REHABILITATION OF MEDIOUNA’S OLD LANDFILL & PROPOSAL FOR THE NEW CASA SOLID WASTE TREATMENT UNIT BASED ON CIRCULAR ECONOMIC MODEL

Capstone Design

Zineb CHOUIHI

Supervised by: Dr. Abdelghani El ASLI
Abstract

Considered as the nationwide site, with no bottom liner, Casablanca Landfill receives about 3500 tons/day of solid waste including urban and industrial refuses. Since 1992 the site has been objected to wild disposal, resulting in a notable deterioration of groundwater due to leachate accumulation, also generating nauseous smell, and smoke, air pollution. In the framework of enhancing Morocco’s commitment toward a green country along with its national renewable Energy program through the protection of the environment, the main purpose of this project is to suggest a sustainable Integrated Solid Waste Management to Mediouna’s discharge via a circular economy concept thus ensuring sustainability. This settlement was accomplished based on a holistic methodology by identifying the ultimate driving factors to the strategy success. This proposal consists of conducting a benchmark of the existing methods regarding municipal waste management i.e. Incineration, gasification, and anaerobic digestion. The waste evaluation revealed a low calorific value content, thus we decided to adopt circular model that meets and respects the 3R’s: Reuse, Reduce, Recycle. The replacement project will consist of both mechanical and biological treatment facility along with a sanitary landfill in order to process the maximum disposed waste. The model resulted in a total capacity of $3.09 \times 10^5$ MWh, 59475 ton of compost as well as recyclable material to be sold to a recycling facility with estimated NPV of MAD 12 billion.
Acknowledgments

The completion of the *-/project « rehabilitation of Mediouna's old landfill & proposal for the new CASA solid waste treatment based on circular economic model » would not have taken place without the contribution of many people. First, I owe my biggest gratitude to my capstone supervisor and El Asli Abdelghanni, who guided me and supported me throughout the whole preparation period with his solid and well-constructed background. Secondly, I am enormously indebted towards my sister Mariem Chouihi who motivated me and reassured me in my many moments of doubts, which enabled me to always give my best. Finally, I would like to acknowledge my family and friends’ for their endless support may it be emotional or intellectual.
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**List of abv:**

**AD:** Anaerobic Digestion

**BTF:** Biological Treatment Facility

**MTF:** Mechanical Treatment Facility

**CHP:** Combined Heat and Power

**MSW:** Municipal solid waste

**MTF:** Mechanical Treatment Facility.

**ISWM:** Integrated Solid Waste Management

**NPV:** Net Present Value

**PNMD:** Program National des Dechets Menagers

**IRR:** Internal rate of return

**WTE:** Waste to energy

**MAD:** Moroccan Dirham
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Part I: An Overview of MSW

Introduction

It is agreed upon that the actual world is producing from 7-to-10 billion of urban waste per year [1]. Besides according to the World Bank report developing countries waste production is expected to double over the next 2 decades. This waste generation growth or collapse is known to be influenced by three main factors that are lifestyle, degree of urbanization and income. As a matter of fact, global population is expected to grow to 9-11 billion by the end of this decade, such that 90% of this growth will take place in Africa [1]. This evolution has serious implication concerning resource consumption and waste generation especially in the urban areas, since the higher the degree of urbanization the greater the waste generation [1].

Developing countries face many challenges concerning the waste management field mainly due to social and financial factors [2]. Bad management of dumpsites, incineration, soil contamination, and high resource consumption along with an increasing population growth has created a rising need for an educated, and sustainable waste management system. Consequently the implementation of an effective and sustainable solid waste management in developing and transitional countries is a particularly challenging activity [2]. The challenge lay in finding an integrated process for solid waste management (ISWM) that suits the geography, history, economy, demography and culture of the operating zone. Three main dimensions for ISWM are accounted during this process: first, stakeholders, and the technical component and waste management sustainability [2].

In that fashion, and before any execution of a MSW management, setting up an analytical framework, which combines quantitative and qualitative aspects built upon specific indicators would be the first step toward a viable MSW management system. These parameters are organized in harmony with regional specific institutional, environmental and financial resources.

Moreover, generating economic benefits is considered one of the main pillars of sustainability, which is achieved via the respect of the three R’s hence the control, and suppression of hazardous substances to avoid endangering human and soil health. To say nothing of the energy extraction as a renewable
form of energy thus leading to a green economy; to put it differently waste management in developing countries such as Morocco should be enhanced by looking beyond the traditional process of generation, collection, and disposal to ensure the viability of the national program.

**Institutional Framework.**

The success or failure of a circular integrated waste scheme depends on the cooperation of the multiple stakeholders and on the legislative and institutional framework currently in place. Participants in an MSW project usually have conflicting interests thus the project may sometimes develop economical, as well as environmental issue with the concerned parts. The stakeholders’ reaction to the project may differ depending on the institutional setting of the plant. The waste to energy plant can be located in the waste sector or the energy sector, or it can be a fully privatized independent entity. Depending on the organizational affiliation of the plant, there is a need for strong irreversible contracts adjusting the supply of waste, the sale of energy, and the price setting [11]. In that fashion and to avoid environmental, institutional, or financial imbalances in the overall solid waste management model a high interaction degree is demanded between the stakeholders to satisfy the viability of ISWM system. The Stakeholder of the system are presented as follow:

1. **Authorities:** Mediouna’s Municipality Urban/regional planning Environment authorities Health authorities Traffic authorities
2. **Community:** Environmental NGOs, Nature/Wildlife NGOs, Mediouna’s neighboring citizens, **Scavengers.**
3. **Waste Sector:** Casablanca population, waste recycling companies waste collection companies (Sita Al Baida) Other treatment plants Landfill operators
4. **Energy Sector:** Power distribution company: **Lydec.** Fertilizer companies (Ecoval).
### Steeple Analysis

#### Societal

One of the project aims is to socially reinsert the scavengers by providing them with a job in the sorting facility, thus allowing the community to get a qualitative, and quantitative (wages) advantage.

#### Technical

Many technologies are available to convert waste to consumable energy; the choice of these technologies will mainly depend on the calorific value of the generated waste, and other technical parameters.

#### Economical

The economical benefit resides in a circular economical model, where almost zero waste production is aimed. Output=input

#### Environmental

Leachate, toxins, greenhouse gases emissions will be minimized such that leakage will be under control through specific technics.

#### Political & Legal

The project falls within the national program for renewable energy production, as well as the household management program.

#### Ethical
The project will enhance the environmental quality of the area, along with job opportunities for more 300 scavengers. Moreover the project will disable agricultural animals to resource their food needs from the dump thus the community will be less eligible to get health complications.

**State of the Art**

In order to design an integrated waste treatment facility aligned with the desired competitive advantage and desired output, one should consider factors such thermal parameters of the waste, environmental impact as well techno-economic consideration. Technologies for ISWM vary such there should be some risk and design assessment to choose the most suitable one.

**Factors Considered in Technology Choice [31]:**

- Number of different components in the waste
- The composition and structure of the input waste
- The particle size distribution
- The degree and kind of contamination being possible
- Which components shall be recovered
- How purified the recovered components should be

As a means to avoid technology failure, the above factors should be quantified and evaluated. The rigorous design is highly relying on the waste composition as well as worldwide regulations

**1. Anaerobic digestion.**

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH4) and carbon dioxide (CO2) otherwise known as biogas. These gases are produced from organic wastes such as livestock manure, food-processing waste [24]. Biogas is recovered and transformed into heat or any other form of energy. The remaining sludge contains many nutrients and can be used in agriculture as fertilizer [29].
The process of anaerobic digestion consists of three steps [44]:

1. The decomposition (hydrolysis) of plant or animal matter. This step breaks down the organic material to usable-sized molecules such as sugar.
2. The second step is the conversion of decomposed matter to organic acids.
3. The acids are converted to methane gas.

