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**ENVIRONMENTAL COST BENEFIT ANALYSIS OF  
WASTE TO ENERGY RECOVERY IN NIFAS SILK  
LAFTO SUBCITY ADDIS ABABA**  
(As a component in the context of integrated solid waste management)

By

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## **KEY WORDS:**

*Level of integration, waste to energy recovery treatment, sustainable solid waste management, waste collection, integrated solid waste management, cost benefit analysis*

## **LIST OF ABBREVIATIONS**

AAEPA	Addis Ababa city Environmental Protection Authority
SBPDA	Addis Ababa city sanitation beautification and park development
EEA	European Environmental Agency
EKC	Environmental Kurznet Curve
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EU	European Union
ISWM	Integrated Solid Waste Management
WMD	Waste Management Department
CBA	Cost Benefit Analysis
MSWM	Municipal Solid Waste Management
RCRA	Resource Conservation and Recovery Act
UNCED	United Nations Commission on Environment and Development
APC	Air Pollution Control System
DOE	Department of Energy
SWM	Solid Waste Management
WTER	Waste To Energy Recovery
LCA	Life Cycle Assessment
MRF	Material Recovery Facility
SW	Solid Waste
NPV	Net Present Value
IRR	Internal Rate of Return
MSW	Municipal Solid Waste
MSE	Micro and Small Enterprise
PISWM	Policy for Integrated Solid Waste Management
US	United States
BCR	Benefit Cost Ratio
PM	Particulate Matter
RDF	Refuse Derived Fuel
WTF	Waste Treatment Facility
ERRA	European Resource Recovery Association
MIRR	Mixed Internal Rate of Return

## TABLE OF CONTENTS

### Section Page

- Acknowledgment
- Abstract
- Key words
- List of Abbreviations
- Table of contents

### CHAPTER ONE

#### 1. Introduction

- 1.1 Background .....
- 1.2 Overview of Addis Ababa's municipal solid waste management
  - 1.2.1 Institutional frame work .....
  - 1.2.2 Rate of MSW generation .....
- 1.3 Characterization .....
- 1.4 responsibilities for waste management in Addis Ababa .....
- 1.5 collection, transport and final disposal of MSW
  - 1.5.1 Collection .....
  - 1.5.2 Transportation .....
  - 1.5.3 Disposal .....
  - 1.5.4 Status of recycling .....
- 1.6 Objectives.....
- 1.7 Rationale for the studies.....
- 1.8 Theory of waste management.....
- 1.9 Conceptual frame work.....
  - 1.9.1 Introducing WTER treatment of solid waste.....
  - 1.9.2 Integrated solid waste management process.....
    - 1.9.2.1 Definition of solid waste .....
    - 1.9.2.2 Theory of integrated solid waste management .....
    - 1.9.2.3 Component of an integrated solid waste management .....
    - 1.9.2.4 ISWM and local economics.....
  - 1.9.3 Environmental economics
    - 1.9.3.1 Introduction to environmental economics .....
    - 1.9.3.2 Why is environmental valuation important .....
    - 1.9.3.3 Cost benefit analysis.....
    - 1.9.3.4 The choice of discount rate .....

### CHAPTER TWO

#### 2. Material and methods

- 2.1 Source of data .....
- 2.2 Instruments .....
- 2.3 methods .....
- 2.4 Data analysis and presentation .....
- 2.5 Scope .....
- 2.6 Out line of report .....

### CAPTER THREE

#### 3. Waste to Energy Recovery

3.1 overview .....	
3.2 waste to energy recovery as a renewable source of energy .....	
3.3 waste to energy recovery for Addis Ababa .....	

## CHAPTER FOUR

### 4. cost-benefit analysis of a waste to energy recovery plant for Nifasilk lafto sub city

4.1 Description of the project .....	
4.2 stake holders and secondary market effects .....	
4.2.1 Stake holders .....	
4.2.2 Secondary market effect .....	
4.3 Non-quantifiable impacts	
4.3.1 Environmental impacts .....	
4.3.2 Economic impacts.....	
4.3.3 Social impacts .....	
4.4 Assumptions	
4.4.1 Technology .....	
4.4.1.1 Available technologies.....	
4.4.1.2 Selecting the appropriate technology.....	
4.4.2 Location.....	
4.4.3 Production of carbon free charcoal.....	
4.5 Monetizing costs and benefits.....	
4.5.1 Monetized costs .....	
4.5.1.1 Investment .....	
4.5.1.2 Operational costs.....	
4.5.2 Monetized benefits	
4.5.2.1 Free carbon charcoal generation.....	
4.5.2.2 Production of liquid bi-product used as a raw material for the production of varnish.....	
4.5.2.3 Benefit from the inorganic parts of solid waste.....	
4.6 Discount rate.....	
4.7 Results.....	
4.8 sensitivity analysis.....	
4.9 cost benefit analysis conclusions.....	

## CHAPTER FIVE

### 5. Conclusions Discussion and recommendation

5.1 Discussion	
5.1.1 The integration of solid waste of waste management.....	
5.1.2 Ways of integrating the wastes.....	
5.1.3 Showing the environmental and economical benefits of a WTER method of Managing solid wastes.....	
5.1.4 Integration of waste or materials collection and handling with the treatment, Processing and disposal methods.....	
5.2 conclusions.....	
5.3 Recommendations.....	
<b>6. References .....</b>	

LIST OF TABLES

Table 1.1 rate of MSW generation in Addis Ababa.....  
Table 1.2 Waste composition of Addis Ababa.....  
Table 1.3 pay back method comparison.....  
Table 1.4 discounted pay back method.....  
Table 1.5 net present value.....  
Table 1.6 comparison between NPV and IRR.....  
Table 4.1 heating value of MSW in Addis Ababa.....  
Table 9.1 cost of collection and final disposal for the municipality of nifasilklafto sub city

LIST OF FIGURES

Figure 1.1 integrated waste management hierarchy.....  
Figure 1.2 major parts of environmental economics in a simplified form.....  
Figure 2.1 composition of the Addis Ababa.....  
Figure 4.1 A typical waste to energy combustor .....  
Figure 5.1 schematic diagram of the mass burn technology .....  
Figure 5.2 schematic diagram of semaas.....  
Figure 5.3 the martin grate combustion system .....

## **ABSTRACT**

Addis Ababa current solid waste management system is in crisis and faces important political, geographical and environmental challenges that make it non-sustainable. Therefore there is an urgent need to move towards an integrated solid waste management that includes modern alternatives, such as waste-to-energy recovery (WTER). In a sustainable development approach, waste should be regarded as a resource for materials and energy recovery and not simply as a product for disposal.

The objective of this research is to propose an integrated solid waste management for lafto sub city that focuses on the use of WTER as the key component. This study offers a cost benefit analysis of one WTER plant that will serve Lafto sub city.

The mass burn technology of the martin reverse –acting grate was selected for a WTER plant of capacity of 1000 metric tones /day but for the case of lafto sub city it is modified to accept small amount of solid waste. This plant will provide 540 kg/ton of MSW of net charcoal out put to utilities.

The cost-benefit analysis indicated that at the assumed benefits from charcoal production, liquid bi-product and inorganic part of solid waste the project has a positive Net Present Value (NPV) of \$9,049,949 at a 9% discount rate, therefore the project should be undertaken. The initial investment would be paid back in 4 years while the WTER plant would have a useful life of at least 30 years. Thus, the sensitivity analysis showed that the WTER facility could charge a significantly lower cost than current dumping system and still have a positive NPV. However, a very small increase or decrease in the charcoal price or heating value can make a dramatic difference in profitability.

Before the construction of the plant, the none-quantifiable impacts such as the environmental, social and economic factors must be carefully examined. The perception of air pollution associated with the incinerators of the past and the location of the WTER plant are factors that could generate opposition from the host community. On the other hand, modern Waste-to-Energy Recovery plants have been shown to result in a dramatic decrease in air emissions in comparison to dumping site. Also, their emissions are much below the EPA standards and lower than coal power plant emissions. In addition, the location of a WTER plant will be closer to the municipality than the present dumping site. This will reduce truck travel and diesel emissions to the atmosphere, and a significant reduction in generated smog. Overall, the non-quantifiable benefits seem to outweigh the non-quantifiable costs, therefore supporting the construction of a WTER plant for Lafto sub city, Addis Ababa. The community would have to be educated about these issues.

Considering that the current waste management situation in lafto sub city is almost identical to the rest of Addis Ababa, the possibilities of WTER as a widespread solution for waste management are very promising.

Addis Ababa's city government should implement an integrated solid waste management system that would perfectly solve the problem arising from solid wastes. Addis Ababa city government has already started recycling solid wastes. This decreases the amount of solid wastes that will be disposed to the dumping site. In addition, the WTER plant proposed

in this research for Lafto sub city could process an additional solid waste stream of Addis Ababa. Under this condition, Addis Ababa's waste to be disposed into dumping site would be reduced.

This would be a major step towards Integrated Solid Waste Management and the goals of sustainable development. Positive experience with WTER and its widespread use in other countries should provide an encouraging prospect for Addis Ababa too.



# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Background

The high population and its associated increase in urbanization and economic activities in Addis Ababa, has made the impact of the society's solid waste very noticeable. The daily waste generation is estimated 5.4kg/capita/day. The current daily waste generation of the city is 800 tones. Of municipal waste per day, 65 % is collected (Addis Ababa city SBPDA, 2003). The remaining 35% of waste is disposed off through informal means, except smaller percentage going to dumped on open sites, drainage channels, rivers and valleys as well as on the streets. The rivers are widely used as disposal sites. As simple observation around rivers bank indicates, large percentage of the uncontrolled waste goes to the rivers. Although the hygiene and environmental sanitation regulation issued by the Addis Ababa city government environmental protection authority prohibits people from disposing waste along roads, avenues, rivers, ponds, and other sites, the regulation is continuously violated by the some peoples due to lack of alternative means for disposal.

The rapid population growth rate is also resulting in a rise of urban waste generation. This implies that the current waste collection and disposal capacity is not matched with the growing generation. These environmental problems also have socio-economic consequences. Poor environmental quality of cities can deprive citizens of a good quality of life as it affects their health and consequently, adversely affect productivity and economic development (Geenhuizen and Van Nijkamp, 1995). Various concepts have been developed over the years to provide the basis for improving the solid waste conditions in developing countries. Among them, integrated solid waste management (ISWM) provides a framework, which has been very successful in various countries.

Inadequate municipal and industrial dry waste collection and disposal creates a range of environmental problems in Addis Ababa. A considerable amount of waste ends up in open dumps or drainage system, threatening both surface water and ground water quality and causing flooding, which provides a breeding ground for diseases - carrying pests. Open air burning of waste and spontaneous combustion in dumping site that lack effective treatments for gas emissions are causing air pollution. The situation is exacerbated in slums where households cannot make use of garbage collection containers. Lack of the most basic solid waste services in crowded, low-income neighbors is a major contributor to the high morbidity and mortality among the urban poor. The adverse effect of inadequate solid waste service on productivity and economic development of the city expected to be significant.

The design and optimization of solid waste management technologies and practices that aim at maximizing the yield of valuable products from waste, as well as minimizing the environmental effects have had little or no consideration in the Africa region.

