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Town Massive Garbage –To - Energy for Maputo City in Mozambique

Subjugated

In Lopsided Fulfilment of the Exigencies to the Grade of

MASTER IN TECHNOLOGY

(RENEWABLE ENERGY)

BY

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STUDENT DECLARATION

I, **FERNANDO AGOSTINHO DZECO** from Maputo, MOZAMBIQUE, do hereby solemnly affirm and declare that this Thesis titled "**TOWN MASSIVE GARBAGE –TO - ENERGY FOR MAPUTO CITY IN MOZAMBIQUE'' is** Subjugated In Lopsided Fulfilment of the Exigencies to obtain the Grade of **MASTER OF TECHNOLOGY (RENEWABLE ENERGY) in the Electrical Engineering Department, Alakh Prakash Goyal Shimla University, India, is my original paper done with the Guidance of Dr. Anand Mohan.**

The thesis was never been support for distinction to diploma or other grade in any none University or Institution. The dissertation is original, other than for material that is plainly identified as for the originating source, with authorization warnings from copyright owners where essential.

Fernando Agostinho Dzeco

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ABBREVIATIONS

AD – Anaerobic Digestion

BTT - Biological treatment technologies

COCO – Cape-Open To Cape-open

CFB – Circulation of fluidized bed

CHP – Combination of Heat and Power

COFE – Cape – Open Flowsheeting Environment

COUSCOUS - Collection of Unit Operations

CORN – Cape- Open Reaction Numeric

DTG - Derivative Thermo Gravimetric)

MBT - Mechanical Biological Treatment

MSW - Municipal Solid waste

NSI - National Statistics Institute

SDGs - Sustainable Development Goals

LCA -Life cycle assessment

LFD - Landfill Gas

PFD - Process Flow Diagram

RDF- Refuse Derived Fuel

TEA - Thermodynamic system for Engineering Applications

TMG – Town Massive Garbage

WtE - Waste – To - Energy

INDEX

ABSTRACT

The growing development nowadays on Mozambique is directly associated to the crescent industrialization and the increasing number of the population on enormous cities of the Nation, what needs more electrical energy and produce more garbage; uncontrolled and putting it in a challenge to face this scenario. Maputo City is facing huge problem with the Town Massive Garbage (TMG), without the structure to treat it, which deposited in the open dumpsite out of normal conditions, contributing for many diseases and environment impact, when it is burnt or it burns spontaneously, the subterranean water body is contaminated with leachate (methane); and proximately 72% of population or citizens have not electrical energy.

The intention of this task is principally to turn the Town Massive Garbage into electrical energy in Maputo City the capital of the country, taking on the different technologies according to the garbage's conditions and increase the capacity of energy which is approximately to 20% on the Country and to reduce the impact of environment from the landfill and, the number of landfill and dumpsites, working and attempting to achieve the sustainable development goals. The country has been recording constant interruptions of power supply due to increased energy demand resulting from the development of their Citizen, construction of new industrial, hotel and Office building together with housing.

The motivations is to apply garbage as other innocuous source of power or energy, knowing that in the country mainly hydropower and solar, wind, biomass in a small quantity, coal, fuel are vanishing; reduce the impact of environment, global warm and ailments caused by it.

The methodologies used to achieve the objectives are thermodynamics, heat transfer expressions and the COCO-OPEN simulation methodology to predate the energy generate from the composition and quantity of MSW.

The results illustrates the possibility to enforce Town massive Garbage as source of energy or power, clearly taking in account the track conditions, as the heating value of it is nearly equal to the coal value which has been used to generate energy in many plants around the world.

Municipal solid waste should be the future source of electricity to many developing countries if they create the structure to deal with it, treating, separating in different categories, controlling the place to

deposit, what will decrease the environment impact and the problem of non renewable source vanishing as well as coal, fuel oil even hydropower as in Maputo city does not receive the water from the rain some years.

From this work is expected to know how much electricity can be generated using the Town Massive Garbage produced in the City taking it as the renewable source of power or energy, increasing the percentage of energy from the grid in the country, mainly in the rural zone, nearly 70% of the country is rural, which is too much low, considering the growing of the Population and the industrialization.

Generating electricity from the Town Massive garbage is hoped to minimize up to zero the environment impact and uncontrolled open dumpsites adding the renewable sources to overcome the replacement of fossil fuel as well as other non renewable sources which are vanishing and are responsible in great part of the green houses gas and acid raining for instance.

It is either waited to increase the nation economy on the other hand, providing job for the citizens, and the electrical energy for the households and lessen the ailments and accidents from the open dumpsites.

Reducing the impact of the environment and increasing the electrical energy will surely provide one pass to achieve some sustainable development goals, for instance:

- **Raise Towns and Human settlements inclusive, out of danger, welfare, resilient and sustainable,**
- **Prompt immediate share in order to oppose a atmosphere and impingement variation,**
- **The whole population must access less expensive, sustainable and reliable energy,**
- **Proper and garbage sustainability.**

Town Massive Garbage to power or energy will reduce landfill and open dumpsites, achieving some sustainable development goals (SGs) and, offer job for households increasing the country economy.

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CHAPTER I
INTRODUCTION

1.1. Experiment and Issues Declaration

Energy means life, and if this development of the people keep growing day after day, what result in the need or huge use of the energy than before, turning less the scarce energy sources or increasing the impact on the environment by using fuel fossil, one of the harmful and responsible of the emission of green house gases. Because of its importance, many countries has been trying to find the solution for vanish of non renewable source. Waste is death, Waste is the future alternative as source of energy and manifold garbage-to-energy technologies are in use around the world illustrating excellent result; They are finding solid waste as useful and are importing municipal solid waste to generate energy and power, what has been putting their economy stable in one way.

The Population and Industrialization grow with generation of different kinds of waste accord to the type of country, whether is developed or developing; balancing the economy much time.

Many developing countries even as Mozambique use to expend tremendous amount of money with the municipal solid waste, and space, which should be resorted for other social infrastructure, like schools and hospitals to serve the needs of their citizens and the economics of these, instead of creating landfill or open dumpsites, answerable of different types of diseases and emission of green house gases, acid rain, global warming caused by the fire on the it , and sometimes life is lost when landslides accidents occur, contamination of surface and ground water from leachate; offensive odours and fires; methane, collapse of waste mountains leading to the loss of many lives; see table number 01, returning the sustainable development in risk; besides this, those countries have about 80% of their habitats without electricity for any kind of activity.

Open dumpsites brings forth the procreation of mice, cockroach, flies, as well as many others pests mainly before the winter’s time The most ailments common in the population dwelling by the dumpsites and responsible of huge deaths in Mozambique are: cholera and malaria.

Table number 01: Accident on improper waste disposal [82]

Month and year	**Country and City**	**Number of victims**	**Cause of accident on the landfill**
February 2018	Mozambique, Maputo	16	collapse
August 2017	Guinea, Conacry	9	collapse
March 2017	Ethiopia , Addis Ababa	115	collapse
September 2016	Benin , Cotonou	Over 100	Fire

On these open landfills or dumpsites the managers of them burn garbage to minimize the quantity collected or it burns spontaneously. The action results in huge pollutants (GHG) emission in the atmosphere in the order of more than 20000 tonnes released per year; those are responsible in great part of groundwater and contamination.

Maputo city has a Population around 1.9 million, whom produce more than 1100 ton/capital/garbage in 24 hours. Some literatures say that $10 to $25 per ton is the cost of collection of the garbage only. Counts take us to approximately more than $15.000 per day, $450.000 per month and $ 5,4 Million per year.[17]

Mozambique is gifted with a distinguished hydro, coal, natural gas, solar and wind sources of energy, nevertheless above approximately 70% have not electricity or they are not connected to the country's energy grid; the vanish of non renewable source is another issue, what illustrates the need of others harmless source of energy; as garbage, agriculture crap should be considered as alternative source of energy, and they are economically practicable besides sustainable environmental.

That is why emerge this small work "municipal solid waste management to Mozambique", which just comes to answer some questions. Such as:

- Why some countries are importing waste to generate energy and others are expending money trying to manage the waste and their people losing lives beneath the dumpster?
- How to get the benefits of the municipal solid waste produced every day by us, turning our world a harmless place without the green houses gases?
- Which is the suitable technology for waste-to-energy to developing countries, as their solid waste has a low calorific value?

The literature review was used to attain the objectives of the work, where more than sixty papers, articles, journals and publication, sites as well as Google Scholar, YouTube from 2015 to 2020 used, and to analyse composition, calorific value, characteristics, and to estimate the amount electrical energy generate or heat recovery and the environmental conditions parameters will be done by the help thermodynamic, transfer

mass and transfer heat expressions. One of the important simulation for the chemistry engineering called Cape-open to Cape-open can be used to predict the energy generate for incineration, gasification and pyrolysis associating the whole plant. Of COCO (CAPE-OPEN TO CAPE –OPEN) Simulation Software, combined to the thermodynamic and heat transfer expressions.

The incineration methods needs first a high calorific value, second huge money for maintained, problems of green house gases emission, corrosion of the furnace because of the presence of hydrogen sulphide (H_2S), and must be installed far the habit places, cost of transport to feed the plant with solid waste from long distance and big space plant operation. The others technologies do not require necessary the `high calorific value and need little area for the plant, what turn them ideal for the city; less cost of transport, less or nearly zero green house gases emission and operated wet waste or plastic gasification and gasification plant; this last has advantage to be genuine and produce methane and carbon dioxide by disintegration of the garbage in the controlled landfill to avoid the groundwater as well as land infection.