---

**Advantages:**

- Ease of implementation
- Incrimination of costs incurred as the landfill expands
- By production of landfill gas to be used in household and industrial
- Generation of biogas and fertilizer: nearly complete retention of the fertilizer nutrients (N, P and K).
- Reduction of greenhouse gas emissions through methane recovery [45].
• Combined treatment of different organic waste and wastewaters.
• Good pathogen removal depending on temperature
• Process stability: high-loads can be treated but anaerobic sludge can also be preserved for prolonged periods without any feeding.

**Disadvantages:**
• Small- and middle-scale anaerobic technology for the treatment of solid waste in middle- and low-income countries is still relatively new.
• Experts are required for the design and construction, depending on scale may also for operation and maintenance.
• Reuse of produced energy (e.g. transformation into, fire/light, heat and power) needs to be established
• High sensitivity of methanogenic bacteria to a large number of chemical compounds
• Sulphurous compounds can lead to odor [45]

**Available Technologies:**
• Wet digestion, where the substrate shall have a dry matter content lower than 10% [35]
• Dry digestion, where the substrate shall have dry matter content higher than 20% [35]
• Processes, which are run at intermediate dry matter contents, are less common, and are generally referred to as semi-dry [35].

**Largest Dry Fermentation Anaerobic Digestion Facility in the World**

The largest Facility in the world of dry fermentation is located in San José in the United States. The facility started processing on November 2013 under a joint venture business arrangement. Input operated waste is said to be 90,000 ton per year with a 1.6MWh capacity. The facility is enclosed and ventilated and includes 16 anaerobic digesters plus four in-vessel composting tunnels [32].
2. Incineration:

A rapid and exothermic reaction between a fuel and oxygen is called combustion. In incineration, mostly waste is used as the fuel, and air as the oxygen source. Combustion results in many of the same stable end products, no matter what the material burned is (natural gas, coal, wood, gasoline, MSW, medical waste, or any kind of waste). An efficient incinerator should have a flame zone hot enough to decompose all organic and inorganic molecules, permitting reactions between the oxygen and nitrogen in air, and most volatile elements of the waste [15].

The overall combustion process:

1. Preparation of feed and waste storage
2. Combustion in a furnace to produce gases and a bottom ash for disposal
3. Reduction in gas temperature, involving frequent heat recovery by generating steam
4. Cooled gas treatment against air pollutants
5. Disposal of residuals after treatment
6. Diffusion of the gas treated into the atmosphere by fan and stack
Advantages:

- Reduction in volume waste by 90%
- Minimal Processing of waste required
- Reuse of clean and stable bottom ash for road coating and construction industry
- Burning of the majority of the organic waste
- Heat combustion possibility to be converted into steam and electricity
- Optimization of land use
- Possibility of collocating combustion facilities and residential areas.
- 1 ton of MSW = 550 KWh of electricity

Disadvantages:

- Operations, maintenance and capital cost are high
- Advanced equipment required for air pollution treatment
- No possible treatment for heavy metals and ashes dumped
- Increase in demand for raw material replacing the combusted ones.
- Formation and reformation of toxic dioxins and furans

Pathways by which these toxic dioxins end up in exhaust steams:

1. Decomposition as smaller parts of larger molecules
2. Reformation: combination of smaller molecules
3. Simple passing through the incinerator without change.
**Largest waste incineration Plant in the World**

The "world's largest" waste incinerator will be running at full speed in a Beijing western suburb in China on the end of 2018. The facility processes 3000 ton of waste per day, for a general capacity estimated at 420 million kilowatt hour of power in a year [27].

![World largest incineration plant - Beijing.](image)

**3. Gasification:**

Like incineration, pyrolysis, gasification and plasma technologies are thermal processes that use high temperatures to break down waste. The main difference is that they use less oxygen than traditional mass-burn incineration. However, they are still classified as incineration in the European Union (EU)'s Waste Incineration Directive, and have to meet the mandatory emissions limits that it sets. The waste is broken down to create gas, solid and liquid residues. The gases can then be combusted in a secondary process [13].

- Throughout the gasification procedure, MSW is not a combustible, but a feedstock for a high chemical transformation process. No incineration occurs.
- Gasification transforms MSW, normally burnt into clean and ready to use syngas.
The latter can be utilized to manufacture energy as well as highly useful products like electric power, chemical materials, fertilizers and gasoline.

Gasification goes hand in hand with recycling. Well before the gasification process is begun, metal, glass, and other matter that can’t be gasified is separated from the waste cycle. Additionally, multiple types of plastic cannot be reprocessed and would be land up in a landfill. As a stellar high-energy fuel for gasification, those plastics would lessen the quantity of landfill-occupying, unrecyclable materials.

MSW gasification is environment-friendly it lowers the demand for landfill land, thus, diminishing methane discharges emanating from the decay of organic materials in the landfill, thereby lessening the danger of pollution due to surface water and groundwater in landfills.

Note: This calorific value is contingent upon the material’s particular make-up.
Advantages:

- Less air emissions will be developed when a small amount of oxygen is utilized: In order to form or re-form dioxins and furans require enough oxygen. However, due to the lack of oxygen in the gasifier, furans will neither form nor reform.
- In order to reform, dioxins require small metal particulates in the exhaust, whereas syngas produced from gasification is usually cleansed of particulates prior to being utilized.
- The plants are modular. They are consist of tiny units that can be adjoined or removed as waste flows or as volumes change (because of accrued recycling), thus, they are adaptable and can function at a lower scale compared to mass-burn incinerators.
- Faster construction time.
- In the case a gas engine is utilized (and even a fuel cell), the syngas could be manipulated so as to produced energy more systematically, whereas incineration can could only produce energy in a less efficient way through steam turbines.
- All waste is oxidized no sorting or fetching is required
- Gas is halted from getting away by an airlock
- 1000 KWh of electricity is generated by one ton of MSW.

Disadvantages:

- The pyrolysis processes could sabotage recycling and composting.
- Some firms prefer to dispose of ash and other by-products rather than to incinerate them.
- The data is gathered from single businesses is contradictory as methods are contrasted.
- For instance, those in favor of incinerators will proclaim their high-energy efficiency.
Largest Gasification Plant in the World

The facility is located in the United Kingdom, as it is upon completion The Tees Valley plant once operational will process up to 350,000 metric tons of non-recyclable waste from landfill per year. The technology produces 50MW of electricity as well as 42 per cent fewer CO₂ emissions per MWh than incineration [20].

![Figure 8: Layout of Tees Valley plant](image)

MSW and Circular Economy

In a world where consumption rate is exponentially increasing, and where the greater the input the higher the output, linear supply chain model has been constructing a real threat for our future environmental, and societal needs. Sustainability through an enhanced reuse of our sources and “zero-waste strategy” is a key element for ensuring a wealthy life for the future generation. The notion of a circular economy secures a way out. Products do not rapidly turn to waste, but instead are reused to extract their maximum value before securely and fruitfully returning to the biosphere [15]. Most importantly for business leaders, such an
The economy can deliver growth aligned with social atmospheric responsibility as well as durability.