The inadequate information on quantification and characterization of waste; health, social, economics and environmental impact of municipal solid waste management is a common occurrence in Addis Ababa. The problem is only compounded by insufficient funding. The waste management system so far in Addis Ababa has not properly integrated other solutions as collection, treatment, and supply for re-use, reprocessing and

final disposal. The system has also not delivered the optimum economic and environmental result for now and has not provided enough room to adapt to future pressures (increases in waste quantities and composition). The present SWM system in Addis Ababa relies entirely on the municipality, which is expected to provide the full range of waste collection and disposal. This is proving to be an impossible task, and except for privileged areas, the services offered are found to be largely inadequate. This approach neglects the many activities and actors that waste management comprise to tackle a range of problems associated with waste management in order to achieve socially and environmentally responsible waste management. An integrated approach to SWM seems to be the best option and could well hold the key to effective and sustainable waste management system in developing cities such as Addis Ababa. As effort to improve solid waste management, Addis Ababa city government environmental protection authority already started different activities that will solve the problems arising from solid wastes. In addition to Addis Ababa city government EPA Addis Ababa City Sanitation, Beautification and Park Development Agency have established with the objective to make the city naturally balanced, green and favorable environment through integrated management and urban recreational area development.

The Addis Ababa city government is also faced with the problem of land acquisition for citing dumping sites as residents reject the citing of this facility. This makes the siting of waste treatment facilities quite difficult. The only dumping site with in Addis Ababa is Repi or Koshe dumping site. However this dumping site may be filled even before the estimated lifetime if proper management system is not put in place. It is time therefore to establish a paradigm of waste management with a necessity of an integrated waste management system whereby collection/sorting, waste to energy recovery treatment, recycling and composting of the municipal solid waste are incorporated. In practice solid waste management must combine many different methods based on an integrated system.

## **1.2 Overview of Addis Ababa Municipal Solid Waste Management**

### **1.2.1 Institutional Framework**

Addis Ababa is divided in 10 sub-cities which are responsible for the collection, transport and final disposal of municipal solid waste. The Addis Ababa city government Environmental Protection Authority is responsible for setting environmental standards and norms and enforcing their implementation. Based on an environmental assessment, Addis Ababa city government Environmental Protection Authority decides on the approval of dumping site and landfills or other industrial projects regarding the final disposal of MSW. EPA is also responsible for the imposition of penalties for non compliance with environmental regulations.

### **1.2.2 Rate of MSW Generation**

According to the most recent census, Addis Ababa Region with 3.5 million inhabitants represents nearly 4.7 % of the Ethiopian population. The city produces 5.4 kg of garbage per capita daily. As shown in Table 1, the annual amount of MSW produced in Addis Ababa in 2001 was about 242,874 metric tons. It is expected that by the year 2011 the annual amount of MSW generated in Addis Ababa will reach 297,000 metric tons.

Table 1.1: Rate of MSW Generation in Addis Ababa

Year	Metric tons/year
2001	242,874
2002	247,870
2003	269,432
2004	270,543
2005	279,876
2006	280,564
2007	288,000
2008	291,000
2009	292,000
2010	295,876
2011	297,000

- Projected by Addis Ababa City Sanitation Beautification and Park Development Agency,2006

### 1.3 Characterization

About half of all residential solid waste generated in Addis Ababa is organic, while paper accounts for 12.21%, plastic 12.43% and textiles 2.98%. Metals and glass make up a smaller percentage, 2.15% and 3.22% respectively.

Table 1.2 waste composition of Addis Ababa

	Type of waste	Amount of waste in percent
1	Food wastes	48.65
2	Yard wastes	3.00
3	Plastic	12.43
4	Paper	12.21
5	Cardboard	2.22
6	Beverage and milk boxes	0.32
7	Rubber and leather	1.06
8	Textiles	2.98
9	Glass	3.22
10	Metal	2.15
11	Woods	2.46
12	dirt ashes and other fines	3.69
13	miscellaneous	5.59

Source: Addis Ababa City Sanitation Beautification and Park Development Agency

## **1.4 Responsibility for Waste Management in Addis Ababa**

The current regulation is pressed and complete and is controlled by Addis Ababa City Government Environmental Protection Authority (AAEPA).AAEPA is responsible in putting rules and laws regarding waste management in Addis Ababa.The authority plays a great role in controlling environmental, social and economical problems resulting from wastes.

In addition to AAEPA, Addis Ababa city sanitation beautification and park development, newly established, also responsible for waste management. Since Addis Ababa is divided by sub city an important share of sub city budgets is spent on the administration and management of solid waste services. Another problem faced by the sub cities is that all sub cities in Addis Ababa has only one dumping site where it can dispose its wastes. This generates a lack of transparency in the awarding of some contracts and creates a wide distribution of process for the same services.

## **1.5 Collection, Transport and Final Disposal of MSW**

### **1.5.1 Collection**

Municipal waste collection is handled in three ways: door-to-door collection for households along accessible streets; block collection for clients (large hotels, enterprises, and institutions) requesting the municipality to provide them with refuse containers; and containers system, which expects residents to carry and dump their waste in 8m<sup>3</sup> refuse containers placed supposedly accessible sites.

In practice 85 per cent of the waste is collected through the container system. Although the objective is to service every 2-3 days, containers are actually emptied in more than a week period on average. Besides, some households are located 1 km away from their closest container that people tend to through their waste in sewer and ditches. All solid waste collected by the municipality to single dumpingsite, Repi dumping site, 40 years old (located south of the city) that is proved to be difficult to prevent scavengers from scratching through hazardous waste. The efficiency of this method is limited because of the capacity of the city council to deploy adequate number of vehicles and waste containers, which in turn have direct relationship with revenue generation of the city. Other waste disposal method such as composting of agricultural wastes, incineration and recycling of wastes are not used.

Recently, 674 Micro and Small Enterprises (MSE) are engaged primarily collection from households to municipal container - improved collection of waste and created job for jobless youths.A recent study made by the Addis Ababa City government shows that the coverage has been constantly increasing from 38 percent in 1993 to 40 percent in 1994 and 53.9percent in 1996. The amount of waste generated in the city increased by 4 per cent (Hassen, 1998). Generally, in Addis Ababa, each keble (equivalent to neighborhood) has no more than two or three solid waste collection containers. According to 1994 population census, population of keble ranges 2500- 7031. According to Yami (1999), a single container shared by 14934 people which is 8 times higher than recommend by NUPI (one container for 2000). The settlement pattern of Addis Ababa is a spreading out. People need to travel long distance to use containers while the recommended distance by the same study is not to exceed 200mts.

Besides, containers are not protected from rain and sun that makes the garbage to cause

smell pollution, unsightly urban scene and deterioration of the neighborhood and disturbance of human activities. The site is also exposed for animals like dog, cat, and others during scavenging scatter the waste in the surrounding area. The situation in the newly developed parts of the city is not different.

### **1.5.2 Transportation**

Out of the total trucks, only a few of them work daily because of the average age of trucks more than 5 years, maintenance difficulties, negligence of drivers, frequent accidents during traffic congestion. The vehicles carry only a single container at a time to disposal site. A trip is made to and from collection sites only for single container of maximum capacity of 8m<sup>3</sup> or 2160kgs. Considering the cost of fuel, manpower and overhead costs for transportation per single trip that the system is inefficient and not economical. Some time the trucks have no cover for waste container and it distributed while travels to disposal site.

### **1.5.3 Disposal**

Reppi or "Koshe", the dumping site located 13kms away from the city center. This site has been giving service since 1968. The present method of disposal is crude open dumping; hauling the wastes by truck, spreading and leveling by bulldozer and compacting by compactor bulldozer. The dumpsite is getting full; it is partly surrounded by residents and institutions and has no gas control. The gas generated from the dumping site causes spontaneous fire and air pollution. It contribute enormous amount of methane (green house gas) to the atmosphere. The site has low area capacity (25 ha), poor road connection.

### **1.5.4 Status of Recycling**

Presently, it is not obligatory to separate recyclable from trash in Addis Ababa. As a consequence, there is little recycling consciousness among the citizens. Where recycling exists, it is minimal, sporadic and accomplished in an informal and voluntary way. It is estimated that 3.5% of the total amount of MSW generate in Addis Ababa is recycled.

Whatever sorting of recyclable materials is done is done manually. This informal economic sector is made up of street cardboard collectors ('cartoners') and scavengers who as individuals recover small volumes of paper, glass and food wastes from homes and businesses. Another informal commercial sector buys the collected material and resells it to a handful of recycling companies. There is no a Materials Recovery Facility (MRF) where all the recycling materials are processed together. The government goal is that by 2020 recycling of MSW generated should increase. However, to reach that, recycling must be mandatory and there should be an appropriate framework and regulations. Also, the public should be educated since, as mentioned above, there is no a recycling consciousness among citizens.

A study by the Ethiopian environmental protection authority showed that the cost of recycling in Addis Ababa is less than the cost of final disposal into dumping site, which should encourage further recycling.

## **1.6 Objectives**

This study is aimed in providing a basis for addressing some of the lapses through an integrated solid waste management approach incorporating waste to energy recovery plant for waste treatment as one of the components and finding its benefit using environmental cost benefit analysis. The specific objectives are to:

The specific objectives are :

- to find the economic impacts of Waste To energy Recovery plant in Solving the problems arising from solid wastes
- to find the environmental impacts of a Waste To energy recovery of Managing solid wastes

The specific objectives are to:

- Assess the notability of waste to energy recovery plant for waste treatment as a useful and potentially applicable method of handling the city's waste.
- recommend practices that will improve and yield benefits in municipal solid waste management process in the city.
- calculate the cost and benefits of solid waste management activities using environmental cost benefit analysis (CBA)
- demonstrate how important the environmental cost benefit analysis is for the reduction of solid wastes

## **1.7 Rationale for the studies**

The rapid increase in volumes of unattended to solid wastes with the associated risk to human health is a source of concern. There is also a steady increase in the cost and logistical difficulties of municipal solid waste management. This has put increasing pressures on the infrastructure and authorities responsible for the management of solid waste. Dumping spaces are diminishing and there is difficulty in finding suitable locations and getting public approval. Large investments are required for constructing landfill and new dumping sites facilities. It is therefore prudent to look for and implement long-term integrated waste management strategies that ensure a sustainable approach for waste management services.

The study is also to provide an understanding of the fact that a substantial percentage of the waste in Addis Ababa is organic and therefore potentially re-useable or recyclable for energy extraction. To convert the waste into useful resources, the appropriate technology and resources have to be employed. Waste is a subjective concept and that what is considered waste presently, may become a resource in the future because the 'waste' has not been put to its full potential use. Even in properly networked industrial set ups, the waste from one factory becomes the raw material of another. Therefore "the rearrangement and closing of material cycles, for example, opens the way to reduce wastes that will disposed in to dumping sites and landfill and contributes to the conservation of resources".

Another rationale for the study is to elicit the fact that waste to energy recovery treatment of the solid waste in Addis Ababa provides the optimum benefits to society and the environment. With the present system of dumping, organic waste has the potential to cause significant pollution through leachate production, which can seriously affect water sources. Uncontrolled emission of methane gas to the atmosphere also adds to global

warming and fire outbreaks. This dumping is also a source of transmission of pathogens to animals and soil as well as production of odors and flies. Thus treatment of solid waste by waste to energy recovery, which is an engineered process of solid waste management when practiced, can provide a range of benefits. These benefits include: waste treatment, reducing pollution, odors and disease; recycling of nutrients back to the soil; reducing the spread of soil-borne pathogens due to the high temperature and chemical environment of the waste to energy recovery process. The waste to energy recovery's potential to become a major part of the waste management system is dependent on the value of the organic waste as a source of useful energy, solid and liquid residues to agriculture and the environment. With these benefits, the logic for treatment of waste using WTER over other techniques becomes superior. The other rationale for the study is since there is no enough information on the environmental cost benefit analysis of integrated solid waste management system in Addis Ababa it is important to show the WTER treatment plant benefits using environmental cost benefit analysis.