Anaerobic digestion, landfill gas, gasification and pyrolysis technologies are suitable for municipal solid waste in Mozambique, according to the composition, heating value and Town Massive garbage condition.

The country is wasting amount for money attempting to manage it, so garbage becomes the issue to the Nation economy, that is why the necessity to minimize the cost which is keeping increasing with the number of new activities, business, household and the population, as well as town massive garbage to energy plant is one step to decrease the cost and harmful pollutants released into the environment; assuming that modern incineration, pyrolysis, landfill gas, gasification plants are harmless by producing limpid energy can substitute fuel, nuclear, coal plants some of the responsible of global warming and green houses gas emissions.

From this work is expected to know how much electricity can be generated using the Town Massive Garbage produced into Maputo Town taking it as the renewable energy source, increasing the percentage of energy from the grid in the country, mainly in the rural zone, nearly 70% of the country is rural, which is too much low, considering the growing of the Population and the industrialization.

Generating electricity from the town massive garbage is hoped to minimize the impact of environment nearly to zero and uncontrolled open dumpsites adding the renewable sources to overcome the replacement of fossil fuel as well as other non renewable sources which are vanishing and are responsible in great part of the green houses gas and acid raining for instance.

It is either waited to increase the nation economy on the other hand, providing job for the citizens, and the electrical energy for the households and lessen the ailments and accidents from the open dumpsites.

Reducing the impact of the environment and increasing the electrical energy will surely provide one pass to achieve some sustainable development goals.

More studies have to be conducted just to find out the technology to be standardized to the Country and achieve others sources of energy beside organic matter, papers, plastics, wood, agriculture waste..

1.2. Country Mozambique Profile

Mozambique is fund in the South eastern region of Africa, coordinates 25.9500º S, 32.5833º E, with total area of 786,380 km^2, Maputo City is the capital. The country's eastern border lies along the Indian Ocean. Despite its large area, the country only has a Population of approximately 30.8 million (2019) where 64% are rural. The Nation's extensive border bounder land touches six neighbouring countries: Tanzania, Zambia, Malawi, South Africa, Swaziland, and Zimbabwe. It is a developing country with gross domestic production per capita 498.96 USD (2018), gross domestic production growth rate 3.7% annual change (2017).

Figure 01: Mozambique Map [77]

Table number 02: Population of Mozambique

Year	Population
2019	30 366 036
2018	29 496 004
2017	28 649 018
2016	27 829 938
2015	27 042 002
2010	23 531 574
2005	20 493 292
2000	17 711 927
1995	15 483 286

Population of Mozambique (2019 - 1995)[70]

Table number 03: Forecast of the Mozambique Citizens

Year	Population
2020	31 255 435
2025	35 984 620
2030	41 184 834
2035	46 786 293
2040	52 729 200
2045	58 928 294
2050	65 312 929

Mozambique Population Forecast (2020 – 2050) [70]

1.3. Profile of Maputo City

The store of the City comes from the many years ago, it was called Lourenço Marques in the colonialism period for 585 years, and becomes Maputo City very before the freedom of Mozambique in recognized to the Tembe tribe chief Maputsu I, whom belonged the Tsonga People Subgroup. Maputo city is situated in the southern of the nation; Gaza, Inhambane and Maputo are the neighbour Province, with 348 Km^2 of the land space. Its Citizens keep increasing because of the commercial activities the town flag responsible for

immigration. The national Statistics Institute (NSI) considering the last census 2017 estimates 1 808 457 inhabitants.

Table number 04: Population of Maputo city.

year (census)	Population
1997	801 449
2007	1 205 709
2017	1 908 078

Population development in Maputo City [70]

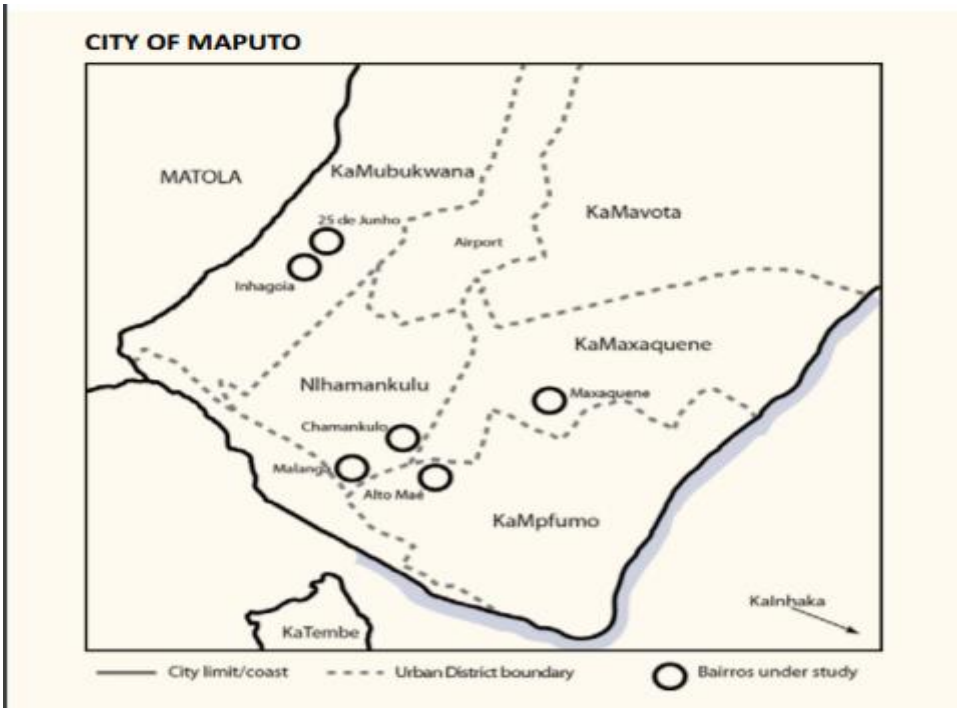


Figure 02: Maputo city Map

1.4. Disposal Municipal Solid Waste in Mozambique

The collection of waste that is disposed at the local dumpsites in the inner city of Maputo increased profoundly from 76 million kilograms in 2007 to 253 million kilograms in 2014, posing the challenge of how to collect it and where to dispose, the Maputo municipality is using different manners from tracks to gathering garbage around the big avenues and street in the inner city with the help of some privates companies dealing with trash, outer city other private collect waste in the enormous bins brought by wheel bays which pass house by house to collect the waste joint to the households, from where start the environment impact because it is done in improper way posing in risk the workers as the producer of the

garbage, uncovered bins and the wheel bays move all the streets. This increased collection reduced the uncollected waste mass from 300 million to 158 million kilograms, what illustrate the necessity to do more waste management activities [1][5][34].

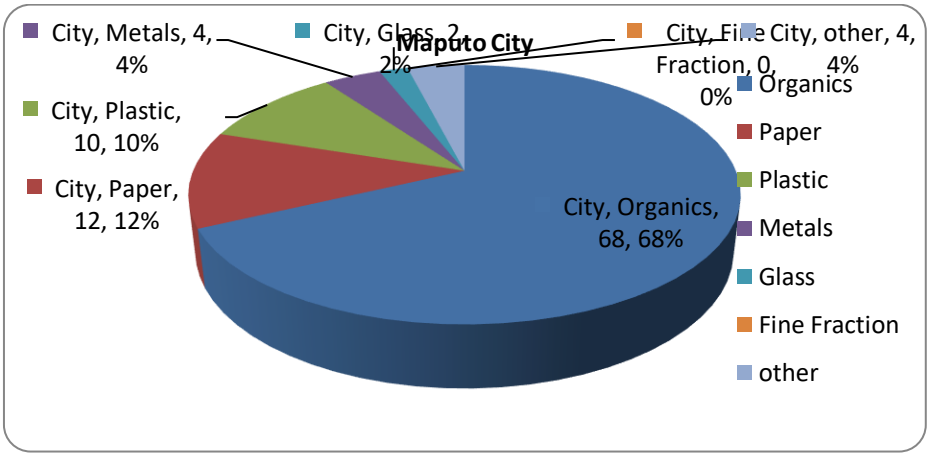
Municipal Solid Waste in Mozambique is dumped in basic open-air dumpsites in all municipalities [6]. At waste dumps, waste is generally burnt, buried and compacted. As most dumpsites are situated within the city centre, burning of waste causes air pollution and may release toxic chemicals to the environment harming the nearby residential areas.[5][6][34].

The largest waste dump in Mozambique is Hulene site in Maputo. It is situated in a suburb of the city, about 120 000 m^2 large, and the only legal dumpsite in the city it receive all kind of garbage generated in the town. [5][6][7]34][8].

It is built upon a former wetland in close proximity to the Hulene river which serves as the source of water for the city residents. The site is also threatened by a high water table. The underlying soil is sandy and hence highly permeable. With these conditions, it is very possible that the leachate from the dumpsite can enter and pollute the nearby river and groundwater.[1]

1.5. Composition Town Massive Garbage in Maputo

The composition of town massive garbage of Mozambique in Maputo according to the Graphic number 01, is approximately equal to some Europeans, Asiatic, Americas and Africans cities; which are using the garbage as the source of renewable energy turning their towns safety and very less environment impact, free of dumpsites or landfills and with good economy at all. The 1.8 million inhabitants in the city of Maputo produce a total of 676 000 kg/day of MSW and the total waste production is close to 980 000 kg/day when industrial waste is added. The MSW composition depicts a clear difference between the city and the suburbs [3]



Graphic 01: Maputo City Genaral composition of Tonw Massive Garbage [3]

1.6. Scenario of Energy in Mozambique

Looking to African scenario of energy Mozambique is consider as making part of the highest energy potential generators countries, second the literatures the Nation produce approximately 2 500 MW, although nearly 71% of the population have no power or energy from the main grid; many problems are illustrated as the reason of bad transmission and distribution of the energy in the Nation, taking the example of lackage of money but the principal is the continues war and the extension of it; the energy generated in the country is uncontrolled, there is no rulers or policies for the distribution of energy, and much energy is waste because of it, no energy efficiency and saving policies to regulate the situation cause by the negligent workers.