The circular economy refers to an industrial economy that is restorative by intention. It aims to enable effective flows of materials, energy, labor and information so that natural and social capital can be rebuilt. It seeks to reduce energy use per unit of output and accelerate the shift to renewable energy by design, treating everything in the economy as a valuable resource. The idea goes beyond the requirements of the production and consumption of goods and services. The concept of the circular economy is grounded in the study of real world, non-linear, feedback-rich systems, particularly living systems.

**Circular Economy under the MSW scope**

Consumption in reality mostly means ‘destruction’ and the loss of potentially valuable products, components, and materials—and their associated embedded energy and restorative value. The circular model came to suppress or at least to diminish the energy losses associated with the linear approach. The concept has mostly been employed by developed country in both the goods and energy production industries [11]. However, the model has shown great insights regarding the energy reconstruction than goods production. In that scope and as circular economy keeps more raw materials and products in circulation by increasing repair, reuse, recovery and recycling. Sustainable waste management approaches along with the model principles has shown great compatibility since instead of only disposing waste in landfill where incremental environmental, societal, and economical undesirable impact occur, the tactic takes every residual output as valuable source to be reused as a feedstock. The ultimate goal of the circular economy under the solid waste scope is to evolve into a society where residual waste is reduced to a minimum with high levels of capture and reuse via a combination of eco-design, new business models (including rental, repair and reuse) and new recycling, composting technologies. The business and technical model undertaken should be assessed in order to evaluate the relevant parameters for attaining a high level circular flow of matter along with economical benefit.
PART II: MOROCCAN SOLID WASTE ASSESSMENT

1. The flow & Management of MSW In Morocco

Morocco has been administrating changes in terms MSW policies [3], by taking many initiative and development strategies. These strategies oscillate around low carbon emissions, and improvement of solid waste collection then disposal in controlled landfills along with the diversification and optimization of reliable competitive energy.

1.1 Solid waste facts

1. Overall solid waste generation: 6.825 M metric tons [3].
2. Urban waste generation: approximately 0.76 kilos per day per capita [3].
3. Rural waste generation per capita is about 0.3 kilos per day [3].
4. Daily Urban solid waste collection for an estimated 5.5 million metric tons (MT) per year [3].

5. Solid waste reform 2006 including legal and institutional framework [3].

6. Urban solid waste collection: 85% of the waste generated in urban areas [3].

7. 37% of the total waste generated is disposed of in controlled landfills [3].

8. An increase of 10% in 2008 of landfilling waste disposal [3].

9. 2010 National solid waste plan (PNDM) [3].

10. International and bilateral agreements regarding waste and the environment: the Montreal Protocol, the Kyoto Protocol, and the Protocol on the Prevention of Pollution of the Mediterranean Sea, the Basel Convention, the Stockholm convention on POPs [3].

1.2 PNDM
The National Plan for Household Waste Objectives: [5]

- Ensure the collection and cleaning of household waste to achieve a collection rate of 85% in 2016 and 90% in 2020.

- Conduct landfill and recycling centers for the benefit of all urban centers (100%) in 2020.

- Rehabilitate or close all existing landfills (100%) in 2020.

- Modernize the waste sector by the professionalization of the sector.

- Develop the sector of "sorting-recycling-valorization" with pilot projects sorting to reach a rate of 20% recycling by 2020.

- Generalizing the household waste management master plans for all prefectures and provinces of the Kingdom.

- Train and raise awareness of all stakeholders on waste challenges. [1,3]
1.3 Technical component

<table>
<thead>
<tr>
<th>BACKGROUD INFORMATION</th>
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<tbody>
<tr>
<td>Total population</td>
</tr>
<tr>
<td>MSW Generation Per Capita</td>
</tr>
<tr>
<td>Urban Areas</td>
</tr>
<tr>
<td>Rural Areas</td>
</tr>
<tr>
<td>MSW Generation growth rate</td>
</tr>
</tbody>
</table>

Table 1: Background Information of MSW in Morocco

1.4 Financial components.

**SWM Financing sources**
- Local taxes (includes Ecotax)
- Subsidies from the government budget
- Clean Development Mechanisms (CDM)
- The Municipal Equipment Fund (FEC)
- Loans: $US 400 Millions

**Actual Costs of Waste Management**
- Average waste collection cost: 411 MAD/MT
- Average waste disposal in controlled landfill: 300 MAD/MT

1.5 Private sector immersion

Morocco has been relegating the waste market to private operators for:

1. **Collection**: outsourcing management contracts with an investment margin from the subcontractor [3] and smaller portion from municipalities

2. **Disposal**: BOT contracts (Build-Operate-Transfer) for new sanitary landfills

Approximately **80%** of the current market is controlled by four subsidiaries of international groups.
2. MSW in CASABLANCA

2.1 Historical background

Situated in the center of the kingdom, Casablanca city is considered to be driving economic force of the country with the largest surface, and densest population however it also known to be the most polluted [1] and urbanized city. The Casablanca dumpsite is considered to be the largest of the kingdom, within an estimated 60 Hectares of surface area; since 1986 it has been accepting industrial, medical and domestic disposals for a total of 3500T/day. These waste disposals have been causing serious harm to the environment mainly due to leachate increase in the ground soil as well as dioxin gas caused by trash incineration. As a remedial to these challenges the government has decided delegate the waste management activities to private operators [6,5,7].

2.2 Main milestones of Mediouna’s site

Figure 11 : Timeline of Mediouna's main events
2.3 ECOMED contract clauses

- Contract life span: 18 years (2008-2026) [10].
- Setting up sorting area of 7000 m² has been set up allowing the reintegration [6] of 250 rag pickers operating in the landfill
- Casablanca Plant: - Waste of 22 M VS Production of 1.2 M.
- Possibility to produce 26600 Gallons/day of fuel - Equivalent of planting a forest of 4,500,000 Hectares (6.5% of Morocco) [9].
- CO₂ emissions reduction of 296,459,000 liters of petrol [9]
- Noticeable Reduction In Respiratory Illness [9]
- Possibility of production of both Liquid Natural Gas and Compressed Natural Gas Fits all the vehicles [9]

2.4 Onsite Visit Report

- Rehabilitation process is done through first, a biological treatment of leachate  Soil (40 cm), 2. Gravel (drainage), 3. Vegetal soil (60 cm)
- The municipality pays Ecomed : 300 MAD /Ton as a Fee gate.
- Implementation of 4/48 well only since 2008
- Progress is slowed down by:
  1. Medioua's community acts of vandalism (i.e well destruction)
  2. The presence of more than 900 scavengers.
  3. Cattle often cover the landfill perimeter, which is approximated to 15000 units in total.
  4. The technician inability to confine the waste
  5. Municipalities don’t assume the responsibility to ensure security in the landfill
- The conditions of waste management i.e compact, and confined waste, low level of humidity, and low level of oxygen are hard to achieve
- Ministry of the environment future project: Compost industry to invest the Eco tax income, however risk of failure due to the adoption of European model not fitting with our humid waste, refer to the industry built in the 70’s which witnessed a shut down due to sieve malfunctions.
- A sorting and fetching center in Bernousi community
• The difficulty in implementing “Home sorting” also called upstream fetching and involving the citizen in this process resides in a financial and social feasibility.

![Image](image1.png)

**Figure 12: Pictures illustrating the informal sector of waste management in Mediouna’s landfill**

### 2.5 Key data

In order to conduct a constructive assessment of the ISWM, parameters such as degree of waste generation, waste composition, degree of urbanization, and the growth level are very decisive in developing a consistent management plan.

