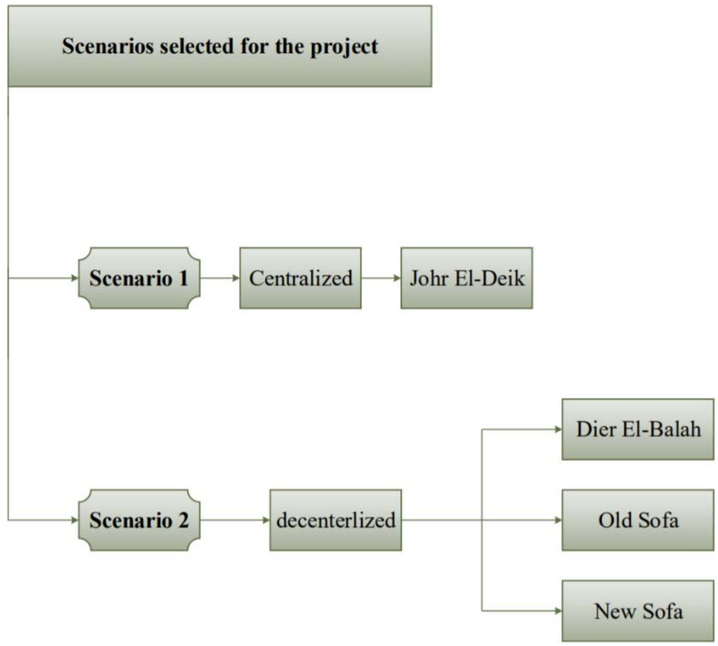


Figure 4.4: The two scenarios proposed

4.7.1. Scenario 1: Centralized facility

The centralized facility is to be a one large plant that collect the waste of Gaza strip and produce water from one place that it is distributed by the closer municipalities priority, a centralized planet means by the financial view less cost but otherwise, the cost of transportation of MSW and potable is to be raised, environmental impact is to be concentrated in single place which may be disadvantage to the public.

The proposed location of the centralized station is to be near the top capacity sanitary landfill of Johr Al-Deek that it must be close to the coast for desalination process, as Figure 5.3 shows the Location 1.

4.7.2. Scenario 2: Decentralized facility

The decentralized facility is to be a three separate planets that works in the north, middle and south of Gaza strip, as the transportation of MSW and potable water is less cost than centralized planet, the capital cost of 3 separate plants and maintenance costs is to be much higher, with less harmful effects toward neighbors since the concentration of fumes and smoke are less than the centralized one.

The proposed location is to be near the 3 sanitary landfills in the strip and close to the coast, where the construction of 3 water distribution grids and 3 suction pipes toward seawater, that means more costs added to the capital, as Figure 5.3 shows location 1,2 and 3 of proposed plants.

4.8. Financial analysis

For the initial costs of incinerators and MSF desalination unit, the following equations are used with proper modification of followed variables, for incinerator capital cost:

$$I = 2.3507 \times C^{0.7753}$$

Where C is the plant capacity of MSW (1000 tonne of waste/year) and I is the initial cost in million dollars [24], where it is assumed to be take in the MSW of the strip of 1300 tonne/day. The previous equation includes the electricity generation where it is avoided in this study, which decrease the initial cost by 30% ().

The MSF desalination unit is estimated upon the following equation:

$$C_{MSF} = 4.65 \times 10^6 \left(\frac{F1}{2500}\right)^{0.7} \times \left(\frac{GOR}{7}\right)^{0.45}$$

Where F1 is the desired output of water (m^3/day), and GOR is the performance ratio of the plant (kg distilled/kg stream) [25], depending on calculations, 176,000 m^3/day is the output with a performance ratio of 0.8.

A comparison is then conducted between centralized and decentralized plants for both the incinerator unit as well as the desalination unit. Tables 5.2 and 5.3 show the comparison between each scenario taking into account investment and O&M costs.