Among many sources of energy in the country like, Hydropower, tidal, solar, wind, biomass and geothermal, the mainly font of energy is hydropower plant which generate to the country and to the neighbouring countries, for instance Malawi, Zimbabwe and South Africa.

The increasing numbers of industries, households, schools, hospitals are posing in risk the demand of energy forcing the need of more and more source of energy, renewable energy is the keen and is coming in a very small capacity to reduce the energy demand, energy efficiency and saving are not took in consideration yet. .

CHAPTER 2
LITERATURE REVIEW

2.1. Literature Survey

(Sallwey, Hettiarachchi and Hülsmann, 2017) explained that Municipal Solid Waste in Mozambique is dumped in basic open-air dumpsites in all municipalities [20]. At waste dumps, waste is generally burnt, buried and compacted. As most dumpsites are situated within the city centre, burning of waste causes air pollution and may release toxic chemicals to the environment harming the nearby residential areas. [1]

(Atul Kumar, S.R. Samadder; 2017); Provided technologies which are capable to generate energy from garbage onto efficacious energy recuperated as well the difficulties faced by many countries; which are: incineration, pyrolysis, gasification, anaerobic digestion, and landfill gas.[9]

(Gupta, Srivastava, Kumar Agrahari and Detwal, 2018); Reported that municipal solid waste generation and management are the challenging problem to the developing countries. However, waste to energy technologies are used to produce various by products like electricity, heat, compost and biofuels. The waste to energy technologies mainly are incineration, pyrolysis, gasification, composting and anaerobic decomposition. [17]

(Andreadou, Christina, 2015); Studied the modelling of a Fluidized Bed Combustion Boiler CHP plant for energy production from MSW of Thessaloniki, by using the COCO simulation software. Taking three cases with three different pressure types of fluidized boilers have been examined. The boilers pressures that have been studied are 2MPa, 5MPa and 10MPa. Apart from the boiler, each potential CHP plant consists of a high and a low pressure turbine, a condenser and a low pressure pump. Simulation models for these different cases have been developed and validated against available experimental data.

(Tangsathitkulchai, Punsuwan and, Weerachanchai, 2019) working with the commercial COCO simulation program was used to mimic the experimental slow pyrolysis process of five different biomasses based on thermodynamic consideration.

(Dong, Tang, Nzihou and Zhou, 2018) compared the Incineration and gasification technologies in term of life cycle assessment and found that the overall environmental performance of the gasification system is better than incineration. The use of gasification technology, attributed to an intermediate syngas purification step, can provide benefits of both reducing the stack emissions and increasing the energy efficiency.[18]

2.2. Technologies of Waste –to – Energy

The developed of many countries come with the town massive garbage issues, what take or provide the idea to minimize the situation, recycling, educing, reusing the garbage a part of these different initiatives is the garbage –to- energy technologies just to maintain the ecosystem and environment equilibrium. Three are numbers of technologies to turn waste into energy which have been developed nowadays each one with its characteristics, general example are: Thermal conversion, Biological Conversion and landfill gas recovery.

Each month millions of tons of waste are produced. This causes huge environmental impact in terms of wildlife, ecosystems and to human health. Keeping this in mind, many new waste treatment plants have come up and have developed new ways to generate energy from landfill waste. Municipal solid Waste –to-energy is a smart form to manage the municipal solid waste which has been increasing according to the development of the country.

A variety of waste conversion processes are available, in which the three most widely used technologies are;

- ✓ Thermal conversion - (incineration, pyrolysis, gasification, production of energy from refuse derived fuel (RDF), plasma arc gasification, plasma pyrolysis)
- ✓ Biological conversion (anaerobic digestion); and
- ✓ Landfill gas recovery.[9][10][15]

These different technologies will deal with the town massive garbage in varies way, minimizing and providing a safety place to stay and dwell , low environment impact control of all kind of waste and improve the country economy generating energy for industrial, household and government respectively.

2.2.1. Thermal Conversion Technologies

Thermal refinement processes and energy extraction from municipal solid wastes are utilized successfully around the world. These technologies will cause a quick weight (about 70 to 80 %) and volume reduction of waste (80-90 %). Therefore, it will result in reduction of required land areas in landfill centres; this method is suitable for areas facing a shortage of space and the garbage with high organic composition as the technology has capacity to treat this matter generating energy, gas and oil of the fuel, it is functional with dried garbage [15][9].

These technologies will be useful for Maputo, looking for the composition of the town massive garbage produced by its citizens, industries and commercial in their daily activities to achieve the expected development.

2.2.1.1. Incineration

Incineration (figure number 04 illustrates the scheme of the incineration technology) is used in the treatment of town massive garbage consisting on burning it to reduce its volume, development of the science and the necessity to salvaged the environment impact and the emission of green house gas, modernity incineration plants a useful to produce energy, they heat a boiler to generate steam with run the turbine a coupled to the generator which by this way produce energy to the grid and feed the household, nowadays is equipped in such manner that the process release low harmful pollutants, turning the commonly helpful for many developed and developing countries to control the waste disposal as it destruction completely the garbage.

Incineration technology of waste to energy as it uses homogeny municipal solid waste, waste pre-treatment has to be done to turn more efficient the process reducing the presence of inert wastes and harmful pollutants general example; mercury and chlorine, not wet waste at all and with a calorific value near to the coal, just to not need any additional component, this technology is used in countries which have got high calorific value, as well as developed one.

The disadvantages of incineration technology is concerning the huge costs of construction , operation and maintenance, environmental impact, human health, population in the plant of incineration use to oppose it because of the air pollution, the presence of hydrogen sulphur, chloride salts, chlorine and sulphur in the process which are responsible of the rapid corrosion.

Mozambique has to strictly work with the regulations to decrease the quantity of polluting emissions of harmful substances as: nitrogen oxide, hydrogen fluoride, sulphur dioxide, carbon monoxide and nitrogen dioxide, traces of dust and heavy metal for instance volatile one, in its gasification and incineration plants.

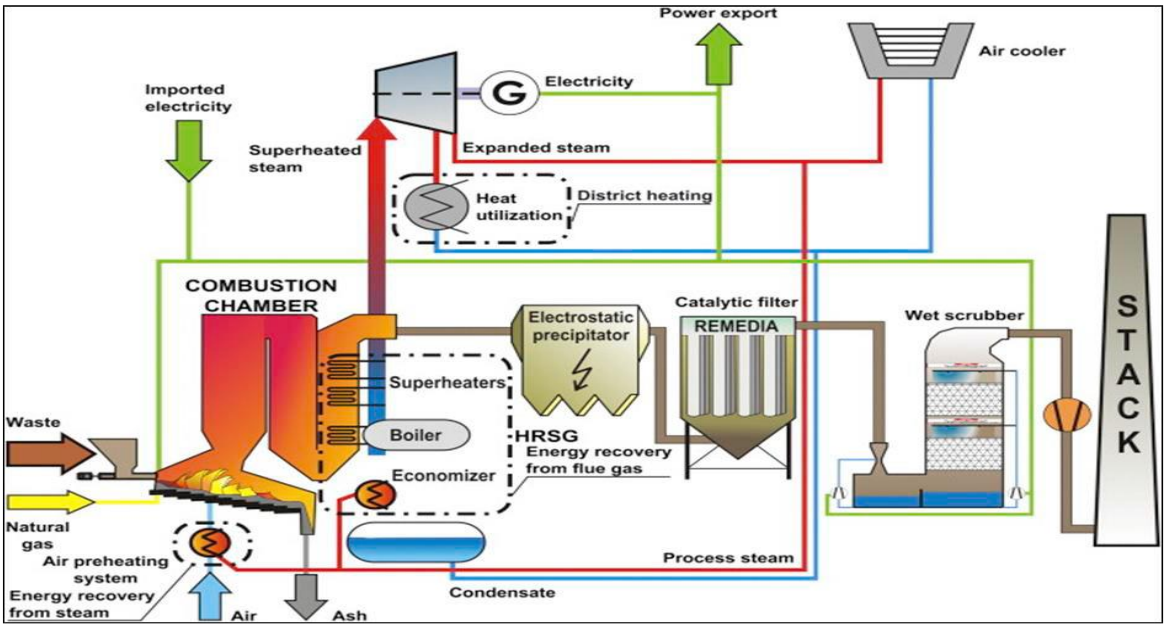


Figure 03: Scheme of Incineration plant of TMG.

2.2.1.2. Pyrolysis

Pyrolysis technology play a good role to the developing countries as Mozambique according to their garbage composition and condition to minimize the organic garbage the high component of the waste generate by different activities on them, because it decrease in more than 92% this kind of trash, the process is done without oxygen needing the additional heat to keep the thermal degradation around 310 degrees Celsius.

Technology generates huge gases as: carbon dioxide, carbon monoxide hydrogen and methane, forming the synthesis gas important to produce energy.

The advantages of pyrolysis process are: the equipment is flexible for installation; waste separation is not necessary; there are minimum environmental issues; all waste materials are used to produce different bio-products; and the produced synthesis gas can be used in different energy applications such as engines, boilers, fuel cells, turbines and heat pumps. The gases can be burned to produce energy, and, these gases can be condensed to produce bio-fuels. [10]

The advantages of the process are: the capacity to decrease garbage compost with tyre, plastic, electric, wood and electronic material responsible for the quality and it has the efficiency around 30 – 45% .