<table>
<thead>
<tr>
<th>Casablanca MSW Key DATA</th>
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<tbody>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Population Growth</td>
</tr>
<tr>
<td>Generation:</td>
</tr>
<tr>
<td>Kg/capita/day</td>
</tr>
<tr>
<td>MSW growth</td>
</tr>
<tr>
<td>MSW generation t/ day</td>
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<tr>
<td>MSW generation t/ year</td>
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### Table 2: Casablanca Key data

<table>
<thead>
<tr>
<th>Household Waste composition</th>
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<tbody>
<tr>
<td>Plastics</td>
<td>10%</td>
</tr>
<tr>
<td>Glass</td>
<td>3.00%</td>
</tr>
<tr>
<td>Metal</td>
<td>4.00%</td>
</tr>
<tr>
<td>Paper/cardboard</td>
<td>10.00%</td>
</tr>
<tr>
<td>Organic</td>
<td>65.00%</td>
</tr>
<tr>
<td>Others</td>
<td>8.00%</td>
</tr>
</tbody>
</table>

### Table 3: Household Waste composition

<table>
<thead>
<tr>
<th>Portion in T/day</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>350.00</td>
</tr>
<tr>
<td>Glass</td>
<td>105.00</td>
</tr>
<tr>
<td>Metal</td>
<td>140.00</td>
</tr>
<tr>
<td>Paper/cardboard</td>
<td>350.00</td>
</tr>
<tr>
<td>Organic</td>
<td>2275.00</td>
</tr>
<tr>
<td>Others</td>
<td>280.00</td>
</tr>
</tbody>
</table>

### Table 4: material Portion in metric ton/day

3. **The environmental impact of MSW on Mediouna’s site (EPI)**

**Greenhouse Emissions**

Besides the incremental cost of unsanitary landfills, the real issue resides in its environmental impact. The environmental quality of Medioua's site has been witnessing years of incremental pollution contamination of the groundwater aquifers, and soil, and methane production. The three most important and dangerous substances generated are toxins, leachate and greenhouse gases.

**Toxins:** poisonous substance, especially a protein, that is produced by living cells or organisms and is capable of causing disease when
introduced into the body tissues but is often also capable of inducing neutralizing antibodies or antitoxins.

**Leachate:** a liquid that drains or ‘leaches’ from a landfill. It varies widely in composition regarding the age of the landfill and the type of waste that it contains. It usually contains both dissolved and suspended material. In 2007 the daily estimated produced amount of leachate in Mediouna’s Landfill has been measured to be 1277 m³/day According to a hydrochemical study of the site “the groundwaters in the vicinity of the landfill are characterized by high contents of organic and inorganic chemicals: more than 11 mS/cm in electric conductivity, 2500 mg/L in chloride, 156 mg/L in sulfate, 0.05 - 0.1 mg/L in cadmium and 0.04 - 0.23 mg/L in chromium”. This ground water quality is due to leachate infiltration to the aquifer [1].

**Greenhouse gases:** When organic material such as food scraps and green waste is put in landfill, it is generally compacted down and covered. This removes the oxygen and causes it to break down in an anaerobic process. Eventually this releases methane, a greenhouse gas that is 21 times more potent than carbon dioxide. The implications for global warming and climate change are enormous [46]. Methane is also a flammable gas that can become dangerous if allowed to build up in concentration.

4. **Waste as Fuel**

A most critical factor in the feasibility of an ISMSW plant is the kind of the waste/Biomass and its calorific value along with its thermal properties such ash moisture, volatile matter, High heating value, Bulk density. [17]

4.1 **Biomass**

An assessment of the use of biomass as a fuel requires a basic understanding of the types of biomass. They include straw from grains; husks from rice, coconuts, or coffee; stalks from maize or cotton; and
Bagasse from sugar cane [16]. Biomass is composed largely of carbon, hydrogen and oxygen. Nitrogen and small quantities of other atoms, including alkali, alkaline earth and heavy metals can also be found. Biomass is the building block or ‘feedstock’ for many other fuels [16]. Biomass takes carbon out of the atmosphere while it is growing, and returns it as it is burned. If it is managed on a sustainable basis, biomass is harvested as part of a constantly replenished crop [16].

4.2 Thermal Properties of the Urban Moroccan biomass.

4.2.1 Calorific value

The heating value of a fuel is an indication of the energy chemically bound in the fuel with reference to a standardized environment. The standardization involves the temperature, state of water (vapor or liquid), and the combustion products (CO₂, H₂O, etc.). These standard conditions are widely available in the literature on the measurement of heating values. The energy chemically bound in the fuel is given by the heating value of the fuel in energy (J) per amount of matter (kg). This energy cannot be measured directly, but only with respect to a reference state. Reference states may differ, so a number of different heating values exist. The best known are the lower heating value (LHV) and higher heating value (HHV). For the LHV, the reference state of water is its gaseous state; for the HHV, the reference state of water is its liquid state. The net heating value (LHV) decreases as the moisture content of the biomass increases. The figure 2.2 illustrates the relationship between calorific value (LHV & HHV) and moisture content [16].

**LHV Calculations are done based on the following equation:**

\[
LHV = HHV(1 - M) - 2.447M
\]

- **M**: wet basis moisture content
- **2.447**: the latent heat of vaporization of water in MJ/kg at 25°C.
The LHV of household waste is estimated to be: 1000Kcal/kg
The moisture content of household waste varies between: 60-70%

5. Assessment Interpretation

To ensure the techno-economic viability of the adopted technology, data and parameters such as the waste calorific value are crucial to the strategy success. Thereby, the previously presented data will be illustrated quantitatively and qualitatively to allow a settlement concerning the choice of the facility layout and implementation requirements.

5.1 MSW Growth and the Contained Energy

<table>
<thead>
<tr>
<th>Year</th>
<th>MSW Generation /T</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>3500.000</td>
</tr>
<tr>
<td>2014</td>
<td>3547.600</td>
</tr>
<tr>
<td>2015</td>
<td>3595.847</td>
</tr>
<tr>
<td>2016</td>
<td>3644.751</td>
</tr>
<tr>
<td>2017</td>
<td>3694.319</td>
</tr>
<tr>
<td>2018</td>
<td>3744.562</td>
</tr>
<tr>
<td>2019</td>
<td>3795.488</td>
</tr>
<tr>
<td>Year</td>
<td>MSW Generation in Casablanca ton/day</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>2020</td>
<td>3847.107</td>
</tr>
<tr>
<td>2021</td>
<td>3899.428</td>
</tr>
<tr>
<td>2022</td>
<td>3952.460</td>
</tr>
<tr>
<td>2023</td>
<td>4006.213</td>
</tr>
<tr>
<td>2024</td>
<td>4060.698</td>
</tr>
<tr>
<td>2025</td>
<td>4115.923</td>
</tr>
<tr>
<td>2026</td>
<td>4171.900</td>
</tr>
</tbody>
</table>

*Table 5: MSW Generation in Casablanca ton/day*

*Figure 14: Household Waste Generation Forecast ton/day*
Technologies to be considered:

**Figure 15: Moroccan MSW Composition**

<table>
<thead>
<tr>
<th>Waste Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>10%</td>
</tr>
<tr>
<td>Paper/cardboard</td>
<td>10%</td>
</tr>
<tr>
<td>Metal</td>
<td>3%</td>
</tr>
<tr>
<td>Glass</td>
<td>4%</td>
</tr>
<tr>
<td>Plastics</td>
<td>8%</td>
</tr>
<tr>
<td>Others</td>
<td>65%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHV kcal/kg</td>
<td>1000</td>
</tr>
<tr>
<td>Moisture content</td>
<td>65%</td>
</tr>
<tr>
<td>Energy in 1 ton Kwh</td>
<td>1162.22</td>
</tr>
</tbody>
</table>

Table 6: Data enabling Technology choice

- **Incineration**
- **Gasification**
- **Anaerobic Digestion**

The low calorific value excludes the incineration along with the gasification plant option and puts the anaerobic digestion plant in the most suitable box based on Casablanca’s waste characteristics in terms of moisture and LHV.