## **1.8 Theory of waste management**

In industrialized nations the waste management practices evolved with the 1970's focusing on reducing environmental impacts (Tanskanen 2000). This was done by creating controlled landfill sites (Read, 2003), establishing waste transfer stations or redirecting waste collection vehicle routes (Truitt et al. 1969). The 1980's and early 1990's focused on new technological solutions for waste management while the mid 1990's until today, the focus is on resource recovery (Read, 2003). In this regard recycling, incineration, composting and bioreactor treatment for energy, nutrient recovery and waste to energy recovery methods are included in MSWM systems (Chang and Wei 1999 and MacDonald 1996).

To achieve waste management objectives and abide by these policies, model or systems of waste management have evolved. These decision support models involve the use of methods and tools such as cost benefit analysis (CBA), life cycle analysis LCA and integrated waste management (Morissey and Browne 2004; Read, 2003). Waste management systems based on CBA usually convert all economic, social and environmental impacts into monetary terms (Berkhout and Howes 1997). In this case economic impacts are readily obtained by the cost of building waste management facilities and the revenues generated from such facilities. Social and environmental impacts are estimated by the cost of abating pollution from a waste treatment facility and or how much the public is willing to pay for an environmental improvement (ISO 14040: 1997). These estimations go into deciding which waste management option offers the best benefit and has been adapted in the Irish waste management plans (O'Sullivan 2001). Maximizing economic efficiency is usually the dominant factor in CBA at the costs of environmental and social criteria (Morissey and Browne 2004).

Those waste management practices based on the LCA of products involve the "evaluation of the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and final disposal" (ISO 14040: 1997). Very recent waste management systems are concerned with the whole life cycle of products (Brorson and Larson 1999; McDougall et al., 2001) with the aim of making a complete assessment of the systems environmental impact. This approach is essentially for waste

minimization as it affords the producers the opportunity to alternative production routes and waste reduction strategies (Berkhout and Howes (1997). LCA is however, a specific and technical environmental accounting process that is unable to deal effectively with social issues. Petts (2000) observes that LCA though covers environmental and economic sustainability does not consider social aspects such as health effect predictions and therefore, cannot be considered a sustainable waste management system.

Other waste management systems are based on integration of different waste management practices. The concept of integrated waste management developed by McDougall et al. (2001) links waste streams, waste collection, treatment and disposal methods with the LCA concepts while aiming at achieving environmental benefits, economic optimization and social acceptability. “For a waste management system to be sustainable, it needs to be environmentally effective, economically affordable and socially acceptable (Nilsson-Djerf and McDougall 2000). This point is buttressed by Petts (2000) who stressed that the best MSWM must be related to local environmental, economic and social priorities and must go further to involve the public before important waste management decisions are made. Social, environmental and economic compatibilities are therefore observed to be the dimensions of sustainable waste management models or strategies (Joos et al 1999; Morrissey and Browne 2004).

In this paper the proposed solid waste management concept is based on integrated waste management system that brings together a range of management options, considering the local conditions, while aiming at social, economic and environmental aspects of sustainability. For, the waste management system as it aims at sustainability, should function within the principles of Agenda 21 (established at the UNCED World Summit in Rio in 1992) and within its local manifestation (Local Agenda 21).

## **1.9 Conceptual Framework**

Concepts are sometimes seen as foundations of communication, which are abstracted from perceptions and are used to convey and transmit information (Nachmias and Nachmias 1996; Lundeqvist 1999). This study is based on the conceptual development of an integrated waste management system that has the ability to include social, environmental and economic compatibilities as the dimensions of a sustainable waste management system and with the concept of environmental cost benefit analysis. This focuses on the existing waste management system, the feasibility of waste treatment by waste to energy recovery, the integration of waste management practices and calculation of their benefit using environmental cost benefit analysis.

### **1.9.1 Introducing WTER treatment of municipal solid waste**

The only dumping site, Repi or Koshe, is becoming full because of this there must be another option to solve this problem. One of the tools which will solve the existing problem associated with the solid waste management in Addis Ababa is managing the wastes using integrated solid waste management and calculating their benefit using environmental cost benefit analysis. Integrated solid waste management has different components. Among the components, waste to energy recovery (WTER) is chosen for



this research. WTER is one type of integrated solid waste management, which uses solid waste to convert in to usable energy forms like carbon free charcoal, electricity, etc. WTER treatment of solid wastes uses high temperature to convert organic component of the waste in to usable carbon free charcoal.

## **1.9.2 Integrated solid waste management process**

### **1.9.2.1 Definition of solid waste**

Solid waste as defined under the Resource conservation and Recovery Act (RCRA) is any solid materials discarded from industrial, commercial, mining or agricultural operations, and from community activities. Solid Waste can be classified in to different types depending on their source.

- a) House hold waste (Municipal/domestic waste)
- b) Industrial waste
- c) Agricultural waste
- d) Bio- medical waste
- e) Hazardous waste
- f) Non-Hazardous waste
- g) Biodegradable waste
- h) Non-bio degradable waste.

### **1.9.2.2 THEORY OF INTEGRATED SOLID WASTE MANAGMENT**

Integrated solid waste management or ISWM is a tool to determine the most energy-efficient, least-polluting ways to deal with the various components and items of a community's solid waste stream.

The ISWM hierarchy is based up on the material and energy that is embodied in solid waste and that is associated with its recycling and disposal. The twin goals of ISWM are to:

- (1) retain as much as possible of that energy and those materials in a useful state, and
- (2) Avoid releasing that energy or matter in to the environment as a pollutant.

Integrated waste management sets up a hierarchy of approaches and technologies for managing solid waste in order to meet these goals. (Shown in fig.1.1). Generally, the further "up" the hierarchy from which the technology is chosen, the more benefits in efficiency and retained economic value.

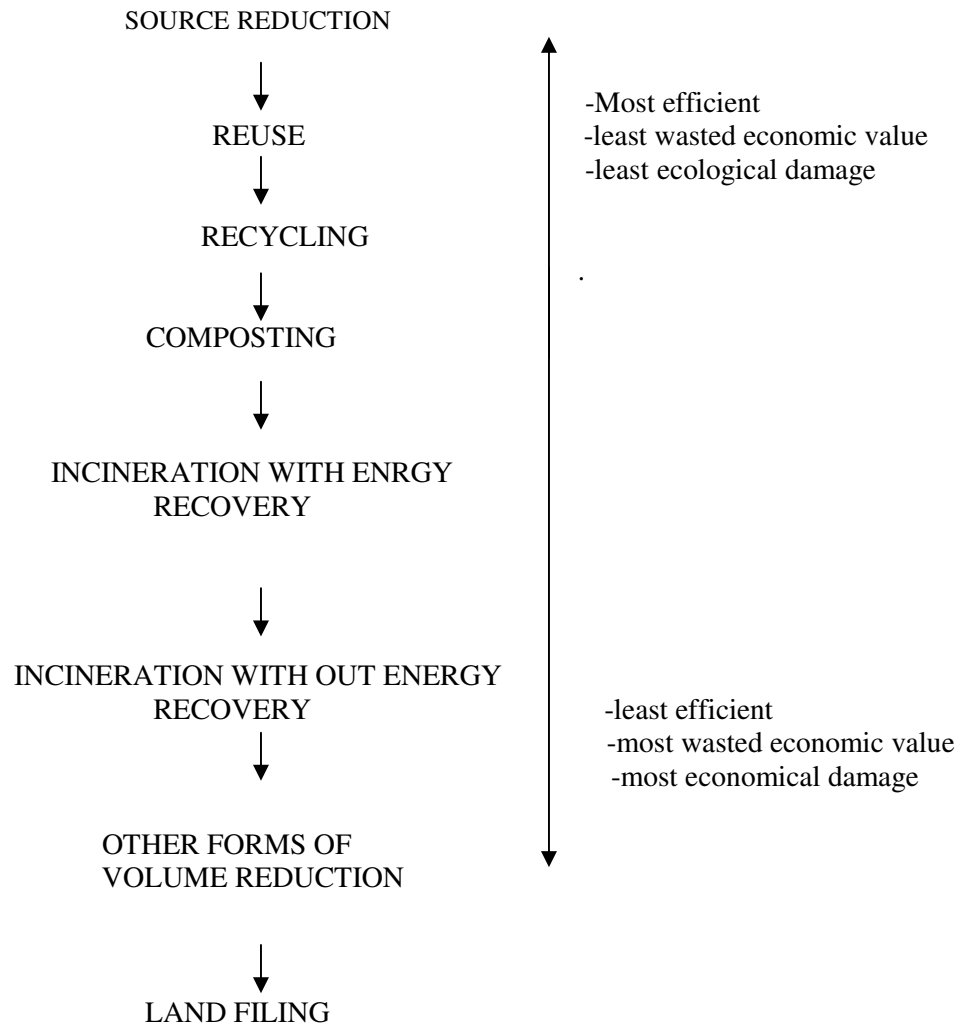


Figure 1.1 Integrated waste management hierarchy

### 1.9.2.3 Components of Integrated Solid Waste Management

As noted earlier, SW consists of many materials with entirely different properties. Under ideal circumstances of sorting, processing, and recycling, these materials should go to different destinations. For example, metals and glass are not combustible or compostable; then, recycling would be the most appropriate course for such materials. Most of the collected paper and some plastics (e.g. PET) should be sorted out and recycled. The non-recyclable paper, plastics and fibers contain useful energy: therefore they constitute a fuel that can be burnt in a properly designed combustion chamber to generate steam and then electric energy. Finally, the only materials to be landfilled or disposed should be inorganic compounds such as non-recyclable glass and ashes from Waste-to-Energy Recovery power plants.

Recycling: A key component of a recycling system is the Material Recover Facility (MRF), which is a specialized plant which separates, processes and stores recyclables (Paper, cardboard, glass, metals, plastic containers, aluminum cans) which have been collected either separately from waste (a 'clean' MRF) or co-mingled with it (a 'dirty' MRF). These facilities separate, remove contamination, densify and ship recyclable materials to recyclers for processing. Any residual material not suitable for processing goes on for disposal.

Anaerobic/Aerobic digestion: The natural organic components of SW (food and plant waste) can be composted aerobically (i.e. in the presence of air) to generate carbon dioxide, water, and a compost product that can be used as soil conditioner. Anaerobic digestion consists of the degradation of organic material in the absence of oxygen. It produces mainly 55% of methane and 45% of carbon dioxide gas and a compost product suitable as a soil conditioner. The generated biogas in some cases produces electricity.

Waste-to-Energy Recovery: In a WTER plant, non recyclable SW is combusted at high temperatures and converted in to usable form of energy such as charcoal, electricity etc. The heat of combustion is used to produce steam that drives a turbine generator of electricity. In this process, a sophisticated air pollution control system is used to remove particulate and gaseous pollutants before the process gas is released into the atmosphere. Trash volume is reduced by 90% and the remaining residue is regularly tested and consistently meets strict Environmental Protection Agency (EPA) standards allowing beneficial use or disposal in landfills.

Land filling: The last option is the final disposal into landfills. Landfill is a waste disposal site, usually hundreds of hectares, for the deposit of waste into land. The waste is spread and compacted and a cover of soil and/or liner is applied so that effects on the environment are minimized under current regulations, landfills are required to have treatment systems to prevent contamination of ground water and surface waters. In an ideal situation, the fraction of SW that cannot be subjected to recycling, composting or energy recovery, plus the residues from combustion (e.g. ash, non-usable glass, etc) must be disposed in properly design landfills.