Table 4.2: Centralized vs. Decentralized (Incineration)

Incinerators [26]	Centralized	Decentralized
Investment cost (-30% for excluding electricity generation)	195.5 m$	230.5 m$
Fixed operating maintenance (Cost of administration and salaries) 2% of total investment	3.91 m$/year	4.61 m$/year
Variable operating costs (Coal, Chemicals, electricity, residual disposal, etc.) 12$/ tonne incinerated 60$/ tonne coal	12.812 m$/year	12.812 m$/year
Maintenance cost (Machinery and buildings maintenance) 3.5% of total investment	6.843 m$/year	8.068 m$/year

Table 4.3: Centralized vs. Decentralized (Desalination)

MSF [24]	Centralized	Decentralized
Investment cost	97 m$	131 m$
operating costs (Maintenance, labor, chemicals, materials and parts) 3.94% of total investment	3.82 m$	5.16 m$
Electricity cost 2.1% of total investment	2.04 m$	2.75 m$

A simple calculation of 1300 tonne/day feedstock of MSW is the capacity of the facility, regardless to the MSW annual growth, whether it is in 3 different incinerators or in single large incinerator, it is obvious to observe that the centralized facility is more economically feasible.

4.8.1. Current tariff values of incomes and outcomes

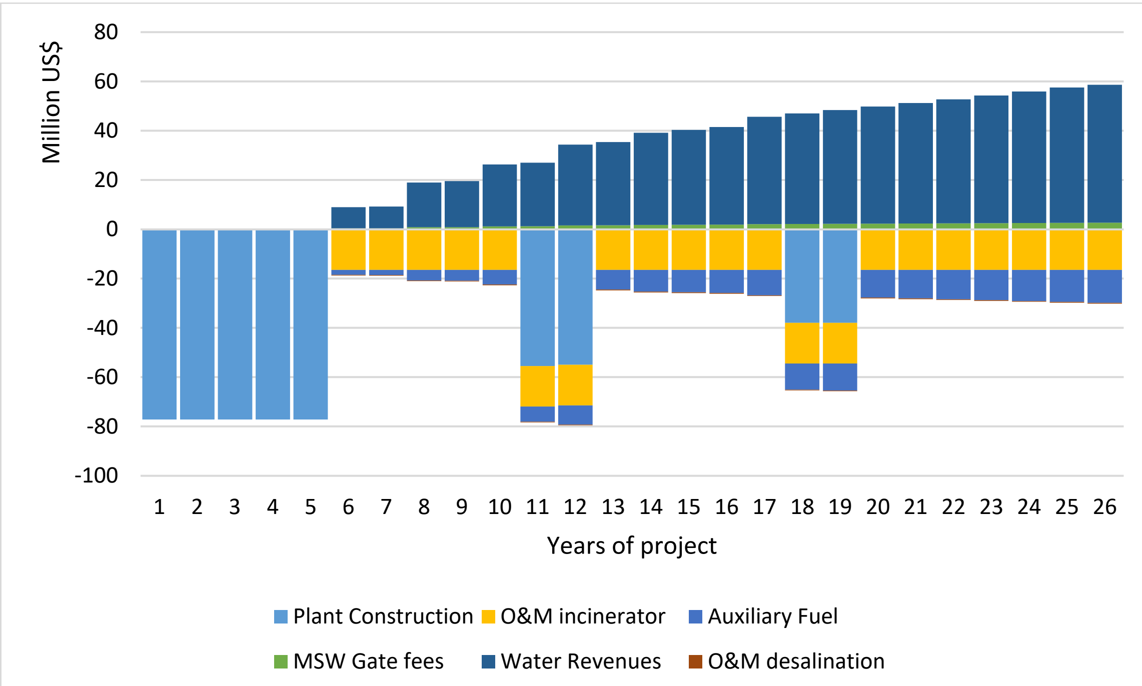
The potable water prices provided by municipalities, private wells, MEKEROT and UNRWA are varied from place to another, and it is unpredictable for the next years or in comparison with meeting the desired output of the proposed plant, however the assumption of average value of Gaza strip potable water is taken from the data observed in statistical studies in 2017 [27].

The MSW disposal costs are included in collection, transportation and landfilling, where the collection and transportation tariff costs takes the majority, the tariff of landfilling is the actual concern of the proposed plant, leaving the responsibilities of collection and transportations for municipalities and joint service councils (JSCs), due to lack of collected data, the tariff of Dier Al-Balah landfill assumed to be the same for the rest of other sanitary landfills, which called in the term of (Gate fees)[14], the following table shows the assumptions taken into consideration in this financial analysis.