5.2 Social Aspect Assessment:

Based on the onsite visit the real issue that is decelerating the positive development of the waste sector remains in those families that are highly relying on the site value to generate income, and assess their family needs. Due to low authorities’ implication such as municipalities, communal security, and NGO’s, the scavengers of the community monopolize the informal sorting sector, which raises the need for social reinsertion of the Mediouna’s community.
Part III: Implementation Plan and Replacement decision

The implementation part has been constructed in alignment with Casablanca’s waste sector assessment in terms of environmental, societal, as well as technical aspects. The conclusion drawn from the previous assessment allowed for the implementation part to include first the rehabilitation plan of the site, second the set up for mechanical treatment facility along with a biological treatment.

Phase I: Rehabilitation Plan of the Landfill

Dumpsite Rehabilitation actions will be aimed at both reduction and stabilization of the risks associated with the accumulated waste, i.e. leachate control, landfill gas removal, and nuisance reduction (odor, wind scatter, birds, scavengers, pests, etc.). The general transition to dumpsite closure will include the following works [22]:

1. Shaping the main capping
2. Topsoil application, grass sowing (and possibly bush planting),
3. Gas collection and removal
4. Leachate management.

Note: Vegetation must be selected so that it doesn’t destroy the cap and it should fit into the surrounding natural landscape.

1. Dumpsite Assessment and Closure Plan:
Before starting the rehabilitation, it is important to set a plan to be approved, and available for implementation. The main components of the developed plan for Mediouna’s dumpsite:

**Solutions:**

1. Instauration of an onsite sorting and separation facility
2. If organized waste picking is allowed at the disposal site, a small space can also be allocated for these displaced families. Organized or managed waste picking may be allowed at controlled disposal sites with certain procedures in place depending on the amount that will be treated in the mechanical and biological treatment facilities. [22]
1. The potential after use of the site, which includes an MTF and BTF Facility.
2. Operational requirements to ensure the capping for the after use
3. Material to be used for capping
4. Drainage control systems
5. Security

2. Remediation
The objective of remediating an open dump is to minimize the environmental health and safety problems created by the dump. One option for the remediation of a closed site is to remove all dumped material to a replacement sanitary landfill. This is likely to be an expensive approach. It will also use space in the new landfill. It may also be possible to use bio-remediation techniques. The main considerations in selecting a cleanup technology include the following [22]:

1. • Types of contamination present
2. • Cleanup objectives and planned after use of the site
3. • Length of time needed to achieve cleanup objectives
4. • Post-treatment care needed
5. • Budget

3. Assessment and plan for a Sanitary Landfill:
Concerning the fulfillment of the remediation plan, critical slopes, capping, zoning securing, prevention of illegal disposal form the elements to be considered for the plan assessment.

- Stabilization of critical slopes
- Final cover (Capping)
- Drainage control systems
- Fire control
- Prevention of illegal dumping
- Security

Figure 16: Assessment and Plan for a Sanitary Landfill
3.1. Stabilization of Critical Slopes

A simple method for stabilization of the steep side slopes is to re-profile and re-grade them to a gentle slope of the order of 4 (horizontal): 1 (vertical). Such gentle slopes have adequate safety against sliding of components of the cover material over the waste. Thus, it may be necessary to level the heaps of garbage in order to reduce the hazards posed by unstable slopes. The final surface of the fill should be graded to about 2 - 4%, while the side slopes should have a vertical to horizontal ratio less than 1:3 [22].

3.2 Final Cover

The final soil cover (or cap) is applied to a completed disposal facility to act as a barrier in order to:

1. Reduce penetration of water into the dumping area
2. Reduce gas migration
3. Prevent digging animals from harming the cover
4. Prevent the emergence of insects/rodents from the compacted refuse
5. Minimize the escape of odors

A uniform layer with a minimum depth of 0.60 m is recommended as final soil cover.

It is usually comprised of a layer of compacted soil with a depth of at least 0.45 m and a topsoil of at least 0.5 m. The topsoil, which is generally not compacted, will serve as protection layer for the compacted soil cover, as well as support plant growth [22].

![Figure 17: Accommodated soil cover](image-url)
3.3 Drainage Control Systems
Run-on and runoff of surface waters can cause erosion and scouring of the final cover, as well as water ponding. Thus, to mitigate these effects, drainage control systems are installed in and along the periphery of the disposal area [22].

3.4 Leachate Management Systems
Leachate pipes are to be mounted to collect the leachate for later treatment. The pipes will be contingent on several aspects such as depth of the waste, topography of the area, underlying soil, and age of the deposited waste. Sources of leachate leakage at and around the surface of the dumpsite should be assured before application of the final soil cover. For seepages on the surface, these will be intercepted by constructing canals/ditches to collect the leachate. The collected leachate would then be channeled towards a leachate retention basin situated down gradient of the site. To capture leachate movement underneath the ground, an interceptor trench, cutoff wall, and assembly pipes will also be constructed down gradient of the disposal site [22].

3.5 Gas Management Systems
The generation of landfill gas, such as methane and carbon dioxide, will continue as long as waste degradation occurs. Thus, based on the environmental sensitivity of the area, it is necessary to accumulate the gas and vent it freely, flare it, or recover it for energy use. Vent pipes made of perforated polyvinyl chloride (PVC) at the edges may be used for gas management [22].

4. Elements for Rehabilitation
To ensure the feasibility of the remediation, major elements must be built and taken into consideration these essentials are presented in the table underneath.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Check box</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fencing and Security</td>
<td></td>
</tr>
<tr>
<td>Providing/Improving the access roads</td>
<td></td>
</tr>
<tr>
<td>Sign and direction boards</td>
<td></td>
</tr>
<tr>
<td>Monitoring of incoming vehicles</td>
<td></td>
</tr>
<tr>
<td>and waste characteristics</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Providing a viable alternate facility for waste disposal.</td>
<td></td>
</tr>
<tr>
<td>Prevention of open burning</td>
<td></td>
</tr>
<tr>
<td>Control of stray animals</td>
<td></td>
</tr>
<tr>
<td>Controlled scavenging</td>
<td></td>
</tr>
<tr>
<td>Lay out planning and designation of areas for filling and Controlled tipping (Zoning)</td>
<td></td>
</tr>
<tr>
<td>Provision of appropriate equipment and machinery</td>
<td></td>
</tr>
<tr>
<td>Office and record keeping</td>
<td></td>
</tr>
<tr>
<td>Environmental monitoring</td>
<td></td>
</tr>
<tr>
<td>Protection of workers (Gloves, masks, Boots etc.)</td>
<td></td>
</tr>
<tr>
<td>Drainage diversion</td>
<td></td>
</tr>
<tr>
<td>Promotion of waste segregation at source</td>
<td></td>
</tr>
<tr>
<td>Progressive rehabilitation including leachate and landfill gas management, Compaction, daily cover and organized Landfill mining</td>
<td></td>
</tr>
</tbody>
</table>

*Table 6: Elements for Landfill Rehabilitation and their Phase II: Implementation of the Replacement Decision*

**I-METHODOLOGY**

1. **Define the Feedstock and Projected Quantities:**

   The feedstock material that is used in anaerobic digestion constitutes the most important initial parameter when considering the application of anaerobic treatment. Anaerobic digesters typically can accept any biodegradable material, but the level of biodegradability is the key factor for its successful application.