#### **1.9.2.4 ISWM and Local Economies**

There are several ways to describe integrated waste management and its benefits. Perhaps the best way is to look at the effect of solid waste on the economy and environment of a community. The job creation and economic potential of ISWM stem from the following:

1. The economic value of recovered materials as re-usable products or as raw materials.
2. The opportunity for simpler, more decentralized sometimes more labor-intensive solid waste management solutions which can create jobs.
3. Opportunities to intentionally create and recruit business and industries which use the waste streams of existing business as feed stocks.
4. The short-term and long term economic value communities of avoiding land filling. Benefits of this include:

1. Deferring expensive Landfill sitting process.
2. Reducing annual operation and maintenance costs for existing land fills.
3. Reducing transportation costs to community, and
4. Reducing the rate at which successive cells of expensive new subtitle land fills must be developed and lived.

Community resources saved at the landfill can be diverted in to economic development efforts. The traditional economic model views economic activity and its benefits as the extraction of raw materials, their manufacture or processing, the sale of the production commodity, and then its use by consumers. The rest of the life cycle of the raw materials and energy consists of disposal at some cost, and control of the associated pollutants. In other words once a product, by-product or material becomes classified as a “waste”, it has not only zero value but a negative value, i.e. the cost at local government of “disposal” pollution control, and the health cost to society of any pollutants not successfully controlled. Integrated waste management provides a new approach to solid waste. It seeks to keep products, the materials and energy embodied in their manufacture, and the by-products energy of their manufacture, in the productive part of the economy and out of the “waste” stream as long as possible, and to wring as much economic value out of them as possible before giving up on them as “waste” when this is done, the following happens:

1. Local and regional economies benefit by the continued exchange value the reclaimed materials and products and the jobs created in reprocessing and reselling them,
2. Private business often find these materials a cheaper sources of raw materials then virgin sources especially when virgin materials are becoming scares, more difficult to access, under more stringent regulatory controls, or must be shipped from far a way.
3. It often takes less energy to reprocess or re-manufacture these reclaimed materials than raw materials, because of the energy already embodied in their original manufacture. This increase the value of these materials to industry, since energy savings in manufacturing can be added to the equalization saving for a more competitive “bottom line”.
4. National and global resource natural depletion is reduced contributing to a more sustainable long-term economy.
5. Local government benefit through reduce cost of ultimate “disposal” of the materials because many would-be “waste” materials and products are diverted from their land fills for an extended period of time.
6. Pollution from landfills is reduced because many toxic or otherwise polluting materials are diverted from the landfills, and because the overall volume of land filled materials is reduced.

Another valuable feature of ISWM is that it applies to all solid waste situations, from the largest city or industry to commercial and office waste streams, light down to the individual household. This means that its positive impact can be understood and enjoyed by the whole community. It also means that the economic impact of ISWM can be felt by all economic sectors in the community.

## **1.9.3 Environmental Economics**

### **1.9.3.1 Introduction to Environmental Economics**

Environmental economics is a distinct branch of economics that acknowledges the value of both the environment and economic activity and the environmental impacts by taking in to account all the costs and benefits. The theories are designed to take in to account pollution and natural resource depletion, which the current model of market systems fails to do. This “failure” needs to be addressed by correction pieces so they take in to account “external costs”. External costs are uncompensated side effects of human actions. For example, if stream is polluted by run off from agricultural land, the people down stream suffer negative external costs or externality. The assumption in environmental economics is that the environment provides resources (renewable and non- renewable) assimilates waste, and provides aesthetic pleasure to humans. Economic value could be bought and sold in the market place. However, traditionally, their value was not recognized because there is no market for these services (to establish a price) which is why economies talk about market to reflect the full social costs or benefits of a good Service or state of the world. Therefore, when markets fail, the result will be inefficient or unfavorable allocation of resources. Since economic theory wants to achieve efficiency, environmental economics is a tool to find a balance in the worlds system of the resource use.

Another basic term in environmental economics is the idea of scarcity. Historically goods and services provided by the environment were seen to be limitless, having no cost, thus not considered scarce. Scarcity is a misallocation of these services (which are not limitless) due to pricing problem. Due to Such assumptions many of the peoples in the world destroys the environment.

Many economists have been criticized for putting a price tag on nature. However, decisions are being made every minute regarding resources allocation. These decisions are economic decisions and therefore based on society’s values. In essence, the environment itself is not being valued instead individual preferences for the environment is what are being measured and compared. Environmental valuation can be useful, yet also difficult and controversial tool. There are two types of values: Use and nonuse. Use value is defined as the value derived from the actual use of good or services, such as hunting, fishing, bird-watching, or hiking. Use values may also include indirect uses, Such as the value of a bug that a fish may eat which then a fisher person may catch. Though that bug is not directly used by the fisher person, it has an indirect value because of its place in the food. A Large part of environmental economics has been devoted to valuing use services. Non use values also referred to as “passive use” values, are values that are not associated with actual use, or even the option, to use a good or services. Existence value is a type of nonuse value and is the value that people place on simply knowing that something exists. Even if they will never see it or use it. Non- use value is the most difficult type of value to estimate. Total economic value is the sum of all the relevant use and non- use values for a good or service.

The natural environment may be seen as providing four main services namely;

- a) Extractive resources for the production ultimately of consumer goods and services
- b) Natural amenities for recreational use
- c) Space for productive wastes
- d) Pollution problems

As there is often a choice between (a) and (b), the extraction of resources and the maintenance of natural environment, it is convenient to consider them both under the general topic of the limitations of the environment as a supplier of resources. Likewise congestion and pollution problems (c) and (d) are related through the concept of externalities, which suggests that the major cause of both problems is the ability of one individual to impose costs on someone else without paying for them. The separation of the two main subjects—scarce productive resources and pollution—helps to clarify the environmental issues but they are often of course interrelated problems.

The major elements of environmental economics are shown in simplified form in fig.1.2

### **1.9.3.2 Why is environmental valuation important?**

Currently, environmental valuation is used in five different ways:

1. Project evaluation
2. Regulatory review
3. Natural resource damage assessment
4. Environmental costing
5. Environmental accounting

Cost/benefit Analysis (CBA) is used in project evaluation and regulatory review. Environment costing is used in decisions regarding investments and operation. The costs of producing something along with the social costs (including external costs) are all included in the cost of the good it has been used in the energy sector and somewhat in waste disposal.

Environmental accounting is a way to account for the services of environmental assets within the framework of economic activity or business. It is an assessment and evaluation of the results, costs and savings attributable to environmental protection activities. Some examples include pollution prevention, environmental life cycle assessment or environmental performance reporting.

It is clear that environmental economics is being used more often for discussing environmental issues whether utilized as a tool to determine which projects have the greatest benefits or to determine natural resource damages, those individuals who have an understanding of some of the concepts will have a distinct advantage.

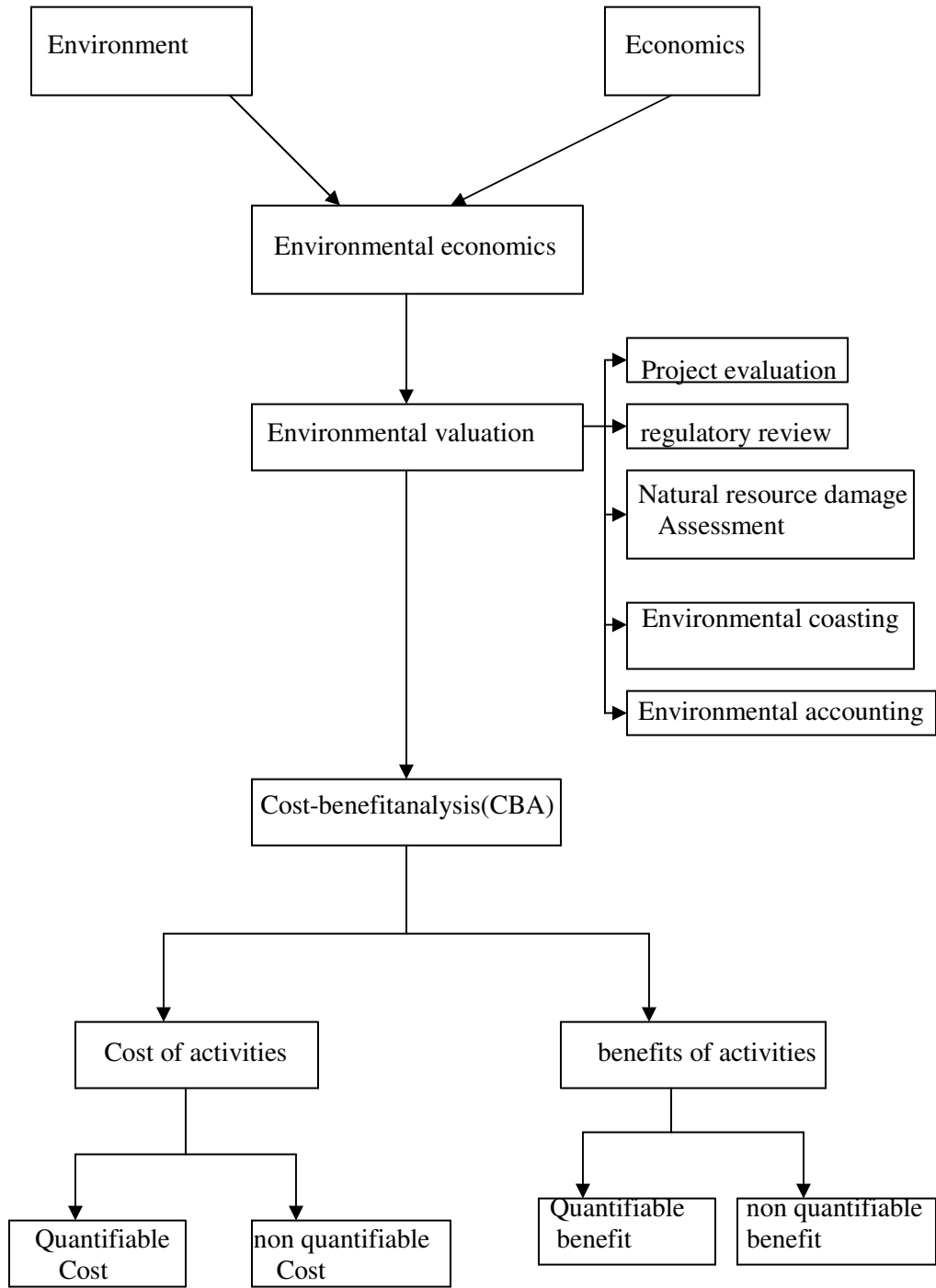


Fig.1.2 major parts of environmental economics in a simplified form

### 1.9.3.3 Cost/Benefit Analysis

Cost-benefit Analysis (CBA) is an analytical way to make decisions about complicated issues such as education, health care, transportation or the environment. Like most personal decision, it involves comparison of the costs for an action compared with

considerations of the benefits of that action. However for public policy it is formalized and quantitative. For instance, public policy can be evaluated by calculating and weighing the benefits against the costs, once all factors have been given a common unit of measurement.

Cost – Benefit Analysis (CBA) estimates and totals up the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile. These projects can be dams and highways or can be training programs and health care systems.

**Commonly used Measures for intertemporal Comparisons:** Several measures are commonly employed to determine the value of capital project. These are (1) the pay back (2) discounted pay back (3) Internal rate of return (IRR) and (4) net present value (NPV). These sections will discuss in detail how each measure is calculated and how each compares to the criteria listed above.