Pyrolysis has capacity to reduce the Municipal solid waste volume in about 93% with emission of none harmful gas to the environment, the process content more energy recovery what add it's efficiency.

it uses wet waste and heterogenic and need a small space, reducing the cost of transport as it can be developed in the City.

Pyrolyzer, heat exchanger, gas turbine, generator and synthesis gas are constituent of the pyrolysis technology plant to generate energy, clean energy harmless renewable energy, the figure 04 shows the scheme of the town massive garbage using the technology.

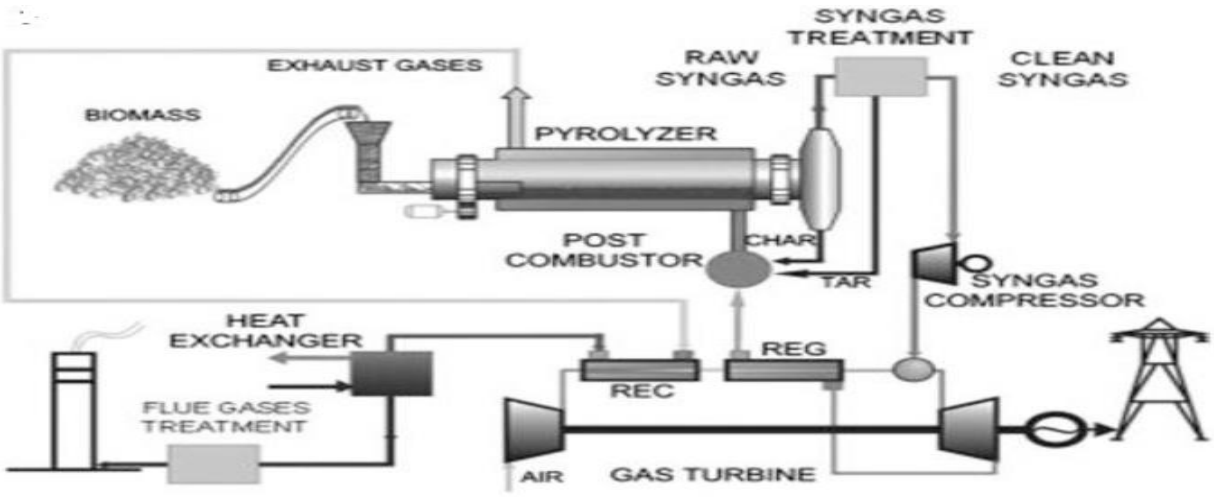


Figure 04: Pyrolysis Process of TMG to Energy [10]

2.2.1.3. Plasma Pyrolysis

Plasma Pyrolysis is adapted to manufacture synthesis gas via modification of plastic refuse having elevated heating value; it is the loudly far gone techniques and generates synthesis gas of hydrogen-rich source of electricity, and inactive material for construction. It is a future technology to minimize the massive garbage recovering the energy on it.

In this process, the nature of most of organic wastes converted to liquid, gas, and solid inside a reactor without oxygen and in effect of heat changed due to an external thermal source (900- 1700 0F). It usually is achieved under high pressure and temperature. One of the disadvantages of pyrolysis is high expense of manufacturing and sustaining internal power to generated coal.

2.2.1.4. Gasification

Gasification Ignition is accomplished with attendance of lessen oxygen to the normal stoichiometric value, this gas is employed in the boilers and turbines. The advantages of this technology are; the capacity to be implanted in a small space, minimize the garbage in the order off 85% with lessen emission of harmful gases, generate heat and electrical energy, affordable process, it is harmless and the presence of methane, hydrogen, carbon dioxide, the admixture of gases whereby hydrogen into the synthesis gas turn the technology with high capacity to generate energy.

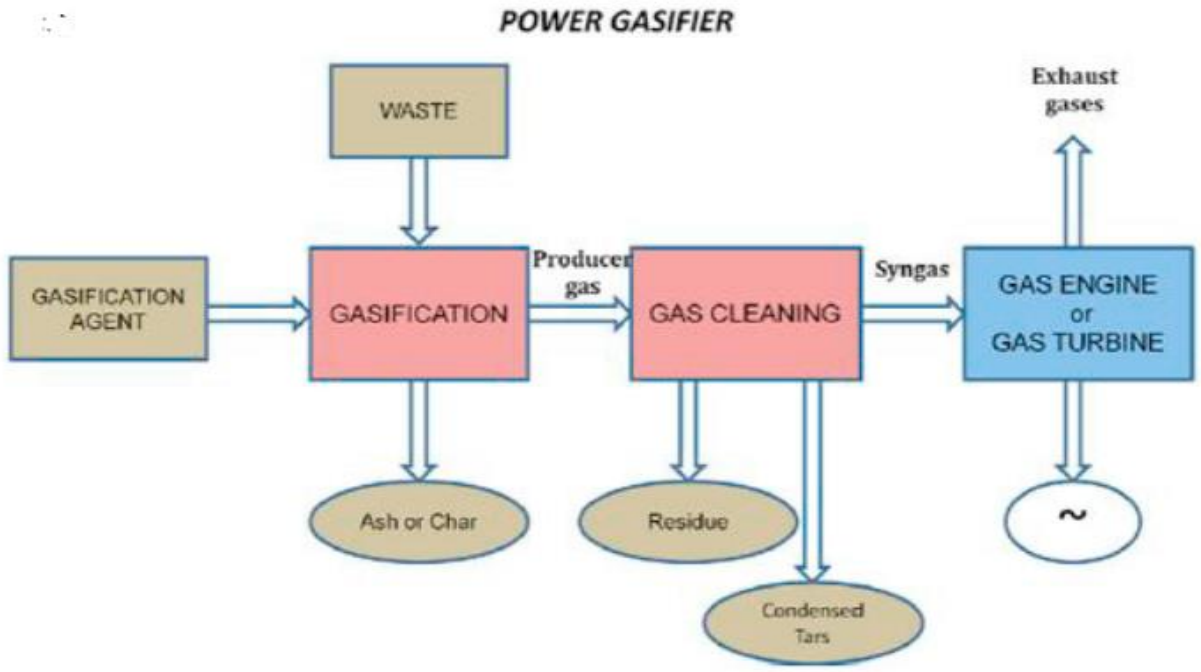


Figure 05: MWS to Energy Using Gasification Process

2.2.1.5. Arc Plasma

Arc Plasma technology had influence in urban wastes management from late 1980s in Europe, but its facility has not been implemented in complete scale for them, the fast decomposition of garbage and the process of turning them into gas (slag) is possible because of elevated heat of the technology, the slag the source of clear energy.

Slag is a solid glass material that is potentially neutral. Among advantages Plasma system, as it is designed in a modular and compact format, provides the possibility to use synthesis gas as much as a clear fuel, and affordable from economical viewpoint The cost of investing and implementing one unit of incinerator powerhouse with plasma reactor was evaluated as 350000 tons/year that is equal to 80 -100 million dollars and its production takes 18 months.[15]

2.2.2. Biological Conversion Technology

These treatments are divided into two different processes according to the conditions in which happen: the aerobic process or composting (in the presence of oxygen) and the anaerobic process (in the absence of oxygen). The main product of the anaerobic process is a combustible gas which is a mixture of methane and carbon dioxide. This process requires less energy than the aerobic process and creates much lower amounts of biological heat. The biodegradable fraction is converted into a fuel known as biogas. This biogas is burned to produce heat and electrical energy. [10]

In these methods, biological resources are applied to produce electricity, heat, and fuels, which are used in the transportation industry. In these technologies, biological materials are products of metabolic actions of living creatures used as fuel due to their high thermal values. Methane, obtained by the anaerobic digestion process, is one of the most important biologic products.[15]

2.2.2.1. Anaerobic Digestion

The decomposition process of biomass resources is conducted by bacteria, anaerobic and produced methane and by products with average thermal value in them. The clearest appearance of this process is in landfills. Recently, reservoir digesters have become very noteworthy. Result of biological decomposition, is a flammable gas called biogas.[15]

This gas includes two general components; methane (and a small amount of other hydrocarbons) and carbon dioxide along with partial values of impurity like H_2S, vaporized water, and N_2 etc.

Biogas technologies are classified as ‘wet’ and ‘dry’ techniques. Wet technologies process more liquid material whereas dry technologies treat drier materials. Table 1 illustrates the advanced anaerobic digestion technologies to produce biogas, their advantages and disadvantages. In general, ‘wet’ anaerobic digestion

technologies have been adopted in well-established systems to treat municipal wastewater. The digestion process produces biogas and decontaminated water [13]. 'Dry' anaerobic digestion technologies operate with higher solid content and produce greater heat [14].

The production of biogas reduces the amount of waste and, therefore, reduces the amount of waste for disposal in landfills. This biogas is usually used in two ways: to generate electricity and to produce heat in different required processes [15]. Anaerobic digestion is used to recover both nutrient and energy from biodegradable waste. Reported that, the quality (as a fertiliser) of solid products of anaerobic digestion depends mainly on the quality of feedstock (proteins, minerals and vitamins content of waste) The anaerobic digestion processes are mainly of two types, ''wet" (10–15% of dry matter content), and ''dry" (24–40% of dry matter content) processes [36][10].

The anaerobic digestion beside the energy regeneration in the town massive garbage, the process have be useful in the it domestic sewage, trash of agricultural, garbage of organic and animal manure as well, and at all one of the cheapest technology from all and environmental friendly, what shows that is very suitable technology for Mozambique as well as for others developing countries.