2. **Develop scenarios**
In our case we will be defining 2 scenarios for the facility replacement project. The scenarios will be measuring: The actual model adopted by delegated industry/facility of Ecomed. The second scenario will consist of developing a circular supply chain where the consumer waste returns to the consumer in other forms i.e energy and organic fertilizer

Scenario 1: Actual Model
Scenario 2: MTF + AD + Compost

3. Operations Management

3.1 Develop process flow diagrams:

In order to determine handling and production modes of the scenarios a basic process description of the project will be provided along with its flow diagram. Moreover, we will be able to determine which process strategies to be adopted: Process focus, repetitive focus, product focus, and mass customization.

3.2 Develop Site layout

An overall determination of Surface acquirement, engineering equipment, including civil, mechanical, electrical, engineering, buildings, weighbridge is required to achieve an effective and efficient layout that will meet the project competitive necessities.

4. Technical Performance

The Gas Production will be defined based on the mass input, since according to the American protection agency EPA 1 ton of household is equivalent to one fuel barrel this latter has 6.1 Gj in its calorific value. Moreover 1 fermented ton of organic waste will produce 115 m3 of biogas and every 1 m3 of biogas produced have an energy value of 6KWh[37]. (See Appendix A for biogas quantity generated per waste nature).
5. Financial Performance

As minoring finance student we decided to conduct a well-structure dynamic financial analysis. It will be conducted under the scope of capital budgeting techniques to conclude which projects will have the higher yield, the most return over a given period of time. The project in this case is identified as replacement project where the parameters that are taken into account are the net present value NPV, internal rate of return IRR, and the discounted payback period DPP.

\[
NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0
\]

*Equation 1: Net Present Value*

\[C_t = \text{net cash inflow during the period } t\]
\[C_0 = \text{total initial investment costs}\]
\[r = \text{discount rate}, \]
\[t = \text{number of time periods}\]

**Cost:** Investment/ Capital cost, operating cost, financing cost.
**Revenues:** Gate fee, Energy, compost revenue, recycling revenues

II- DECISION MAKING

1. Feedstock
   The feedstock choice was determined based on the moisture content of the organic matter, and since it has a 65% average of moisture level the most suitable AD technology is the dry digestion

2. Scenarios
   As mentioned above two scenarios will be constructed a linear scenario and a circular model setup and by comparing their Financial indicator, and
environmental indicators we will be concluding which scenario is most suitable.

**Linear Strategy:** Consists evaluating the actual model used in the landfill.

**Circular Strategy:** Consists of an MTF, as well as BTF.

### 3. Overall Layout/ Process Description:

The overall circular layout of the waste management plant, will contain several areas and facilities, each contributing differently to the project objectives of recovery and recycling, residual treatment and energy recovery:

#### 3.1 Engineered Landfilling:

Space allocation for disposal then the isolation of the landfilled wastes from the environment until the wastes are stabilized and rendered innocuous as much as possible through the biological, chemical and physical processes of nature [22].

![Figure 18: Engineered Landfill operating process and Main component](image)

#### 3.2 Mechanical Treatment Facility

The dry portion (paper/cardboard, plastic, metal) is separated from the organic fraction. The dry fraction is then separated via various methods in order to recover recyclable materials.
### 3.2.1 MTF Component/Process Description

The MTF is a single production line which consists of a manual handling presorting stage; a bag opener; a 80mm rotating sieve; over band magnets; a flip-flop vibrating sieve; a ballistic separator; optical separators; an eddy current separator; and a handpicking stage [36].

The sorting facility will engage both advanced mechanical and manual systems for the separation of materials, such that the recyclable portion will be decomposed into:

- Glass
- Aluminum and steel cans
- Paper
- Cardboard
- Plastic bottles and packaging
- Other non-recyclable material

### 3.2.2 The MTF Process Layout steps description

The facility will be composed of five components and will be processing operating under five main steps [30].

| **1. Waste Reception Area** | 1. Mixed recyclable waste enters the reception area.  
2. The vehicles tip the waste in the reception area, which is usually staffed by a loader driver and/or a banksman.  
3. Waste bags are fed into a bag opener by a mechanical shovel, telehandler or via a conveyor belt. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Pre-sort Cabins</strong></td>
<td>The first stage of sorting where any unwanted items, or items, which may damage or block the downstream</td>
</tr>
</tbody>
</table>
| 3. Mechanical Sorting Machines | 1. Mechanical sorting machines then further sort recyclable materials.  
2. Trommels is used to separate the biodegradable proportion from mixed waste and to separate recyclable materials such as newspaper or cardboard.  
3. The sized waste is transported to an over-band magnet that removes steel, and then through an Eddy Current Separator that removes aluminum.  
4. Series of paddles that oscillate in pairs so the material is agitated in such a way that the light fractions move forward and the larger fractions move backwards. |
| 4. Sorting Cabins | Sorting cabins allow the manual sorting of waste in a potentially clean and safe environment.  
1. Waste passes through the cabins on conveyor belts where technicians are stationed along their length.  
2. Operators manage the Materials such that they are picked off by hand to be fixed afterward to a bunker underneath the sorting cabin where they |
5. Baling Area

Automated compressing and baling of the sorted waste. Processors dispatching

| Table 7: MTF Facility component process description |

3.2.3 Safety and health consideration

In order to provide a safe, and operating environment for the rehabilitated scavenger's key elements such as safety and health considerations must be met. These considerations are as follow [28]:

- Guarantee workload does not exceed safe levels
- Guarantee all workers are vaccinated against the biohazards for that workplace, subject to the Collective Agreement, etc
- Guarantee there is a functional Joint Occupational Health and Safety Committee in the workplace
- Guarantee the facilities are frequently checked for safety issues by the Joint Occupational Health & and Safety Committee
- Ensure sanitation and hygiene
- Afford dust control measures
- Afford proper lighting installation
- Install handrails
- Afford proper clothing and footwear
- Afford noise protection
- Afford training on all equipment
- Afford Lockout/Tagout (LO/TO) training or procedures
- Perform checkups and maintenance platforms for all equipment
- Reporting procedures for all damages and prompt, documented follow-up
- Ensure claims avoidance and suppression does not occur
3.3 Biological Treatment Facility

The organic fraction of waste is subjected to anaerobic digestion (AD) and biogas is produced for energy generation [36].

3.3.1 Digestion Process Description

An association of microorganisms functioning synergistically accomplishes the anaerobic digestion of organic material. Digestion occurs in a four-step process: hydrolysis, acidogenesis, acetogenesis, and methanogenesis see Figure Below [36]:

Figure 19: Picture illustrating auxiliary workers with safety items
1. Large protein macromolecules, fats and carbohydrate polymers (such as cellulose and starch) are broken down through hydrolysis to amino acids, long-chain fatty acids, and sugars.
2. These products are then fermented during acidogenesis to form three, four, and five-carbon volatile fatty acids, such as lactic, butyric, propionic, and valeric acid.
3. In acetogenesis, bacteria consume these fermentation products and generate acetic acid, carbon dioxide, and hydrogen.
4. Finally, methanogenic organisms consume the acetate, hydrogen, and some of the carbon dioxide to produce methane. Three biochemical pathways are used by methanogens to produce methane gas. The pathways along with the stoichiometries of the overall chemical reactions are:
   a. Acetotrophic methanogenesis: $4 \text{CH}_3\text{COOH} \rightarrow 4 \text{CO}_2 + 4 \text{CH}_4$
   b. Hydrogenotrophic methanogenesis: $\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O}$
c. Methylotrophic methanogenesis: \[4 \text{CH}_3\text{OH} + 6 \text{H}_2 \rightarrow 3 \text{CH}_4 + 2 \text{H}_2\text{O}\]

### 3.3.2 Dry anaerobic digestion

*This technology* do not operate under dry conditions; however microorganisms require moist content [31].