	Landfill gate fees (Input MSW)	Average water tariff (Output fresh water)
Gaza Strip current prices	10.8 NIS/tonne	1.7 NIS/m^3

4.8.2. Cash flow and levelized cost of water

Taking into consideration that the stage of acquisition, installation and construction of the proposed plant assumed to be accomplished in 5 years, where in the next few years the facility is to be expanded twice (on a stage of couple of years) to include the MSW generation growth and produce more quantities of fresh water, the gate fees of MSW assumed to be 11 NIS/tonne, water unit price to be 1.7 NIS/m^3 and coal prices to be 60$/tonne, the following cash flow represents the proposed project.



Using excel software, the internal rate of return (IRR) is to be -5%, which means that the project is economically not feasible, and the levelized cost of water is to be calculated as the following formula:

$$LCOW = \frac{sum\ of\ costs\ over\ lifetime}{sum\ of\ water\ produced\ over\ lifetime} = \frac{\sum PW\ of\ annual\ costs}{\sum PW\ of\ annual\ production}$$

Assuming that the inflation and interest rate merged to be 7%, the resulted LCOW is to be 4 NIS/m^3, where it is sold in average nowadays at 1.7 NIS/m^3.

4.9. **Environmental review**

Impacts on the environment from any sort or form of human action is inevitable. However, some actions may be more or less impactful on the environment around both in positive and negative ways. The severity of those actions on the environment can be measured through environmental sciences.

Environmental sciences take into account chemical, biological, and physical parameters to study the environment and discover solutions accordingly. Moreover, it also focuses on climate change, natural resources, energy and pollution. In this research, pollution and energy production techniques will be studied through here [28].

One of the simplest and usually the cheapest ways of waste disposal is landfilling [29]. This is why landfilling techniques are very common in low to medium-income countries. However, when organic waste is decomposed in landfills, various gaseous pollutant products are formed [29]. These pollutants include but are not limited to, carbon dioxide, methane gas, hydrogen, and nitrogen gases with different levels of production. Landfill gases, especially methane and hydrogen, are highly flammable and if they are not collected, and used for energy utilization or flared off, and they will lead to a potential fire and explosion hazards [29].

As a result, countries all over the world are moving forward to finding solutions to use waste gathered from landfills in energy production and generation. Many technologies are being implemented nowadays in most municipalities and governmental entities around the world to reuse waste. Pyrolysis, gasification and incineration of waste are few of the common WtE technologies used. Those different WtE techniques impact the environment differently, but this research focuses on incineration of waste and how it affects the environment surrounding it.

Gaza strip has an average collective production of municipal solid waste of 1330 tonnes/day, with 0.7 kg/day production per capita. Additionally, there are eight refugee camps in Gaza that produce 67369 tonnes of waste per year [14]. This makes landfills in the strip filled by waste and new technologies should be implemented to reuse the waste for energy production.

Different waste compositions produce gases and products at different rates depending on the material. Common materials in waste from Gaza and their negative impacts are summarized in Table 4.1 below [30].

Table 4.4: Ultimate Analysis of waste components

Sample	Ultimate Analysis						HHV (MJ/kg)
	C (wt%)	H (wt%)	O (wt%)	N (wt%)	S (wt%)	Cl (wt%)	
Newspaper	52.1	5.9	41.86	0.11	0.03	n.a.	19.3
Cardboard	48.6	6.2	44.96	0.11	0.13	n.a.	16.9
Recycled Paper	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13.6
Glossy Paper	45.6	4.8	49.41	0.14	0.05	n.a.	10.4
Spruce	47.4	6.3	46.2	0.07	n.a.	n.a.	19.3
HDPE Plastic	86.1	13.0	0.90	n.a.	n.a.	n.a.	46.4
LDPE Plastic	85.7	14.2	0.05	0.05	0.00	n.a.	46.6
PP Plastic	86.1	13.7	0.20	n.a.	n.a.	n.a.	46.4
PS Plastic	92.7	7.9	0.00	n.a.	n.a.	n.a.	42.1
PVC Plastic	41.4	5.3	5.83	0.04	0.03	47.7	22.8