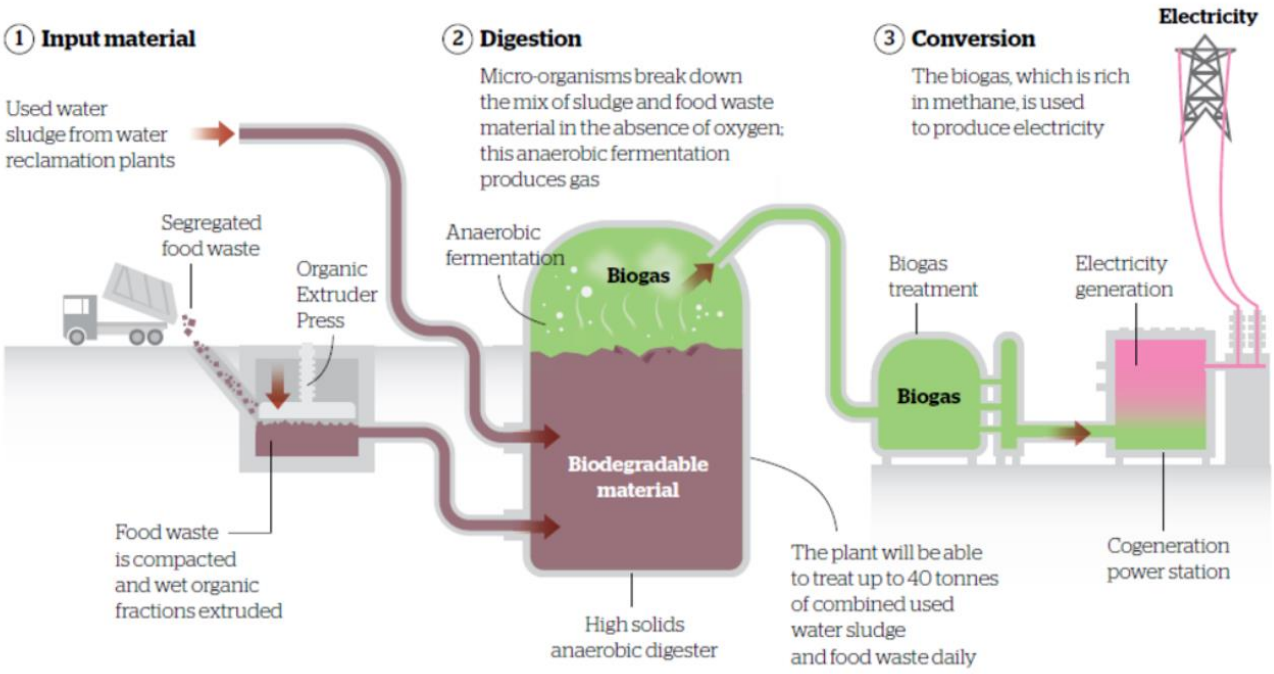


Figure 06: Anaerobic digestion of MSW to energy

2.2.3. Gas of the Landfill Generation

The decomposition and degradation of the town massive garbage results always in generation of gases methane and carbon dioxide harmful and responsible impacts in the environment around the world,

contaminating the land and the groundwater posing in risk the population which drink or have as a row material.

Gas of the landfill is a technology or solution to minimize the gas methane from the garbage; it uses the methane to generate energy along the cogeneration plants. The technology is nowadays applied in the global and Mozambique can cut of the issues of uncontrolled dumpsites with it.

The advantages of the process are; the use of the space to disposal the waste, after the decomposition generate energy and after complete the formation of gas methane the space may be useful for others activities and it can be used in different manners as Stirling cycle engine, Organic Rankine Cycle, Solid fuel cells and gas turbine in Brayton cycle[10].

The Figure 08 provides the operation of the landfill gas technology; three steps are the mainly important, from gathering, treatment and the use of Methane.

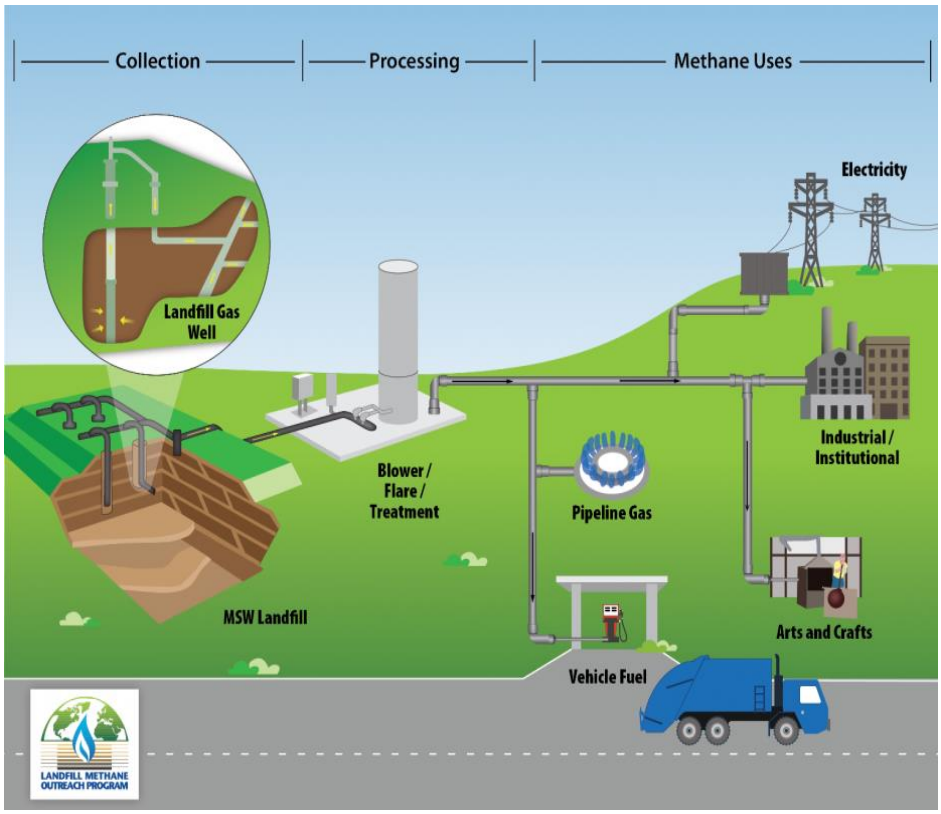


Figure 07: Landfill Gas to Energy Process [10].

The simplest process employs buried piping installed in the landfill to gather the gas, coming after it the treatment and different uses. Landfill gas is suitable for the condition of the waste in Maputo and Mozambique.

2.2.4. Need of Garbage to Energy Options in Mozambique

Mozambique is facing issues with the energy demand caused by its rapid growing of population as of the industrialization immigration, centre of commercial besides many others activities developed by its citizens, those activates come with the produce of one matter useful and rich of heating value essential element to produce energy, here comes the necessity to apply the town massive garbage -to – energy.

Nowadays only less than 20% of the country population has energy from the grid, mainly into the big cities, the challenges is to achieve the rural areas with affordable energy as will be used the garbage produced on this area.

Non renewable source a vanishing reducing by this way the sources of energy, another fonts are needed, garbage, wind, solar are good for replace them. Mozambique has got pretty condition to introduce the garbage –to – energy, space, row material and manpower and thoughtful ones.

2.2.5. Countries and Different Technologies

The world is using the garbage as source of renewable energy in umpteen distinct technologies depending in the condition of the solid waste, activities and the economy, developing and developed ones, reducing many issues on it, for instance; environment impact, deforestation cuts of trees and, used as source of energy biomass , global warming, impact of air pollution, pollution of groundwater and emission of green houses gas from open dumpsites, recent studies illustrate the necessity to take massive garbage to win the depletion of non renewable energy turning the world safety and sustainable.

The world is doing a big enforce just to minimize the infection and town massive garbage approximately to zero, generating energy from the municipal solid waste, increasing their economy and providing job for citizens. The examples of the countries are: Mozambique, India, China, Japan, Sweden, Unites States, Italy, Denmark, France, Germany ; UK, Turkey, Egypt, Kenya, Ethiopian Canada, Australia; they are using incineration plants based on circulating fluidized bed, combination of gasification and pyrolysis, fixed bed gasification using pyrolysis, a gasification plant , thermal treatment plants and plasma gasification plant. Aerobic landfill technology is the most used technology nowadays and is the way for the future solid waste management; with less impact environment, no greenhouse gas produced, what reduce the cost of this technology.

2.3. Gaps of Research

- ✓ The Town Massive Garbage deposited in the open landfill or dumpsites is burnt with the proposed to reduce it or sometime burns itself resulting in emission of harmful gases to the environment; responsible of global warming, acid rain, green house gases, posing human health in risk.
- ✓ Cholera and malaria one of the ailments with are killing in Mozambique principally the people living nearby the dumpsites or landfill, were the pests breeding in dumpsites are responsible, all these because of the inappropriate management of the garbage;
- ✓ The absence of electrical energy in the Country induced by the less sources of it and approximately 80% Population in the country have not energy from the Hydropower grid;
- ✓ The lack of structures, policies and regulations in the country to manage the municipal solid waste;

2.4. Objectives

The purpose of this work is principal to develop my country Mozambique, in some ways as well as:

- ✓ To manage the landfills and dumpsites in the country and implement waste management structure;
- ✓ To Produce power or energy using town massive garbage as source;
- ✓ To find best technologies for Town massive garbage to power or energy plant according to Mozambique condition;
- ✓ To reduce the environment impacts from the landfill and dumpsites decreasing it.