1. Payback: The payback method is the simplest measure to calculate and the least consistent with the criteria listed above. The payback method simply calculates how many periods into the future it takes for a capital project to repay the initial investment.

2. Discounted Pay back: The discounted pay back method attempts to rectify one of the short comings of the pay back method, the incorporation of the time value of money .The cost – benefit flows are discounted to reflect the value of time. For example, suppose the appropriate discount rate is 5% .The net benefit stream for projects and A and B can be recalculated reflect this new piece of information .The present value (the value of some future amount in to day’s dollars given a discount rate) is calculated using the following

$$PV = FV (1/1+r)^t \dots\dots\dots (1)$$

The symbols represent present value (PV), future value (FV) and the discount rate (r) expressed as a percentage. The number of periods from today (period 0) the net benefit accrues is the number of discounting periods, t. Again, let us examine the cost–benefit flow streams of projects A and B.

3. Net Present Value: Net present value (NPV) is similar to the discounted pay back method in that the cost–benefit flows are discounted to reflect the time value of money. However, unlike the discounted pay back method, NPV considers all future cost – benefit flows. The method yields one value that is easily interpreted. If the value is positive, the project yields benefits that exceed its costs. If the value is negative, costs exceed benefits. The discounting calculations are based on the same formula that is used to discount cost–benefit flows in the discounted pay back method.

4. Internal Rate of Return: It is often difficult to determine the rate at which future benefits should be discounted to today’s dollars. In addition, decision makers are often more comfortable with value expressed in percentage terms rather than some other metric. The internal rate of return (IRR) is a method for determining value that does not depend on the determination of discount rate and that expresses value in terms of percentage. Essentially, the method requires the calculation of discount rate such that the



discounted value of future cost – benefit flows exactly equals the initial investment. In other words, present value of costs minus the present value of benefits equals zero. To calculate the IRR it is necessary to find the discount rate that would equate the initial investment with the future cost–benefit flows. This can be expressed mathematically as:

$$\begin{aligned}
 & \$(\text{net benefit at zero year}) = \$\text{net benefit at the first year}(1/1+r) + \$\text{net benefit at the second} \\
 & \text{year}(1/1+r)^2 + \$\text{net benefit at the third year}(1/1+r)^3 \dots\dots\dots(2)
 \end{aligned}$$

This calculation requires a financial calculator, computer, or trial and error. IRR is based on the assumption that the cost–benefit flows are reinvested at the internal rate of return. If we are examining projects that are mutually exclusive, IRR may yield results that are inconsistent with a ranking based on the NPV method. At first this inconsistency may seem surprising. However, one should note the effect of the timing of the cost-benefit flows on the IRR calculation. Any project that has relatively large positive cost–benefit flows early in its life will generate a relatively large IRR. Finally, the use of IRR as a measure for choosing between projects is inappropriate when capital rationing exists. This problem is again due to the assumption that the cost – benefit flows are reinvested at the internal rate of return rather than at the cost of capital as in NPV. What this implies for the decision maker is that the ranking of projects will depend as much on their relative size and the timing of their cost–benefit flows as it will on the actual cost–benefit flows, where the actual flows should be the only determinant of acceptance or rejection. By example, suppose we are comparing the following set of projects.

Table 1.3 comparisons between NPV and IRR

project	Investment	NPV	IRR/year
A	\$1,000,000	\$50,000	20%
B	\$2,000,000	\$150,000	18%
C	\$4,000,000	\$3,000,000	16%
D	\$7,000,000	\$800,000	15%

If there were no capital rationing, we would select all four projects since each has a positive NPV and would increase our wealth by \$1.3 million. However, if we impose a capital budget of \$7 million, the choice depends on the method of examination. If we use internal rate of return, projects A, B, and C would be chosen. However, if we use NPV, project D would be chosen. The choice of Project D is optimal because it increases our wealth by 800,000. The inconsistency implies that the usefulness of the IRR method is limited. Due to the mathematics of the calculations, it is possible under these circumstances to calculate multiple IRR's that equate the net present value of costs with the net present value of benefits. This is clearly an undesirable situation.

### 1.9.3.4 The choice of Discount Rate

The discount rate is the rates by which benefits that accrue in some future time period must be adjusted so that they can be compared with values in the present. In principle, this is the rate that equilibrates the demand for savings by investors and the supply of savings from savers who refrain from spending all of their income on current consumption. Savers compare the value of current consumption relative to future consumption and determine a rate of compensation needed to foregone current consumption. Choosing the current rate for a cost–benefit analysis is important because society wishes, in principle, to undertake a mix of public and private investments that maximize social well–being. Whereas the marketplace drives private investments, activities by the public sector can displace private investment.

Consumers evaluate the decision to save or consume based on the opportunity and other consideration about future needs. For example, offered a choice between getting a \$100 today and \$500 one year from today, most people would choose the \$100 today. However, if the amount offered in the future was greater than \$100, say \$110, many would forgo the \$100 in favor of the future amount. By doing so, their rate of time preference is revealed to be at most 10 percent per annum.

Investors, on the other hand consider the rate of return they expect from a given investment, using methods similar to those discussed in regard to calculating capitalized values. To undertake an investment, the expected return on investment must cover all costs, including the rate of interest. Under fairly restrictive assumption one can argue that investment will continue until returns across alternatives are the same and just balance the returns required by saver. Under these conditions, one can argue that a single interest rate and a single rate of return on capital (will prevail throughout the economy) in the real world, however, there are a number of reasons that multiple rates prevail.

There are a number of reasons that multiple interest rates are observed in the real world economy. First, interest rates take into account average changes in the value of money. Most cost – benefit analysis is carried out under the assumption of constant dollars, that is under the assumption that inflation is zero. Rates observed in the marketplace, in contrast, reflect borrowing over strictly specified time periods and hence incorporate expectations for inflation over those periods. For practical purposes, cost benefit analysis can ignore inflation. A second concern is that businesses pay taxes on their profits and that the rates of return they set as target must take the payment of taxes into account. Individuals, likewise pay taxes on interest they receive on savings. Hence, observed interest rates are distorted by the fact they reflect before tax rates of return. A third concern is that observed interest rates incorporate risk and uncertainty. For practical purposes, risk can be thought of as an adjustment that must be made to the interstate to compensate lenders for the eventuality that borrowers will default. Although there are complicated analyses that help savers build portfolios that overcome uncertainties associated with specific borrowers, there remains a level of risk that can not be overcome by portfolio building. In simple terms, if a lender believes that on average one half of the loans made will not be repaid, a risk – adjusted rate of interest equal to double the rate of the lender's time preference will be required.

## CHAPTER TWO

### 2. MATERIAL AND METHODS

#### 2.1 Sources of data

For the general overview data concerning solid waste in Addis Ababa it was used that direct sources from different organization that are concerned with the solid waste management such as Addis ababa city sanitation beautification and park development agency, from Addis Ababa city government environmental protection authority and from different private sectors.

For the detail information about solid wastes in Nifas silk Lafto subcity it was used that direct data capturing from their activities concerning solid wastes, direct data from their documentation about solid waste management (libraries) Primary data was obtained from Addis Ababa city sanitation beautification and park development agency, from region 14 administration solid waste management group and from different private sectors. Secondary data has been the main source of information for the study. The secondary sources of data include books, published articles both on the internet and in journals and government publications.

#### 2.2 Instruments

Questionnaires were administered together with personal interviews with managements of the solid waste group in lafto sub city in the following form

Data collection from the Waste Management Department (WMD) was done through personal interviews and extracts from their records. The data collected here was on waste stream information including waste type and composition, waste collection, waste transportation, waste disposal and type of ISWM used. The data also include the existing methods of waste disposal at Repi or Koshea.

##### 1 . Amount of solid waste generated in Nifasilk Lafto sub city

Year	Amount of solid waste ton/year
2003	25,876
2004	26340
2005	27,986
2006	29,946
2007	30,240

##### 2. amount of solid waste disposed in to dumping site

year	Amount of solid waste disposed in to koshe dumping site
2003	19,654
2004	19,764
2005	20,453
2006	23,453

### 3. collection transportation and disposal of solid waste in Lafto sub city

	Description of the process	Good/points about the process	Problems associated with the process
1. collection of solid waste	Is collected by using door to door collection using containers	The peoples living in this sub city are well informed about the collection of wastes it is perfectly collected	No separation of wastes
2. transportation of solid waste	Wastes are transported to the disposal site using tracks	Since the tracks are limited and small in number it is not well transported to the disposal site	The transportation system have open system this can be a source of odor problem
3. disposal of solid waste	Wastes are disposed in to repi dumping site	Since they are collected from this sub city the problems associated with the waste will decrease	Because it is an open dumping it can cause different types of environmental problems

### 4. Integrated solid waste management in lafto sub city

Component of ISWM	Does it practiced	Does it have Future plan to be practiced
Reuse	To some extent	yes
Recycling	To sum extent	yes
WTER	no	yes
composting	no	yes
Dumping	yes	yes

Study visits were made to the WMD's solid waste management facilities at Repi or Koshe dumping site. Study visits were also made to the solid waste storage facilities available in the various residential areas in Addis Ababa. A study visit was also made to Solomon waste management center at Nifas silk lafto sub city. There for these visits are very essential to get first hand knowledge on the status of the facilities at the various sites in Addis Ababa and of the waste to energy recovery treatment of solid waste.

## 2.3 Methods

The main method used to find the costs and benefits of WTER plant was Environmental Cost Benefit Analysis (CBA). In the study the costs and benefits of WTER plant are calculated in the following manner

1. Monetized costs and benefits was first calculated in a detailed manner
2. Discounted rate was chosen according to the market activities in Addis Ababa
3. Finally the present net value was calculated using CBA formula

## **2.4 Data Analysis and Presentation**

In the analysis of the data, a three step approach was applied.

The first step was comparison between the wastes generated from lafto sub city and the other sub cities of Addis Ababa in order to decide whether the generated solid waste is enough and can represent approximately the same waste management approach as the rest part of the city.

The second step was the qualitative and quantitative identification of solid waste in lafto sub city. Qualitatively the inorganic and organic parts of the solid waste were identified. Quantitatively the amount of organic and non-organic component of the waste was identified.

The third step in the analysis of the data was changing the identified amount solid waste in to monetary value

## **2.5 Scope**

The study centers on the solid waste management in lafto sub city and the need to restructure the process using the concept of integrated solid waste management followed by environmental cost benefit analysis to find its benefit. Even though in considering the suitability of Waste to Energy Recovery treatment of waste in lafto sub city, site selection, acquisition and resettlement of people and detailed technical description of the plant are important parameters, these are not considered highly here. These processes are so broad (including Legal and Institutional framework, Eligibility for compensation, Valuation of compensation, and Resettlement measures) that they cannot be covered though they constitute part of the social concerns that the study hopes to be addressed by a proper waste management system. What is rather considered here is the significance of converting the existing solid waste management system in Nifasilk Lafto sub-city into a waste to energy recovery waste treatment facility by building WTER plant and showing their benefit using environmental cost benefit analysis. The economic feasibility for the construction of the facility cannot be overemphasized. For the purpose of this study the economies of the operational phase is considered the facility's ability to serve as a source of recurrent income and therefore be 'self-sustaining'. Admittedly this model is associated with waste already generated although waste minimization or prevention is the most rational and cleanest means of solid waste management.

## **2.6 Outline of the study**

The report has five sections. The first section comprises introduction to the problem, waste generation and management systems and comprises population and waste, waste stream information that is the amount generated versus amount collected, waste composition, current waste management system in Addis Ababa, objectives, rationale for the study and theoretical framework.