4.10. Project Timeline

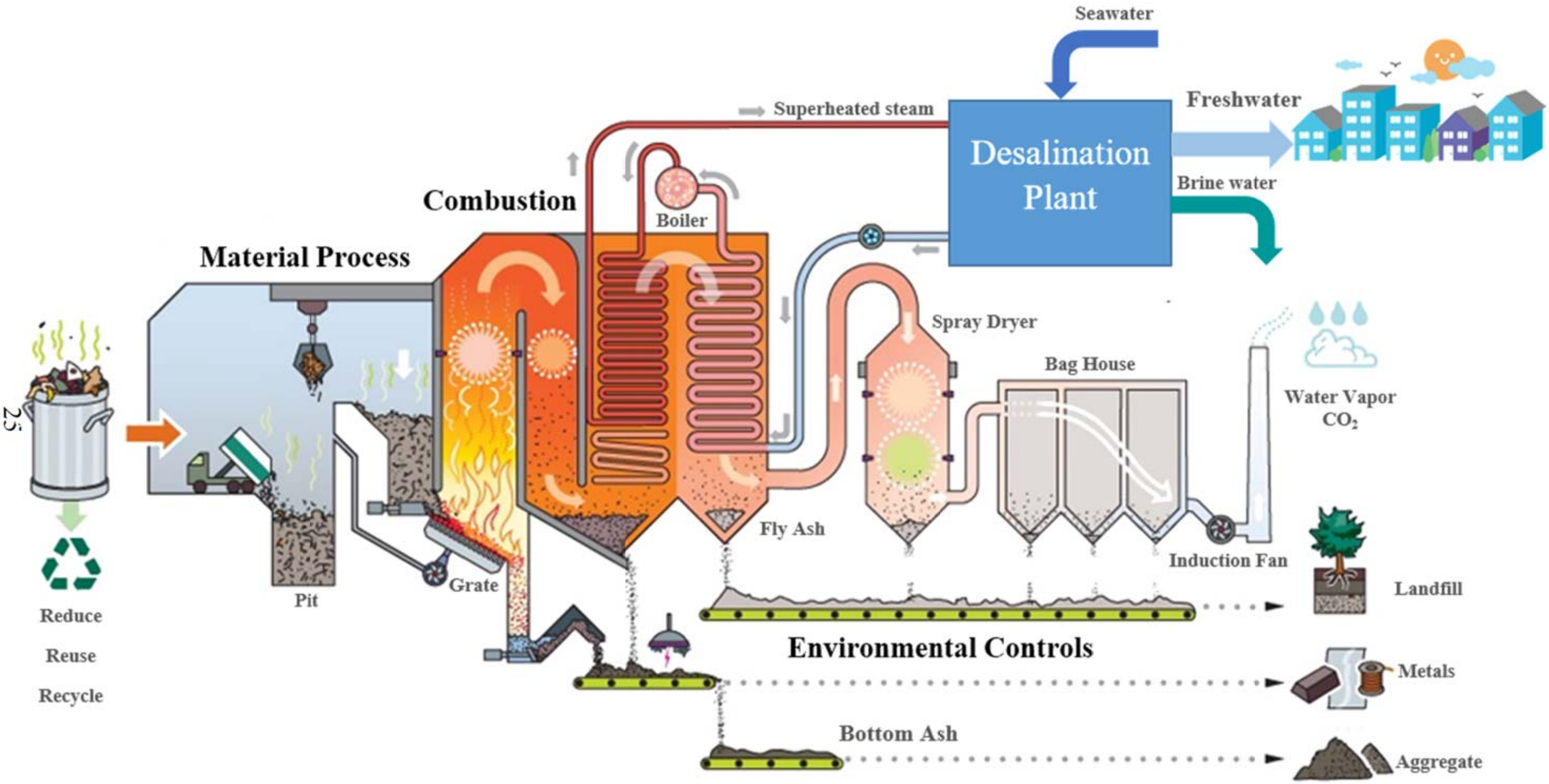
In this section the timeline of the project from the construction of it through the years is shown in the table below. Additionally, the reduction in landfill waste and water generation is shown in Table 5.4 below. This timeline takes into account the population growth rate in Gaza of 2.92% [31], and as a result an increase in waste as well as increase in water demand at the same rate is assumed.

Moreover, the initial sizing of the incineration and the desalination units must be adapted to increase to accommodate to the increase in waste input.