CHAPTER 3
METHODOLOGY

3.1. Proposed Methodology

Literature review about Town Massive garbage – To - Energy had been done to attain objectives of the work, where more than sixty papers, articles, journals and publication, sites as well as Google Scholar, Youtube, from 2015 to 2019 used, and to analyse composition, calorific value, characteristics, cost and to appreciate the potential energy and energy to the grid and environmental conditions parameters will be done by help of COCO Simulation Software.

The components and composition review have been essential in the determination of amplitude of reclaimable in the interior of the garbage stream so as set economic viability and the technical of restoration and recycling objectives and find out the kind of material which in to pass by pre-treatment very before disposal and be used in the garbage –to- energy plan, they help in the dimension and design of it.

It is important to clarify that the composition of the garbage depend on the kind of city, country or suburb second the condition and style of life, industrialization, type of activities on it.

Determination of the town massive garbage composition is possible using some methods as well as ASTM D531-92 STANDARD and RCRA Waste Sampling Draft Technical Guidance, but for the present work data from the literature was useful in order to procedure.

After knowing the characteristic of the garbage is necessary to calculate the possible energy which may be released on the complete combustion. The ratio of output heat produced in the boiler from the samples combustion, calorimeter Bomb see figure number 11 and analytic expression are some methods to find out the heating value essential to estimate the energy.

For the thesis analytic expression had been applied relating the composition of the garbage and the theory heating value for each one, table 06 shows the results for the heating value to the town massive of Maputo City.

Figure 08: Laboratory set-up of bomb calorimeter

COCO - OPEN one of the useful chemist engineering simulation software is essential for town massive garbage – to- energy plant for incineration, pyrolysis, gasification, earthwork gas because it provides from the simulation of income parameters the different outcomes, for instance the energy generated by Technology, temperature, stream, pressure and quantity of emissions gas.

The complete cycle to produce energy using garbage consist of Heater where trash of gas methane and synthesis gases are applied to heat the boiler water or other fluid to become in the of steam in order to run the turbine a coupled to the generators lastly generate energy or power to the grid afterward be transmitted and distributed for different utility, the condensate from the turbine is moved to the condenser afterward transported or pumped by the pump to the boiler completing the normal cycle to commence other one, the COCO methodology to simulate is connected step by step according to units or processes and has the ability to determine for each one the incomes and outcomes along the whole plant.

The distant components to pose in practice the COCO are: The thermodynamic system for engineering Applications (TEA), the Graphical Flow sheeting environment (GOFE), The Collection of Unit Operations (COUSCOUS) and CORN Environment – all components are imported from CAPE-OPEN models.

The thermodynamic system for engineering Applications provides equipments or units like ; boiler, turbine, heaters, condensers, different types of pumps, generators generally applied in the energy plants, to facility the simulation of power or energy generated, among huge others thermodynamics tools

The collection of unit operations yielding joint of running unity, it comprises supporter fundamental agency for configuration flow sheet, assessment action unity and clearance objectives; here is possible to create and edit graphics operations all the parameters and conditioners.

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CORN the Reaction Numeric Package gives the capacity for specification of all type of kinetic or equilibrium reaction in the process of garbage to energy technologies. A string parser facilitates entering expressions for reaction rates, equilibrium constants and heats of reaction, helping in the simulation of combustion reaction in the determination of heating composition and for emission gases reaction products

The CAPE-OPEN sub-models that are usually used are thermodynamic models, unit operation models and a class of models enabling the specification of reactions, such as stoichiometry, reaction rates, heats of reaction, etc. It is a steady state flow sheet simulator including several unit operations linked together by material and energy streams in combination with thermodynamic and physical property models, in order to model complete chemical processes. It is used for designing and operating chemical processes [55][56][57].

Thermodynamic components there are no requirement of built-in sub models or thermodynamics or proprietary interfaces. Furthermore, COFE can be run with COUSCOUS which is the COCO's unit operation models, with any other third-party CAPE-OPEN compliant unit operation models. In similar way TEA and COUSCOUS can be used not only in COFE but in any other third-party CAPE-OPEN compliant simulation environment, as well [52][58][][59].

CHAPTER 4
OUTCOMES AND ARGUMENTS

4.1. Population and Town Massive Garbage Produced

The population in Mozambique have been growing, Maputo City Municipal solid waste Facts;

The population in Mozambique have been growing day after day, according to the data in the table (05); this scenario just put the government constant challenges to deal with the situation, The Country capital illustrates rapid increasing in term Citizens, from the others provinces and others Nations around the world as it is the big commercial place table (07) shows this tendency, looking for the forecast is clear that the town is going to face difficulties to deal with the solid waste and population without energy from the grid see table 06.

The Town Massive garbage generated in the capital of Mozambique according to some literature is estimated in approximately 1, 0 kg per day in the inner city and 0, 56 kg per day for the suburban areas respectively[1]. For the present work knowing the absence of the recent data, is assumed the average of the garbage of 0.75 kg/pp/day to determine the actual and the forecast quantity of trash produced in the city table (05) and (07).

The tables (07) and graphic 04 provide the evaluation of the evaluation of Population and the Town Massive Garbage produced in the country and Town, what bring the challenge for the government to reduce this scenario of Massive Garbage growing.

The forecast of the population and garbage production in the nation and in the municipal was done using a prediction equation; the table (06) illustrates the scenario.

Table 05: Amount of Town Massive Garbage generated in Mozambique (1995-2019)

Year	Population	MSW ton/day	MSW Ton/month	MSW Ton/year
1995	15 483 286	11 612	464498	5651399
2000	17711927	13269	531357	6464853
2005	20493292	15369	614798	7480051
2010	23531574	17648	705947	8589024
2015	27042002	20281	811260	9870330
2016	27829938	20872	834898	10157927
2017	28649018	21486	859470	10456891
2018	29496004	22122	884880	10766041
2019	30366036	22774	910981	11083603

Table 06: Forecast of the measure of Town Massive Garbage in Mozambique (2020 – 2050)

Year	Population	MSW ton/day	MSW Ton/month	MSW Ton/year
2020	31 255 435	23 441	937 663	11 408 233
2025	35 984 620	26 988	1079538	13134386
2030	41 184 834	30 888	1235545	15032464
2035	46 786 293	35 089	1403588	17076996
2040	52 729 200	39 546	1581876	19246158
2045	58 928 294	44 196	1767848	21508827
2050	65 312 929	48 984	1959387	23839219

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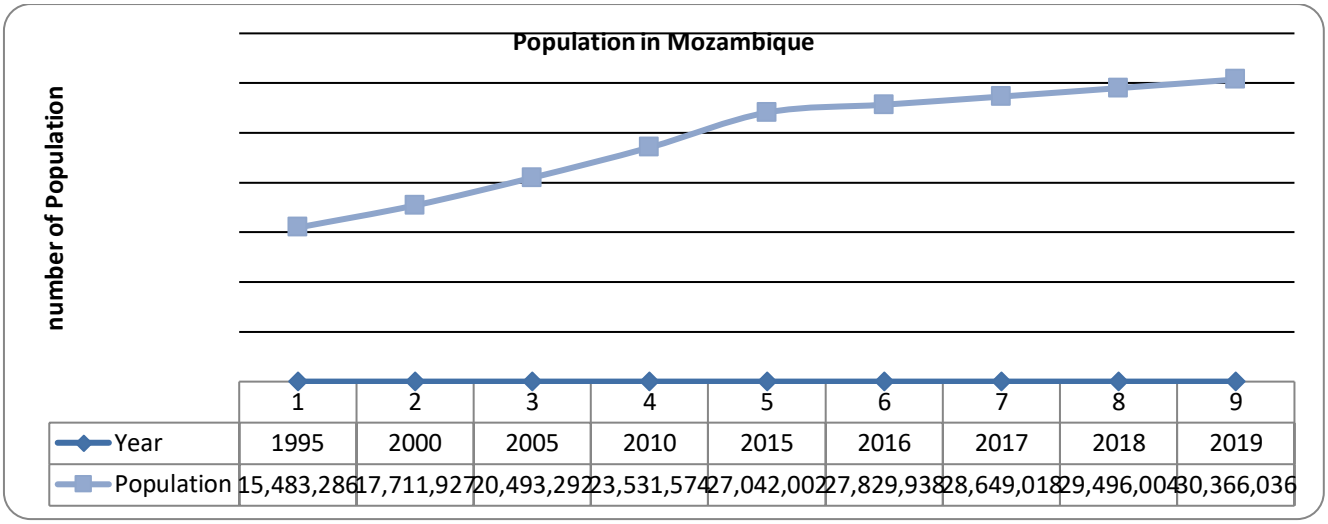
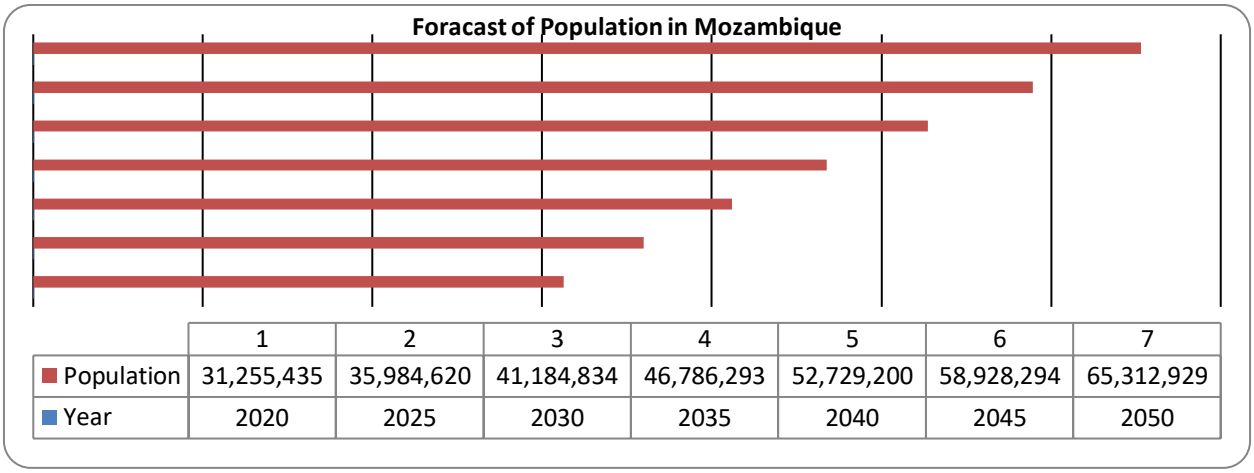