Materials and methods, instrument, data analysis and presentation, scope of the study and the report outline of the report constitute the second section.

The third section deals with the suitability of introducing waste to energy recovery method of solid waste treatment.

The fourth section deals with the cost-benefit analysis of the waste to energy recovery plant in Lafto sub city and discusses the way how to use the cost-benefit analysis in order to solve environmental problems associated with solid wastes.

The fifth and final section entails discussion, recommendation and conclusion.

## CHAPTER THREE

### 3. Waste –to-Energy Recovery

#### 3.1. Overview

Worldwide, over 130 million tons of MSW are combusted annually in over 600 WTER facilities that produce electricity, charcoal and steam for district heating, recover metals for recycling, and substantially reduce the volume of waste that is finally disposed.

In a WTER plant, non-recyclable MSW is combusted at high temperatures and changed in to usable energy form such as charcoal, electricity etc. The heat of combustion is used to produce steam that drives a generator of electricity. A WTER plant that provides charcoal of 540 kg/ton to utilities is equivalent to a saving of 1.43 barrels (190 liters) of fuel oil per ton. In this process a sophisticated air pollution control system is used to remove particulate and gaseous pollutants before the process gas is released into the atmosphere. Trash volume is reduced by 90% and the remaining residue is regularly tested and consistently meets strict Environmental Protection Agency (EPA) standards allowing reuse or disposal in landfills. The combined bottom and fly ashes amount to 20-25% of the weight of the original MSW.

A typical WTER plant comprises the unit functions and processes shown in Figure 4.1 the components of the unit functions and process are briefly described as follows:

- Storage pit for storing and sorting the incoming refuse
- Crane for charging combustion box
- Furnace or combustion chamber consisting of bottom greats on which the combustion occurs
- Heat recovery system of pipes in which water is turned to steam
- Air pollution control system (APC); electrostatic precipitators or bag house filters for physical removal of dust and some heavy metals; additionally chemical flue gas cleaning in dry/semidry scrubbers followed by fabric filters or wet scrubbers for washing/spraying the flue gas.

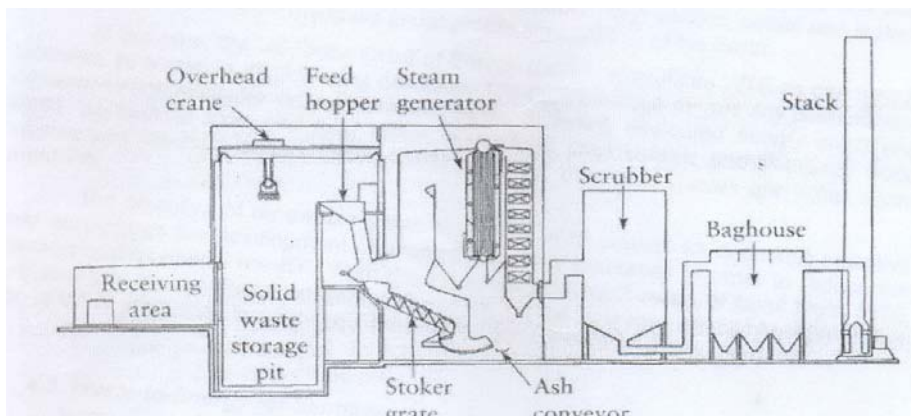


figure 3.1: a typical waste to energy combustor

The heart of the WTER process is the combustion chamber in which the MSW is introduced and reacted with oxygen at high temperatures. In most units the refuse is moved through the combustion chamber on a moving grate. The function of the grate is to move the refuse through the combustion chamber while an air stream (under fire air) is introduced through the slowly moving bed through openings in the grate. The under fire air both assists in the combustion as well as cools the grates. The control of under fire air is also the most important variable in maintaining a desired operating temperature in the combustion chamber. Most WTER plants operate in the range of 980 to 1090 °C, which ensures good combustion and elimination of odors, and is still sufficiently low to protect the refractory materials lining the combustion chamber. The temperature within the combustion may be incomplete. Above 1090°C, the refractoriness in the furnace will have a short life. Thus the window for effective operation is not large, close control needs to be kept on the charge to the combustion chamber and the amount of under fire and over fire (secondary) air.

### **3.2 Waste-to-Energy recovery as a Renewable Source of Energy**

Waste-to-energy recovery has been recognized by the U.S. Environmental Protection Agency (EPA) as a clean, reliable, renewable source of energy. In addition, the combustion of municipal solid wastes for generating electricity and charcoal has been recognized by several US states as a renewable source of energy. The search for renewable energy sources is motivated by the desire to reduce use of fossil fuels.

In the traditional sense, renewable source of energy are those that nature can replenish, such as waterpower, wind power, solar radiation and biomass (wood and plant waste). However, MSW contain a large fraction of paper, food wastes, cotton and leather, all of which are renewable materials under proper stewardship of Earth.

At this time, the US Department of Energy (DOE) categorized WTER as one type of biomass, as shown in the following definition: The term biomass means any plant derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal waste and other waste materials.

The objective of renewable status legislation is to provide an economic incentive that encourages the development of alternative energy resources in order to reduce the environmental impacts resulting from the extraction and combustions of fossil fuels. WTER provides this environmental advantage, because, on the average, the combustion of one ton of MSW produces electricity equivalent to 0.3 tons of coal or one barrel of oil.

### **3.3 Waste –to-Energy Recovery for Addis Ababa**

WTER is the only renewable energy source to offer an additional environmental advantage: the avoidance of the environmental impacts of dumping of MSW. In Addis Ababa, there has been enormous public opposition to the development of new dumping site, especially from the communities that reside close to them. New dumping site developments are likely to face greater challenges. On top of this, the increasing spread of urban areas and its geographical location makes land in Addis Ababa scarce. As a



consequence, there will be not enough space for more dumping sites around the city in the coming decades. In terms of environmental impacts, every ton of MSW dumped, will result an increase in greenhouse gas emissions of carbon dioxide to the environment. Also, during the life of a modern dumping site, and for a mandated period after that, the aqueous effluents are collected and treated chemically. However, reactions within the dumping site can continue for decades, or even centuries after closure. There is a potential for future contamination of adjacent waters.

The use of potential Greenfield site for dumping combustible materials, as is practiced in Addis Ababa, represents a non-sustainable use of land because little can be done with this land after the dumping site is closed. In consequence, accumulation of such a large volume of waste for long time is dangerous for the environment. Therefore, there is an urgent need to investigate new waste management technologies such as Waste-to-Energy Recovery.

## **CHAPTER FOUR**

### **4. Cost-Benefit Analysis of a Waste-to-Energy Recovery Plant for Nifasilk lafto sub city in Addis Ababa**

#### **4.1. Description of the Project**

In view of the demonstrated advantages of WTER over dumping site and land filling in other nations, it is worthwhile to examine the economics of the first WTER in Addis Ababa. It will be assumed that the most suitable location for the first WTER for Addis Ababa is at a site where it will serve the municipality of Nifassilk lafto sub city Addis Ababa Ethiopia. The WTER Plant which is to be constructed with in lafto sub city will have connection with Solomon waste management center which is a private sector aiming to recycle the organic part of the solid waste in to carbon free charcoal (smokeless charcoal)and.The project uses WTER plant in order to convert the solid waste in to carbon free charcoal, in to liquid bi-product which is a main raw material for the production of varnish and sorts , packs and ships the inorganic component of the waste such as plastics, polyethylene and supply to the respective industries for further processing. The WTER found with in lafto sub city uses the mass burn technology with some modification.In January 2006 the author interviewed the Directors of the Department of solid waste of Lafto sub city, concluding that the sub city is experiencing sever waste disposal problems. They are not satisfied with the present waste disposal contracts, and the monopolistic condition of their current waste disposal arrangements. Lafto sub city is spending a large fraction of their budgets on waste disposal and are willing to explore other options. Therefore, there is an opportunity to look at new alternatives for waste disposal. A WTER plant offers the possibility to efficiently address these problems for these communities and eventually for the surrounding sub cities.

The tool to be used to assess the economics of a WTER plant for this sub city is a Cost-Benefit Analysis (CBA). CBA is a standard method of comparing the social cost and benefits of alternative investments projects. Costs and benefits are measured and then weighed up against each other in order to generate criteria for decision-making.

Typically one or more of three decision criteria are used. These are Net Present Value(NPV),Internal Rate of Return(IRR) and Benefit Cost Ratio( BCR).A Project is deemed to be acceptable if the NPV is positive, or if the IRR exceeds the applicable discount rate, or if the BCR exceeds one.In making this analysis, it is necessary to analyze the impact on possible stakeholders, and then develop into the non-quantifiable impacts and the opportunity costs on the basis of certain assumptions. Next, it is essential to monetize the costs and benefits associated with the project, and conclude with a formal cost-benefit analysis including the section of the discount rate. The final section of this chapter describes the results of a sensitive analysis on the effect of changes in some important parameters.

#### **4.2 Stakeholders and Secondary Market Effects**

##### **4.2.1 Stakeholders**

When considering the construction of WTER plant, there will be different stakeholders affected by the change made to the current waste management system. The relevant

stakeholders are the government, authorities, the waste sector, community groups, and the energy sector. The possible stakeholders and interest group are shown in Table 5.1

Table 4.1: Stakeholders for Construction of a WTER plant in NifassilkLafto sub city

<b>Stakeholder</b>	<b>Stakeholder interest</b>	<b>Possible Stakeholder Influence</b>
Federal Environmental protection Authority	The Project requires an environmental impact assessment	Termination, delay, or change of the project
Addis Ababa city government Environmental Protection Authority	The waste is managed properly (odors, noise, etc) and air emissions of the plant meet the emissions regulations	Termination ,delay, or change of the project
Lafto sub city	Have an economically competitive alternative to waste disposal	Supply waste to the plant and payment for waste disposal
Ministry of Energy	Look for new alternative energy options and regulate the energy price	Regulate energy price-incentives for clean energy
Addis Ababa city Government	Social Health Benefit	Approve or disapprove the project
Scavengers	Change in waste management may affect or eliminate their source of income	Scavengers activities may affect the properties and amount of waste
Community groups and nearby citizens	Project may lead to work opportunities. Negative impacts: traffic, odor, visual impact, etc	Terminations, delay, or change of projects due to community protests
Environmental NGOs	Reduce impact of waste management on the environment	Termination, delay, or change or projects due to NGOs protests or support if project due to positive environmental impact
Neighbors	Neighborhood free of noise, dust, traffic loading and visual impact. Impact of real estate prices	Termination, delay, or change or projects due to neighbors protests
Collection and transportation companies	Wish to maintain or expand their business	New requirements for sorting, containers and vehicles
Energy producers (charcoal production)	Current energy available at the lowest possible price	Energy production at lower prices than the ones offered by WTER plant may crowd out energy demand, leaving no buyers for energy output
Buyers of CHARCOAL, Liquid bi-product produced by WTER center	More energy available at the lowest possible price	Provide income stream to offset costs of investment
Waste of disposal facilities (dumping site in Addis Ababa)	Wish to receive more waste	May lower tipping fee due to increased competition
Sub cities nearby the area	Have an economically competitive alternative to waste disposal	Supply waste to the plant and payment for waste disposal

## 4.2.2 Secondary Market Effects

The introduction of a WTER plant will produce an increase in the supply of waste disposal capacity, measured in metric tons/year, thereby affecting the market equilibrium of waste disposal. The demand for waste disposal (D) could be considered highly inelastic; because all produced waste ( $q_1$ ) has to be disposed, even at very high prices. In this scenario, the lesser the supply of waste disposal options, the higher the price. This is the current situation in the market of waste disposal in Addis Ababa, due to the lack of other options, for this municipality, than the current Reppi dumping site.