Table 4.5: Project Timeline

WtE and Desalination Plant						
Population	**Year**	**Waste Generation (tonnes/day)**	**Waste input to incinerator (tonnes/day)**	**Water Generation (m^3/day)**	**Reduction in landfilled waste (%)**	**Met Water Demand (%)**
2,097,269	2019	1300	-	-	0	0
2,158,549	2020	1338	-	-	0	0
2,221,619	2021	1377	371	50,346	26.9	22.6
2,286,532	2022	1417	382	51,839	26.9	22.7
2,353,341	2023	1459	785	106,529	53.8	45.3
2,422,103	2024	1501	808	109,650	53.8	45.3
2,492,874	2025	1545	1088	147,648	70.4	59.2
2,565,712	2026	1590	1119	151,855	70.4	59.2
2,640,679	2027	1637	1423	193,109	86.9	73.1
2,717,836	2028	1685	1464	198,673	86.9	73.1
2,797,248	2029	1734	1621	219,979	93.5	78.6
2,878,980	2030	1785	1668	226,357	93.5	78.6
2,963,100	2031	1837	1717	233,007	93.5	78.6
3,049,678	2032	1890	1890	256,484	100	84.1
3,138,786	2033	1946	1946	264,084	100	84.1
3,230,497	2034	2002	2002	271,683	100	84.1
3,324,888	2035	2061	2061	279,690	100	84.1
3,422,038	2036	2121	2121	287,832	100	84.1
3,522,025	2037	2183	2183	296,246	100	84.1
3,624,934	2038	2247	2247	304,931	100	84.1
3,730,850	2039	2313	2313	313,888	100	84.1
3,839,861	2040	2380	2380	322,980	100	84.1
3,952,057	2041	2450	2450	328,979	100	83.2

4.11. Plant schematic map



5. RECOMMENDATION

In the beginning of this research, the general outline of the project looked quite different from the one that was settled on. At first, and to deal with all the problems on hand, a different approach was proposed. After the incineration unit was designed, a cogeneration plant was initially proposed to be placed after the incineration. The purpose of the cogeneration plant, was to achieve a certain ratio between the production of heat and electricity found in a way to deliver electricity to compensate for the deficit in region.

However, after several analyses and calculations, it was found that inserting the cogeneration part to the project decreases the overall efficiency of the plant. Therefore, it is highly recommended that for any future research involved in this project is to eliminate the CHP unit of the project as done in this paper, since providing potable water is a prior to electricity generation, and generation of electricity requires higher quality of produced heat to operate correctly than desalination of water, which means the efforts and costs of raising up the calorific value of the input of MSW in the incinerator.

The option selected of co-firing waste with pulverized coal is proposed depending on previous experiences of incineration facilities uses low quality of MSW [22], that the ratio selected of 4:1 waste to coal ratio can be optimized via intensive study to obtain the best output of water regarding to coal prices, minimum heat input of desalination plant, proper operation of incinerator unit and selling prices of water to consumers.

Choosing the option of centralized or decentralized facilities requires field work for social study to understand the public reaction of holding a plant, depending on which air pollution system (APC) used, where the centralized plant is holding higher concentrations of emissions from one place than decentralized plants which its emissions separated in three different areas, also intensive environmental study required for the effect of brine water disposal in the sea of Gaza strip, and emissions of stack gasses around the high density population areas.

One thing that must be taken into consideration as well is the fact the occupied strip of Gaza has limited to no free trade in and out of the region. This puts a lot of stress on the work of the project since the coal supply is controlled by the Israeli occupation which can be varied by any political or economic unrest. Additionally, most of the electricity supply to the strip is supplied by the Israeli occupation as well, which in fact can negatively affect the work flow of the project.

6. CONCLUSION

This study focused on reviewing the options and alternatives of waste to energy facilities around the globe. A comprehensive study has been made to establish the optimum combination of the options on hand. This research studied alternatives of waste-to-energy technologies and desalination plants. Additionally, the conditions in Gaza strip were reviewed to find the possibility of executing the chosen options. This project proposed to mitigate and possibly solve two of the major problems occurring in the world and in Gaza. These problems are municipal solid waste management and water scarcity.

Starting off with MSW in Gaza, it was analyzed to find the optimum energy extraction possible required for further steps. Then, incineration technology was chosen to be used in the project paired with implementing ways of co-firing to increase the calorific value of waste incinerated to increase the incineration efficiency. As a result, the environmental impacts of the project was studied to find the severity of the project.

After that, a comparison between centralized and decentralized scenarios were studied and their parameters were compared. Lastly, a timeline of the project has been drawn in order to predict the development of the project over the course of work in the project.

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