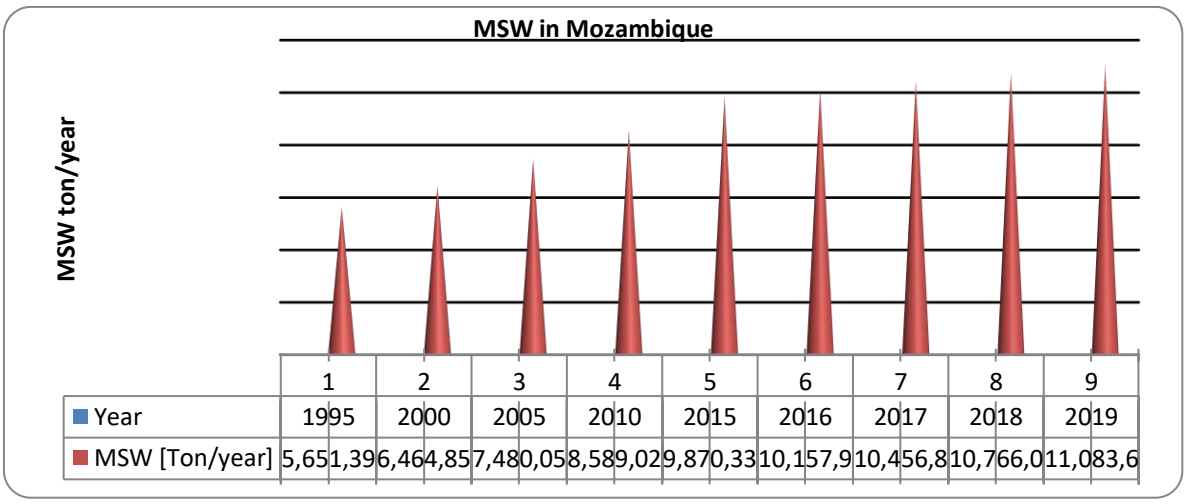
	1	2	3	4	5	6	7	8	9
Year	1995	2000	2005	2010	2015	2016	2017	2018	2019
Population	15,483,286	17,711,927	20,493,292	23,531,574	27,042,002	27,829,938	28,649,018	29,496,004	30,366,036

Graphic 02: Representatiom of the development of population in Mozambique



	1	2	3	4	5	6	7
Population	31,255,435	35,984,620	41,184,834	46,786,293	52,729,200	58,928,294	65,312,929
Year	2020	2025	2030	2035	2040	2045	2050

Graphic 03: Forecast of Population in Mozambique



	1	2	3	4	5	6	7	8	9
Year	1995	2000	2005	2010	2015	2016	2017	2018	2019
MSW [Ton/year]	5,651,396	6,464,857	7,480,058	8,589,029	9,870,331	10,157,9	10,456,8	10,766,0	11,083,6

Graphic 04: Municipal Solid waste in Mozambique

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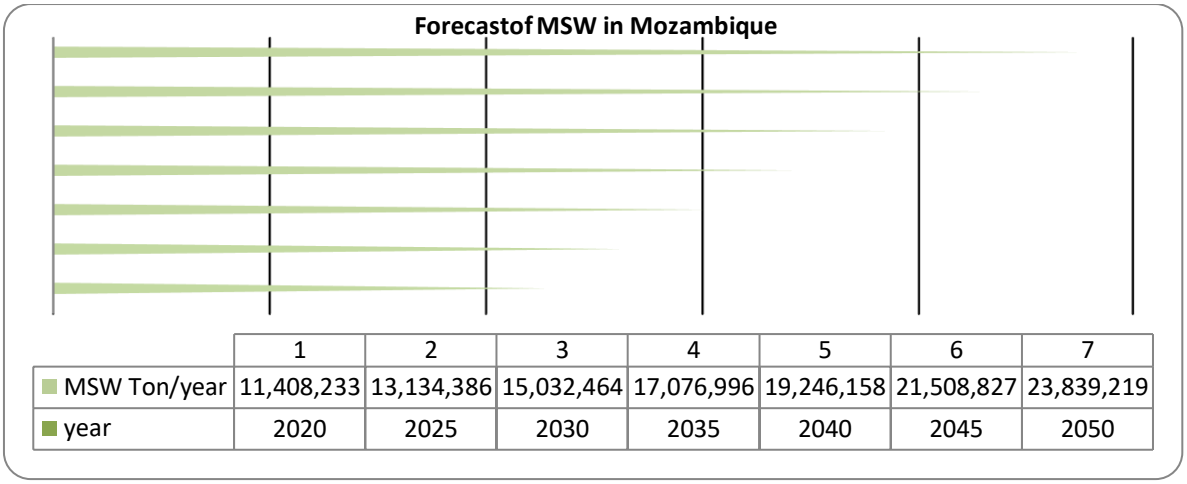

Graphic 05: Forecast of MSW in Mozambique

Table 07. Growing and Projection of the Population in Maputo City

Year (census*)	Population
1997*	801 449
2007*	1 205 709
2017*	1 908 078
2027	3 015 997
2037	4 881 714
2047	7 808 371

The growing of the population in Maputo city is illustrate in the table number 07 using the data of the census done in 1997, 2007 and 2017, by the INE and the forecasting for the next 30 years, so in the capital of the country up to 2047 approximately eight million citizens will be living there.

Table 08: Cost of MSW per ton in Maputo City

Year	MSW ton/day	MSW ton/month	MSW ton/year	Cost US per day	cost US per month	cost US per year
1997	401	12 021	146 365	7 017,5	210 525	76 841 625
2007	603	18 086	220 095	10 552,5	316 575	115 549 875
2017	954	28 622	348 210	16 695	500 850	182 810 250
2027	1 508	45 240	550 420	26 390	791 700	288 970 500
2037	2 442	73 227	890 912	42 735	1 282 050	467 948 250
2047	3 904	117 125	1 425 028	68 320	2 049 600	748 4 000

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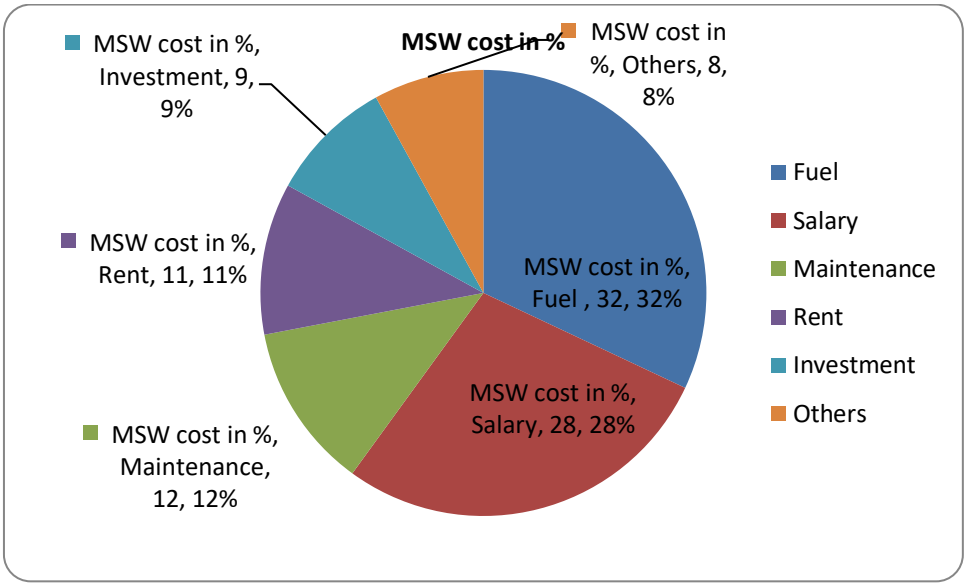
4.2. Cost to manage the Town Massive Garbage of Maputo city

Maputo city is the mirror of the problem of MSW collection and disposal in the country, posing the aesthetic and welfare of it and the Citizens in risk;

Maputo city second the National Statistics Institute (NSI) has the population of about 1.9 million, and generate nearly 1 100 ton of solid waste per day, one average of 0, 50 kg/Person/day the Capital.

The municipality in Maputo spent more than US $600 000 per month on waste management system; the high percentage in transport for collection of solid waste and salary, 32% and 28% respectively; the Population are paying a tax for MSW since some years ago [7]. The table number 08 helps to describe this scenario provide the attention to the government for an action to solve these situations.