**Advantages of Dry Digestion:**
- Very tolerant system for contaminants (sand, fibers, large particles, ...)
- Less complex system compared to wet AD systems
- Less maintenance required - Less critical equipment (pumps, agitation systems, feeding equipment)
- Operation costs may therefore be less compared to wet systems
- Possibility of mobile biogas plants (containers).

### 3.3.3 Digester facts

The digesters are usually heated with the percolate (external heat exchanger for the liquid fraction) [31]

- Other possibilities for combined heat and power.
- Initial aeration
- Wall and floor heating
- The biogas is collected and stored in an external gas dome

![Structure of a biogas plant](image)

*Figure 21: Structure of a biogas plant*

### 3.4 Compost Refinery unit:
The digested material resulting from the anaerobic digestion is additionally treated in an aerobic composting area for the production of compost. Compost is refined and impurities - such as plastics, aggregates and glass - are suppressed [32].

3.5 Residual Acceptance Area:

It should be located within landfill site, adjacent to the MBT site, for the disposal of treated residues. [32]

4. Scenarios and Operations and Management

Depending on process and product strategies aligned with the competitive advantage of the two strategies two flow diagrams has been drawn and they are as follow

4.1 Linear scenario:

The linear scenario adopted by the actual delegator consists of landfilling, and controlling the inputted waste weight, which puts the model in a repetitive continuous high volume, low variety process strategy. Since 2008 only a small portion was processed under a concrete waste treatment method 700 m^2 only of rehabilitated. The following diagram shows the main component flow of the actual discharge illustrated linearly.

![Flow Diagram for the linear scenario](image_url)

4.1.2 Linear Model Technical Performance:

After the onsite visit, and online data extraction we managed to critically assess the technical progress made by Ecomed group. The following table summarizes the fulfilled elements and the uncompleted ones.
The technical performance assessment shows that Ecomed group is not progressing in the fulfillment of their contract promises. Such that the only added value constitute of a controlled tonnage disposal, thus no excess tonnage is accepted. The causes of this slow, not to say non-existing advancement, is the low implication, and synergy between the institutional frameworks.

4.1.3 Financial Performance:

Ecomed has not been processing waste treatment efficiently and effectively, that is why it has been generating higher net revenue than the expected one while the municipality accumulated a relatively great net loss.

The linear model limitations can be illustrated in space requirement as well as the mighty future heavy capital investment to treat the heavy underground-saturated volume of leachate.
4.2 Circular Scenario

Waste fermentation completes the cycle of materials, and competition with areas used for food production and pastureland is avoided [25]. Biogas is substitute fossil fuels for the generation of electricity and heat over different bioenergy pathways CHP mode. The circular model is characterized by high volume, medium variety, and repetitive process product strategy. We will be adopting a process and product layout as our competitive advantage is ensuring the flow of matter for a virtually zero waste production. The model has one input and four different output: recyclables, biogas, compost matter, and residuals to be dumped afterward.

Since The MBT Facility will be accepting 50% of Casablanca’s waste. We we’ll be processing 2 assumptions prototype where the first fully applying the circular model, and the second an enhanced circular/ linear model where all the waste will be handled. This modified circular model will enable the extraction of landfill biogas, which will be chemically treated afterward then sold the in form of electricity to Lydec power grid or highly industrialized companies.

*Figure 17: Circular Scenario Flow Diagram*
3.2.1 Technical-economic Performance

The techno-economic Performance will be evaluated upon the possible input output energy, mass of compost and recyclable materials. Given the fact that the largest facility in the world processes 90000 ton per year. We drew the following assumptions:

**Assumption 1:** The MBF will be processing 50% of the overall waste disposed in the landfill.

**Assumption 2:** The MBF will be processing 50% of the overall waste, and the remaining portion will be treated to extract landfill gas, that will be afterward converted to electricity in enhanced linear model.

4.2.1 Assumption #1

Based on the previous assessment of waste composition we were able to draw the combined mechanical and biological facility technical components using an efficiency of 30% in the digester.

<table>
<thead>
<tr>
<th>Technical data</th>
<th>Column1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Waste T/year</td>
<td>500000</td>
</tr>
<tr>
<td>Organic Portion T/year</td>
<td>325000</td>
</tr>
<tr>
<td>Metal Portion T/Year</td>
<td>20000</td>
</tr>
<tr>
<td>Plastic portion T/Year</td>
<td>50000</td>
</tr>
<tr>
<td>Glass Portion T/Year</td>
<td>15000</td>
</tr>
<tr>
<td>Paper/cardboard T/year</td>
<td>50000</td>
</tr>
<tr>
<td>Biogas volume m³/year</td>
<td>3737500</td>
</tr>
<tr>
<td>Energy output Kwh/year</td>
<td>22425000</td>
</tr>
<tr>
<td>Compost output T/year</td>
<td>59475</td>
</tr>
<tr>
<td>Energy input Kwh/y</td>
<td>67275000</td>
</tr>
<tr>
<td>Energy for sale Kwh/y</td>
<td>15697500</td>
</tr>
<tr>
<td>Landfill gate reception t/y</td>
<td>1277500</td>
</tr>
<tr>
<td>Biogas Volume 1 ton of fermented organic waste</td>
<td></td>
</tr>
<tr>
<td>1 m³ of biogas energy production (Kwh)</td>
<td>113</td>
</tr>
</tbody>
</table>

*Table 9: Circular flow handling half of MSW Generated technical data*
The financial performance has been conducted by reviewing the costs of the available technologies, then adopted and shaped for our circular case. We evaluated the prices of each unit of good or service that will be sold to enable revenue speculation.

<table>
<thead>
<tr>
<th>Unit Price</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Price/kwh</td>
<td>MAD 1.50</td>
</tr>
<tr>
<td>Gate fee/ton</td>
<td>MAD 300.00</td>
</tr>
<tr>
<td>Compost unit price/ton</td>
<td>MAD 1,200.00</td>
</tr>
<tr>
<td>Glass unit price/ton</td>
<td>MAD 500.00</td>
</tr>
<tr>
<td>Plastic/ton</td>
<td>MAD 1,000.00</td>
</tr>
<tr>
<td>Paper/cardboard /ton</td>
<td>MAD 800.00</td>
</tr>
</tbody>
</table>

*Table 10: Unit Price for each good and service*

A financial summary table was constructed combining the main parameters to be considered: NPV, IRR, PBP, and DPB.