Figure 4.1 shows that the increased supply (supply shifts to the right, from curve  $s_1$  to  $s_2$ ) will create a new equilibrium point at a lower price level ( $P_2$ ). The extent of the price change will depend on the elasticity of the supply curve, which was not estimated for this analysis. The demand curve remains the same for the purpose of this exercise (eventually demand for waste disposal grows over time as population grows). The new equilibrium point is total waste disposed ( $q_1$ ) at the new price of  $p_2$ .

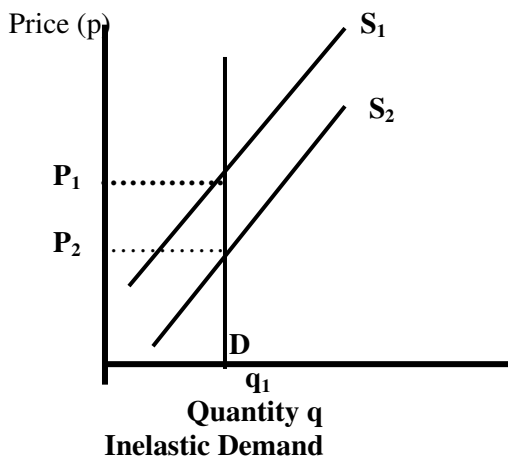


Figure4.1: Secondary Market Effects of Introducing a WTER plant

## 4.3. Non-Quantifiable Impacts

The cost benefit analysis of any project would not be complete without understanding the socio-cultural and environmental impacts of the project, though small and unquantifiable they may be. WTER is a waste management facility that is considered a renewable energy technology. Any means of energy production and waste management impacts the environment in some way, and WTER is no different. The magnitudes of many of these impacts are very subjective and depend on the specific tests employed. The following sections describe some of these environmental, social, and economic impacts.

### 4.3.1. Environmental impacts

#### Odor

The combustion process destroys all odor-emitting substances in the waste, and the slag and fly ash sterile and odorless after cooling. WTER plant odor is thus emitted mainly

from handling and storing waste before combustion. The main sources are the unloading activities and the waste storage pit. To avoid emitting foul air in to the environment, the tipping floor, where trucks drive in to discharge their load in to the waste pit, and the feed hopper of the combustion unit are totally enclosed and the entire building is under draft (negative pressure) so that no air can escape to the outside atmosphere, even when the doors through which the trucks drive into the tipping floor are open. The air drawn by the draft fans is used as the combustion air in the WTER unit. Because of this inherent feature of the process, there are no odors escaping the WTER building. The odor in WTER plants is not an issue.

### **Noise**

Truck traffic in and out of the WTER is the greatest source of noise pollution resulting from WTER plant operations. Well maintained and responsibly operated trucks will help to minimize this problem. Local ordinances may restrict truck traffic to certain hours of the day and to specified truck corridors. Under these conditions, noise pollution should not be a significant factor. Equipment inside the plant generates some noise but due to the fact that all equipment is fully enclosed in the WTER building, visitors cannot hear it when they are outside the building.

### **Reducing the Waste Up To 90%**

An environmental benefit of the WTER is the reduction of the waste by 90% of the volume, therefore only 10% of the volume needs to be dumped in the form of ash.

### **Air Pollution**

The most contentious issue regarding energy recovery from solid wastes is that of emissions to the atmosphere due to the combustion process. Emissions of Particulate Matter (PM), mercury, hydrochloric acid, and dioxins have been the most worrisome problems in the past. However by the end of 20<sup>th</sup> century, emissions in modern WTERs were reduce to extremely low levels by means of reduction of precursors in the feed (e.g. mercury containing products), better combustion practices, and greatly improved gas control system that include dry-scrubbing, activated carbon injection and filter bag collection system.

### **Diesel Emission Reduction**

Since WTER plants require little space, relatively to landfills, and do not emit odors, they can be located close to the municipalities they serve. This will certainly reduce truck travel, which in turn will decrease diesel emissions to the atmosphere. Diesel engines contribute to a substantial portion of the Nitrogen Oxides (NO<sub>x</sub>), PM, and hydrocarbons (HC) emissions from mobile sources. NO<sub>x</sub> reacts with HC and sunlight to form ground-level ozone (song). With the reduction of diesel truck travel, threshold will be a significant reduction in generated smog.

## **Clean Energy Production**

Considering the overdependence on fossil fuel based energy, Addis Ababa government at all levels have encouraged diversification of the energy supply. WTER, in alliance with other renewable energy sources, can play an important role in developing a portfolio of clean energy production for Addis Ababa.

### **4.3.2. Economic impacts**

#### **Real Estate Values**

Historically in Addis Ababa, traditional waste disposal facilities have faced opposition by local neighbors and residents due to the negative impact such facilities have on the price of real state. However, a WTER plant could be used as a way to improve the host area and increase rather than decrease its land value. In selecting the site for the new WTER plant, it is advised to select a site that was an old industrial plant or transfer station.

The objective of the designers of the WTER should be to find such a Brownfield and then design the plant, architecturally and environmentally, to better the previous conditions.

#### **Employment**

Any new construction of an industrial plant will generate employment in the construction process and future in the operation of the plant. Permanent employees will be around 20 and temporary employees (Construction process) will be in the order of 50.

### **4.3.3. Social Impacts**

#### **Land Use**

The location of a WTER plant will certainly produce protests of the community nearby. Because a WTER will be located within Addis Ababa, there would be no need for the waste transfer station that serves the current landfill. In fact, as mentioned, the new WTER may be located on the site of an old Brownfield and improve the neighborhood.

#### **Traffic**

As was noted in the “noise impact” point, a WTER facility will increase the traffic truck in the surrounding area of its location. Local government should plan an organized transport system in order to minimize the surrounding traffic and may restrict truck traffic to certain hours of the day and to specified truck corridors.

Table 4.2 and 4.3 summarize the environmental, social and economic impacts that need to be taken into consideration in any WTER project assessment and that could not be monetized for this analysis. Nevertheless, their magnitude has been scored on subjective analysis and literature review.

Table 4.2: Non-Quantifiable Costs

<b>Kinds of Costs/impact</b>	<b>Nature of Costs</b>	<b>Major Stakeholders</b>	<b>Scores</b>
Environmental	Odor	Neighborhood	Some cost
	Air pollution	Environmental Health Department	Significant cost
	Noise	Neighborhood	Some cost
Social	Land Use	Community groups, neighbors, Environmental NGOs	Significant cost
	Aesthetic Value	Community groups and nearby Citizens	Insignificant cost
	Traffic	Neighborhood	Some cost
Economic	Real estate Value	Neighborhood	Some cost

Table4.3: Non-Quantifiable Benefits

<b>Kinds of benefit</b>	<b>Nature of Benefits</b>	<b>Major stakeholders</b>	<b>Scores</b>
Environmental	Reducing Waste up to 90%	National Environmental Commission	Significant benefit
	Clean Energy Production (carbon free charcoal)	Ministry of Energy	Some benefit
	Diesel Emission reduction	Environmental Health Department	Significant benefit
Social	Aesthetic value	Community groups and nearby citizens	Insignificant benefit
Economic	Employment	Manufactures of wind turbines, people seeking employment, Government	Some benefit

## 4.4 Assumptions

### 4.4.1. Technology

#### 4.4.1.1. Available Technologies

Municipal Solid Waste Combustion systems are mostly characterized as either Mass Burn units or Refuse-Derived Fuel (RDF) units. A third technology is Fluid Bed units.

#### I. Mass Burn Technology

A mass burn unit does not pre-process the solid waste prior to feeding in to the combustion unit. Trucks carrying MSW empty their load in to a large totally enclosed chamber. An overhead "claw" crane scoops material and deposits it at the feed end of a moving metal grate that moves the waste material slowly through the combustion chamber. Many WTER operators favor this technology process because it does not require pre-processing of the feed and is relatively simple operation. However, the rates of heat, mass transfer, and combustion of the large bags deposited on the grate are relatively low and a large combustion chamber is required. The temperatures generated in the combustion chamber are in the order of 900<sup>0</sup>c. This is the most common and dominant WTER technology in the US, and other developed countries. The most widespread great technology is developed by Martin GmbH (Munch, Germany and has an annual installed capacity Worldwide of about 59 million metric tons (year 2000). A second very popular mass burning technology is provided by Von Roll Inova Corp (Switzerland) with an installed worldwide capacity of 32 million tons.

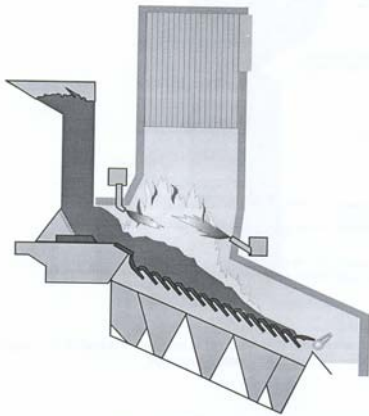


Figure 4.2 schematic diagram of the mass burn technology

#### II. Refuse Derived Fuel (RDF) Technology

In a RDF system, the solid waste is processed prior to combustion to remove non-combustible items and to reduce the size of the combustible fraction, thus producing a more uniform fuel at a higher heat value. The processing generally entails separation of inert materials, size reduction, and densifying (e.g. palletizing). This allows for the removal of both recyclables and hazardous materials. The RDF is fed through a rotary



feeder and injected into the combustion unit above the grate. Some combustion takes place above the grate with the remaining combustion occurring in the grate.

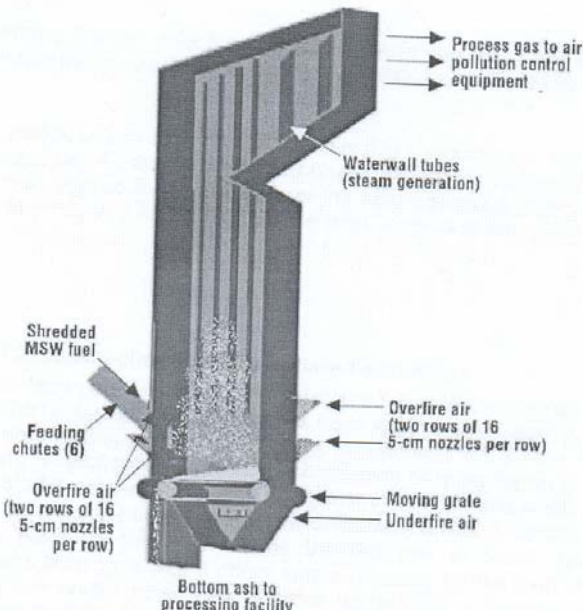


Figure 4.3 schematic diagram of Refuse Derived Fuel(RDF)

The advantage of an RDF plant is that the heat value of the fuel is uniform and thus the amount of the excess air required for combustion is reduced. The amount of combustion air used is important because if there is insufficient oxygen in the combustion chamber, a reducing atmosphere is created which leads to corrosion problems. For RDF systems the excess air is about 50%, while in mass burn plants, because of the large variation in fuel value between items, about 100% excess air is needed. While there appear to be several theoretical advantages of RDF over mass burn plant, they have had their share of operating problems. Processing of solid waste is not easy, and RDF plants have encountered corrosion and erosion problems.