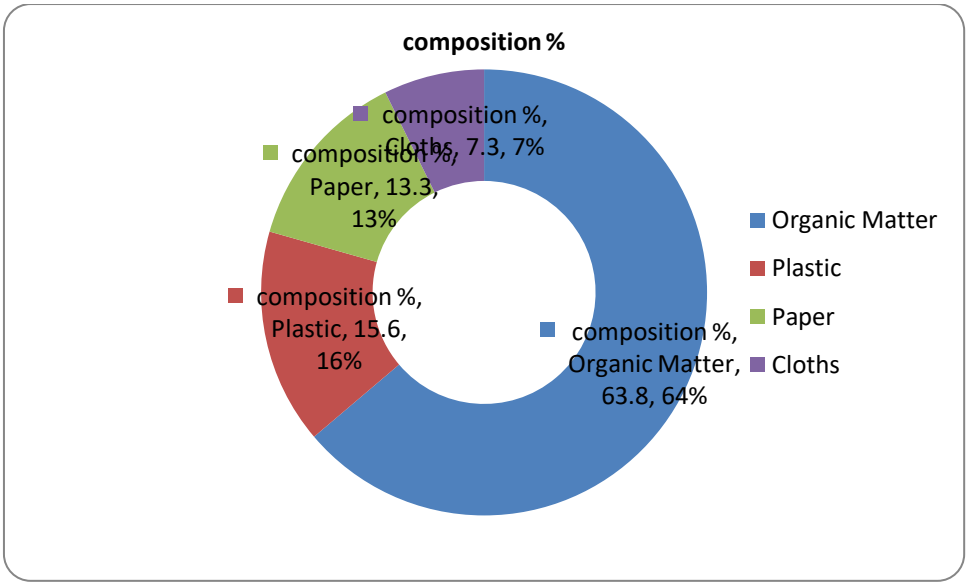


Graphic 06: Cost of manage the Town Massive garbage of Maputo City

4.3. Composition Town massive Garbage in Maputo City for the Plant

The composition of municipal solid waste in Maputo City is nearly egual to the countries which have been developing the waste-to – energy technologies nowadays with good results.

The components do not refer to inert material, glass and metal those can be recycled or reused. As illastrated in the graphic 07



Graphic 07: Composition of TMG to Energy in Maputo City

4.4. The Heating Value of the Town Massive Garbage in Maputo City.

The whole energy released as heat when a substance suffer complete combustion in the presence of oxygen is called heating value.

Knowing the quantity of the gathered town massive garbage and, the heat released from it; engineers enable to design the size of the technology to generate energy. The heating value of municipal waste must be approximately equal the value of CV coal, or more than this.

Table 09: Avarege Heating Value of the TMG in Maputo City

	Composition %	Calorific value MJ/kg		X*CV
Organic Matter	63,8	14	0,638	8,932
Plastic	15,6	35	0,156	5,46
Paper	13,3	13,5	0,133	1,7955
Cloths	7,3	30	0,073	2,19
Avarege CV Mj/kg				18,3775

From the heating value of the component and the composition of garbage by analytic expression was determined the average garbage heating value of Maputo second the table number 09, this value illustrates that town massive garbage produce by the citizens, industry, schools and hospital badly treated and disposed in the dumpsites, results of distant activities in different sections of employment and commercial in

Mozambique can be useful for energy generator , considering the coal plant works with average approximate or equal to this one.

It bring out the logical idea to reduce the garbage around the city and the environment risk, emission pollution in the open landfill ailments to the population dwelling nest to them.

4.5. Town Massive Garbage for Maputo City

A.

Table 10; Estimation of Energy Potential from MSW in Maputo City

Year	MSW ton/day	MSW ton/month	MSW ton/year	MWh per day	MWh per month	MWh per year
1997	401	12 021	146 365	2045,64	61369,2	746658,6
2007	603	18 086	220 095	3077,49	92324,7	1123283,9
2017	954	28 622	348 210	4870,23	146106,9	1777634
2027	1 508	45 240	550 420	7698,12	230943,6	2809813,8
2037	2 442	73 227	890 912	12460,24	373807,2	4547987,6
2047	3 904	117 125	1 425 028	19930,32	597909,6	7274566,8

Knowing from some literature that 7 200 kWh per year can feed one house in the developed countries, the table 10 shows that more than 1000 house will be consuming energy generated by the MSW in Maputo city.

Literature says that one megawatt can power three hundred and sixty houses. The MSW plant of a capacity of 5 MW can generate power for at least 5% of the rural zone.

Table 11; Power Projection of Town Massive Garbage in Maputo

Year	MSW ton/day	MSW ton/month	MSW ton/year	MW per day	MW per month	MW per year
1997	401	12 021	146 365	25,57	767,1	9333,05
2007	603	18 086	220 095	38,47	1154,1	14041,55
2017	954	28 622	348 210	60,88	1826,4	22221,2
2027	1 508	45 240	550 420	96,23	2886,9	35123,95
2037	2 442	73 227	890 912	155,77	4673,1	56856,05
2047	3 904	117 125	1 425 028	249,15	7474,5	90939,75

Table 12; Projection of the power grid form MSW in Maputo City

Year	MSW ton/day	MSW ton/month	MSW ton/year	MW per day	MW per month	MW per year
1997	401	12 021	146 365	17,72	531,6	6467,8
2007	603	18 086	220 095	26,66	799,8	9730,9
2017	954	28 622	348 210	42,19	1265,7	15399,35
2027	1 508	45 240	550 420	66,69	2000,7	24341,85
2037	2 442	73 227	890 912	107,95	3238,5	39401,75
2047	3 904	117 125	1 425 028	172,66	5179,8	63020,9

From the tables number 11 and 12 of the data from the grid and the population is illustrate that more than 5 % of the homes in the Maputo city can be feed by municipal solid waste plant; what will increase the number and the percentage of household linking to the electrical grid in the town as well as in the hole Country, providing a development of the economy and the welfare in the other hand.

4.6. Profit of the Implementation of Garbage to energy Technology in Maputo

From the table number 13 assuming that a family with eight members can consume energy of nearly 5 KWh per day, 150 KWh per month and 1825 KWh per year generated by Municipal Solid waste of Maputo city, this mean that a percentage of 3,5 % household of the town can be powered by the plant. This illustrate that the energy from the MSW source is the future for the developing country

Table 13: Number of household with can be feed by the MSW plant

Year	KWh per day	5 KWh per day	number of Houses
1997	17720	3544	100181,1
2007	26660	5332	150713,6
2017	42190	8438	238509,8
2027	66690	13338	376999,6
2037	107950	21590	610214,3
2047	172660	34532	976046,4

Table number 14; The relationship between the cost of the MSW and the Purchase of estimated energy in Maputo City.

		Purchase energy		Cost with MSW	
MWh per year	kWh per year	9 mts per KWh	US per year	US per year	Mts per year
746658,6	746658600	6 719 927 400	119 998 703,60	76 841 625	4 303 131 000
1123283,9	1123283900	10 109 555 100	180 527 769,60	155 498 755	8 707 930 280
1777634	1777634000	15 998 706 000	28 691 178,60	182 810 250	10 237 374 000
2809813,8	2809813800	25 288 324 200	451 577 217,90	288 970 500	16 182 348 000
4547987,6	4547987600	40 931 888 400	730 926 578,60	467 948 250	26 205 102 000
7274566,8	7274566800	65 471 101 200	1 169 126 807	748 104 000	41 893 824 000

The table number 14 illustrates the viability of the project, taking in the count that the energy will be purchase by 9 Mt per KWh and the cost which the Maputo City expands during the year dealing with the MSW in uncontrolled way and the estimation of the purchase of energy by the population during the same period, what provide a good result for the project of the MSW to energy in the capital of Mozambique.

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CHAPTER 5
CONCLUSION

5.1. General conclusion and Recommendation

The entrance into force of town garbage management structure will help to control it in the source, before it arrive to the landfill and dumpsites what will reduce the impact of environment, acid rain and global warming and, avoiding many diseases, and the number of landfill and open dumpsites, the team of municipal solid waste will awareness the citizens about the relevance of garbage separation to the social and of the country economy, reducing the cost of collecting and deposit of trash , as it comes with the new jobs to the population of that particular area.

The Town Massive Garbage produced every day Maputo City citizens and the heating value which is approximately equal to the coal, one of non renewable source used in thermal plant illustrate the possibility to generate taking it as a source of power or energy as well as heat, application of different technologies like: pyrolysis, incineration, gasification, with a good value of or capacity of electrical energy second the COCO - open simulation methodology.

Anaerobic and landfill gas are most suitable for Maputo waste status as well as to the different area in Mozambique ; as the anaerobic digestive can be used in the small area, and each Person at home is able to develop anaerobic plant to generate gas for cooking and light using is waste, helping the country to achieve three sustainable development goals; it is sustainable development goal of zero waste, environment and energy for everyone. Landfill gas LFG by another way reduces the contamination of the ground water avoiding the different illnesses by using a simples system; the water act ruler and environment Act are being observed (looked on) , all these will add the economy and the energy generate in the whole Nation.
The Town Massive Garbage plant will reduce the number of landfill or dumpsites and directly the environment impact lessen use of non renewable energy source, responsible of green house gas and global warming and provide job to the Population, reduce the issues associated to the ailment like malaria the cholera of the Country.

It is very urgent to separate the municipal solid waste, just to make a good management of it, and avoid the problem of landfills and dumpsites out of control as the process automatically reduce, recycle and reuse ; awareness the population about the risk and Benefits of the solid.

5.2. Further Works and Narrowness

The further work is to determine the daily composition, collect quantity and initiate the process of separation the municipal solid waste in the field for at least six month, this for the whole Country.

Use other type of waste to generate electrical energy or power like liquid waste and human or animal stool as source of electrical energy, taking project of toiler's to generate energy, in School, hospital and market.

One of the limitations of the work was the absence of the actual date of Town Garbage composition and quantity garbage per day or per year for last five or ten years. I cannot forget to say that the novel Coronovirus is the huge restriction for the wok.

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