<table>
<thead>
<tr>
<th>Financial Analysis Summary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Rate</td>
<td>6.5%</td>
</tr>
<tr>
<td>Ecotax</td>
<td>1.5%</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>MAD (1,150,800,000.00)</td>
</tr>
<tr>
<td>Operating Cost/year</td>
<td>MAD (150,700,000.00)</td>
</tr>
<tr>
<td>Financing Cost</td>
<td>MAD (301,400,000.00)</td>
</tr>
<tr>
<td>Total Revenues</td>
<td>MAD 787,582,500.00</td>
</tr>
<tr>
<td>NPV</td>
<td>MAD 12,329,422,418.25</td>
</tr>
<tr>
<td>Payback period (years)</td>
<td>3.4</td>
</tr>
<tr>
<td>IRR</td>
<td>27%</td>
</tr>
<tr>
<td>Discounted Payback Period</td>
<td>3.35</td>
</tr>
</tbody>
</table>

*Table 11: First Assumption Economical performance summary*

*Note:* Over a 20 years lifecycle we obtain an IRR higher than the discount rate, which means the viability of this project is very likely.

#### 4.2.2 Assumption #2: Enhanced linear circular model

This model includes the MBF as well as sanitary Landfill set in order to extract biogas to be converted to energy afterward. The cost and revenues has been computed dynamically such that generation of MSW growth was considered in order to assess the exact remaining portion of MSW/Year. Main technical component are given in the table below:

<table>
<thead>
<tr>
<th>Technical component</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input waste</td>
<td>More than 1000000</td>
</tr>
<tr>
<td>Average Output Energy (Kwh)</td>
<td>3.09E+08</td>
</tr>
<tr>
<td>Total capacity (MWh)</td>
<td>3.09E+05</td>
</tr>
</tbody>
</table>

*Table 12: Total capacity of the enhanced linear circular model*

In this model we can notice a higher energy yield which puts our zero waste prospect in a highly viable perspective.
See Appendix D for detailed financial analysis.

Summary of Findings

<table>
<thead>
<tr>
<th></th>
<th>Linear Model</th>
<th>Circular Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Output (MWh)</td>
<td>0</td>
<td>$3 \times 10^8$</td>
</tr>
<tr>
<td>NPV</td>
<td>MAD 38,590,000.00</td>
<td>MAD 12,740,546,309.45</td>
</tr>
<tr>
<td>Payback Period</td>
<td>6 years</td>
<td>4 years</td>
</tr>
<tr>
<td>GHG</td>
<td>Uncontrolled</td>
<td>Controlled: about 120 kg of CO2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>emissions is saved/ ton</td>
</tr>
</tbody>
</table>

*Table 14: Comparative summary of findings*
CONCLUSION

Mediouna’s dumpsite contains a great potential that it poorly exploited; an effective integrated waste Management is indeed needed such that “no waste goes to waste” and one of the best methods to do so is to adopt the circular economy principle of flow of matter. In fact the conducted techno-economic assessment has resulted in high-energy capacity, and income. The circular/ enhanced linear model processed in this report highlights the efficiency and effectiveness of this supply chain such that it generates high profit margin using the three 3R's Principle: reuse, recycle, and recover.

The circular economy combines both waste and energy management within a low footprint, it also considers the residual output as a valuable input until the cycle limit is reached. That is why the Casablanca municipalities should drive up its waste management strategy and start operating in such manner to be able to provide energy to its people through their own waste. However, the viability of this model lays on a strong intercommunication and synergy between the stakeholders’ institutional frameworks. As a matter of fact the commune should proceed under a joint venture and not as a delegation to avoid conflict of interest, thus aspire for the well-being of the city waste and environment. Besides, a risk assessment of the landfill area should be further conducted to ensure an efficient working, and operating environment thus avoiding failure of the waste treatment unit.
APPENDICES:

Appendix A:

Figure 1: Biogas quantity yields per type of feedstock/livestock

Appendix B:

Box 2.4 Engineered landfill techniques

- Control and avoidance of surface water entering the deposited wastes by installing a well-designed and constructed surface drainage system
- Extraction and spreading of soil materials to cover wastes
- Spreading and compacting wastes into smaller layers
- Collection and removal of leachate away from wastes into lagoons or similar structures.
- Passive venting of landfill gas out of the wastes
- Improvements in the isolation of wastes from the surrounding geology

Box listing the techniques for Engineered Landfill.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Open Dump</th>
<th>Controlled Dump</th>
<th>Sanitary Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting of facility</td>
<td>Unplanned and often improperly sited</td>
<td>Hydrogeologic conditions considered</td>
<td>Environmental, Social and Economic factors</td>
</tr>
<tr>
<td>Capacity</td>
<td>Site capacity is not known</td>
<td>Planned capacity</td>
<td>Planned capacity</td>
</tr>
<tr>
<td>Cell planning</td>
<td>No cell planning and the waste is indiscriminately dumped</td>
<td>There is no cell planning, but the working face/area is minimized</td>
<td>Developed cell by cell</td>
</tr>
<tr>
<td></td>
<td>The working face/area is not controlled</td>
<td>Disposal is only at designated cells</td>
<td>Working face/area is confined to the smallest area practical</td>
</tr>
<tr>
<td>Site Preparation</td>
<td>Little or no site preparation, usually a wetland / swamp areas are used.</td>
<td>Grading of the bottom of the disposal site</td>
<td>Disposal only at designated cells</td>
</tr>
<tr>
<td>Leachate management</td>
<td>No leachate management</td>
<td>Partial leachate collection and simple treatment</td>
<td>Full leachate collection and advanced treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leachate quality control programme</td>
</tr>
<tr>
<td>Gas management</td>
<td>No gas management</td>
<td>Partial or no gas management</td>
<td>Full gas management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gas emission control / warning systems</td>
</tr>
<tr>
<td>Application of soil cover</td>
<td>No covering of waste</td>
<td>Covering of waste implemented regularly but not necessarily daily</td>
<td>Daily, intermediate and final soil cover applied</td>
</tr>
<tr>
<td>Compaction of waste</td>
<td>No compaction of waste</td>
<td>Compaction in some cases</td>
<td>Waste compaction</td>
</tr>
<tr>
<td>Access road maintenance</td>
<td>No proper maintenance of access road</td>
<td>Limited maintenance of access road</td>
<td>Full development and maintenance of access road</td>
</tr>
<tr>
<td>Fencing</td>
<td>No fence</td>
<td>With fencing</td>
<td>Secure fencing with gate</td>
</tr>
<tr>
<td>Waste input control</td>
<td>No control over quantity and/or composition of incoming waste</td>
<td>Partial or no control of waste quantity, but waste accepted for disposal is limited to MSW</td>
<td>Full control over quantity and composition of incoming waste</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Special provisions for special types of wastes</td>
</tr>
<tr>
<td>Record keeping</td>
<td>No record keeping</td>
<td>Basic record keeping</td>
<td>Complete record of waste volumes, types, sources and site activities/events</td>
</tr>
<tr>
<td>Waste picking</td>
<td>Waste picking by scavengers</td>
<td>Controlled waste picking and trading</td>
<td>No on site waste picking and trading</td>
</tr>
<tr>
<td>Closure</td>
<td>No proper closure of site after cease of operations</td>
<td>Closure activities limited to covering with loose or partially compacted soil and replanting of vegetation</td>
<td>Full closure and post-closure management</td>
</tr>
<tr>
<td>Cost</td>
<td>Low initial cost, high long term cost</td>
<td>Low to moderate initial cost, high long term cost</td>
<td>Increased initial, operational and maintenance costs, moderate long term cost</td>
</tr>
<tr>
<td>Environmental and health impacts</td>
<td>High potential for fires and adverse environmental and health impacts</td>
<td>Lesser risk of adverse environmental and health impacts compared to an open dumpsites</td>
<td>Minimum risk of adverse environmental and health impacts</td>
</tr>
</tbody>
</table>

Table: Summary of Landfill types and their comforting criteria explanation

**APPENDIX C**
Sanitary Landfill scheme
Bibliography