### III. Fluidized-Bed WTER plants

Combustion of MSW in fluidized bed reactors is used extensively in Japan. This method requires shredding (to-5cm) and removing inert materials like glass and metals from the feed to the fluid bed reactor. The remainder is fed on top of a fluidized bed of sand or limestone. Combustion under these conditions is very efficient and result in even temperatures and higher energy recover, lower amounts of non-oxidized materials leaving the combustion chamber, and less excess air than mass burn plants. Fluidized-bed combustors operate at temperatures in the rang of 830<sup>0</sup>C-910<sup>0</sup>C and can use additional fuel as required so that they can burn materials with very high moisture content. Because of the lower uniform temperatures, “slugging” and corrosion problems in the furnace are kept to a minimum. On the other hand lower temperature result in the high NO<sub>x</sub> levels and thus an additional dry scrubber is required in addition to the limestone fed into the bed. A main disadvantage of the fluidized bed is that it requires pre-treating of the waste before the fluidized bed so that it meets the rather stringent requirements for size,

calorific value, ash content, and so forth. Because of the heterogeneous composition of MSW, it can be difficult to produce a fuel that meets the requirements at any given point.

#### 4.4.1.2. Selecting the Appropriate Technology

As mentioned above, Addis Ababa lacks a regulated system of trash separation at its origin. The WTER facility will receive wastes without preprocessing of solid waste. For this reason, the most appropriate technology for Addis Ababa is the mass burn plant since no pre-processing is necessary apart from the removal of bulky items like “white goods” (large appliances). Also mass burn plants are easier to operate and install than RDF (with RDF facilities, operators generally have more difficulties). Another advantage of mass burning is that it offers flexibility for the kind of feedstock you supply, e.g. you can co-fire other fuels such as waste tires or sewage sludge residues treatment of sewage sludge residues, so this WTER plant could also be a solution for that subject. Furthermore, the current mass burn systems are very reliable and have been running successfully for a long time, thus are widely considered as a proven technology.

Within the mass-burn category, the Martin Reverse-Acting Grate technology was selected with a capacity of 1000 metric tons/per day (330.000 metric tons/per year). But in the project the system is modified to receive small quantities of solid wastes. The capacity was chosen to receive some of the residential and commercial Waste generated in Lafto Municipality. Figure 4.5 is a schematic diagram of a Martin Grate mass-burn combustion chamber, like the one to be used in Addis Ababa Solomon waste management center. This diagram was taken from the Brescia (Italy) plant, one of the newest WTER facilities in Europe.

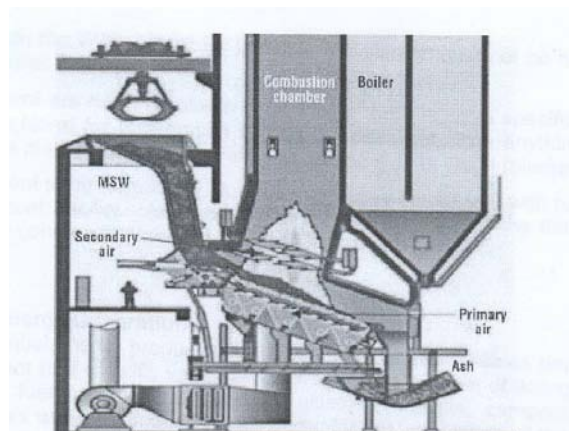


Figure 4.4 the martin grate mass burn combustion

#### 4.4.2. Location

Land is one of the most vital resources used for any kind of enterprise, including WTER. Finding a site is one of the most difficult assumptions in this CBA since any new project involving a Waste Treatment facility (WTF) could generate some protests from the community near by. Prior to considering a site it is necessary to educate the community to let them know that WTER is not a landfill and that a WTER plant will be comparable

to a medium to heavy industry in its environmental impact, potential public nuisances, transport network requirements, and other infrastructure needs. The legal norm for siting a WTER plant is managed by Addis Ababa city government. The administration will give an appropriate land for the waste management center by considering the following points

- AWTER facility is considered an industrial type of plant.
- Can be located inside or outside the Addis Ababa Region.
- The location should be in land uses dedicated for medium or heavy industry and/or exclusive Zones for manufacturing activities.

#### 4.4.3. Production of free carbon charcoal (smokeless)

The potential production of free carbon charcoal and income from free carbon charcoal sales depend heavily on the energy content (net calorific value) of the waste. The amount of energy of heat value in an unknown fuel can be estimated by ultimate analysis, compositional analysis, proximate analysis and calorimetry. In this study, for the calculation of the calorific value, after reviewing all the methods it was estimated that for the case of Addis Ababa the “compositional analysis” was the best method to be used. It is not part of this study to review each of these methods. Moisture in MSW decreases the available heat for combustion in WTER plants that produce free carbon charcoal. Table 4.4 shows the average percent composition of the MSW in Addis Ababa and the heat value of each component. Based on these data, the estimated heating value for Addis Ababa MSW is 9,500 kJ/kg

Table 4.4: Heating Value of MSW in Addis Ababa

Material	Composition %	Heat value (kJ/kg)
Food Wastes	48.65	<b>4,647</b>
Yard Wastes	3.00	6,506
Plastic	12.43	32,531
Paper	12.22	16,730
Cardboard	2.22	16,266
Beverage and milk boxes	0.32	15,800
Rubber and Leather	1.01	21,387
Textiles	2.98	17,445
Glass	3.22	0
Metal	2.15	0
Wood	2.46	18,590
Dirt, Ashes and other fines	3.69	6970
Miscellaneous	5.59	4000
<b>Calculated heating value of Addis Ababa MSW</b>	<b>100</b>	<b>9,490</b>

Source: Addis Ababa City Sanitation Beautification and Park Development Agency, 2006

This is a very high calorific value and fully sufficient for combustion, thus no supplemental fuel is needed. At this high calorific value, it is expected that the Martin Great WTER will produce high amount of energy and using this energy the organic wastes will be changed in to free carbon charcoal. The out put, free carbon charcoal can be sold commercially, and the energy will be used internally for the plant operation.

## **4.4. Monetizing Costs and benefits**

### **4.4.1. Monetized Costs**

#### **4.4.1.1. Investment**

The capital of the project has two major components: the building cost of the plant (construction and equipment) and the cost of the property where the plant will be constructed.

### **I. Building Costs**

Calculating the investment cost was a difficult task. As noted before there are no modern WTER plants in Addis Ababa. Consequently, the following assumptions were made:

1. A cost of construction in the U.S. of US\$175,000 per daily metric tons of capacity of MSW.
2. 60% of the costs of equipment and building construction are procured at Ethiopian costs and 40% at U.S. costs.
3. The plant operates 300 days per year.
4. 1 USD=8.45 Ethiopian birr

The following steps were followed to calculate the cost of construction of a WTER plant in Nifassilk lafto sub city:

1. Determine the costs of building an industrial plant in Addis Ababa and compare it to U.S. costs in order to calculate an adjustment construction cost factor.
2. Prorate the adjustment factor for all equipment and building that will be procured in Addis Ababa.

The cost of building an industrial plant in Addis Ababa, in steel structure, US\$ 504/m<sup>2</sup>. The cost of building an equivalent industrial plant in Washington (US) is USD 597/m<sup>2</sup>.

Ethiopian cost: US\$ 504/m<sup>2</sup>

US cost: US \$ 597/m<sup>2</sup>

Conversion factor: Ethiopian Cost/U.S. cost =0.8442

Therefore, the cost of equipment and construction of a Waste-to-energy recovery plant in Addis Ababa is:

- 60% x USD 175,000 per daily metric ton of capacity x 0.8442 =USD 88,641
- 40% x USD175,000 per daily metric ton of capacity = USD 70,000

→ USD 158,641 per daily metric ton of capacity

Consequently, the cost of construction a WTER plant in Addis Ababa is approximately US\$158,641/per daily metric ton of capacity. Therefore, for the required capacity of 10 metric ton/day, the estimated capital cost is **USD 1,586,410**.

## II. Land

The martin Grate WTER is projected to be located with lafto sub city. The plant will place in an area of 2,000 m<sup>2</sup>.

The cost of 1 m<sup>2</sup> in the industrial area in Addis Ababa is 4,000birr=USD 473.37

**Total Land Cost = 2,000 m<sup>2</sup> x USD 473.37 =USD 946,740.00**

### 4.4.1.2. Operational Costs

The components of the operational costs are: labor, material supplies, maintenance and disposal.

#### I. Labor

The plant will have as permanent workers the following

##### 1. Administrative staff

- 1 General Manager and plant manager
- 1 accountant
- 1 secretary/cashier
- 2 security guard
- 5 janitor
- 1 store/procurement

##### 2. Technical staff

- \_ 1 plant manager
- \_ 2 furnace machine operator
- \_ 1 crusher operator
- \_ 1 drying machine operator
- \_ 1 mixing machine operator
- \_ 1 molding machine operator
- 1 general mechanic
- 1 production supervisor

- General Manage ETB 2,000/month =USD 237 per month

- Accountant ETB 800/month=USD 95/month

-Secretary/cashier ETB 600/month=USD 71/month

-Security guard ETB 500/month =USD 59/month

2 x USD 59 =USD 118/month =USD 118/month

-Janitor ETB 400/month =USD 47/month

: 5 x 47 =USD 235/month

- Store/procurement ETB 500/month = USD 59/month
- plant manager ETB 2000/month=USD237/month
  
- Furnace machine operator ETB 800/month =USD 95/month  
2x USD 95 = US\$ 195 per month
  
- crasher operator ETB 800/month=USD 95/month
  
- drying machine operator ETB 500/month=USD 59/month
  
- mixing machine operator ETB 600/month=USD 71/month
  
- molding machine operator ETB 700/month=USD 83/month
  
- general mechanic ETB 1000/month=USD 118/month

**Total Labor Cost = US\$ 1,673 per month = USD 20,076/year**

## **II. Material supplies**

Material supplied to WTER plant will be solid wastes  
The cost of material supplies will be USD 12/daily metric ton.

**10 metric tons x USD 12x300 days = US \$36,000/year**

## **III. Maintenance**

The maintenance cost comprises machinery and building maintenance. The maintenance cost will be 3 % of the investment cost per year.

**USD 679,890x0.03=USD 20,396.7/year**

## **IV. Ash Disposal**

In a WTER plant the remaining residue is the combination between bottom and fly ashes. The total amount of ashes is approximately 10 to 20% of the original tons of MSW. Approximately 10% of this ash is fly ash and this has to be disposed because of its toxic components: however bottom ash can be reused as road base material, cement blocks, asphalt or concrete applications. To dispose fly ash into dumping site it has to be mixed with bottom ash in order to lower the toxicity in it. In this project evaluation it will be assumed that 60% of the ashes produced will be disposed into dumping site, the rest being reused. Therefore ash disposal will be considered as a net cost.

For this project evaluation it is assumed that the plant will have an ash residue of 11%. The cost of discharge MSW into dumping site is USD 52per metric ton, which includes collection, transport and final disposal. The plant will process an approximate amount of 3,000 metric tons of waste per year (10metric tons/day x 300 days).

(Amount of ash residue) x (amount of ash disposed) x (amount of waste per year)

0.11x.60x3000 metric tons per year =198 metric tons of ash per year

**The cost of dumping this ash is: 198metric tons x USD 52 per metric ton = USD 10,296/year.**

The electricity that it is used by the plant is also an operational cost. It was considered free of cost, because the plant generates more energy than the energy sold.

**Total Operational Cost; USD 1,003,347.39/year**

#### **4.4.2 Monetized Benefits**

The cash inflows of the project are the free carbon charcoal generation and the income from liquid bi-product and the income from exporting the inorganic part of the solid wastes.

##### **4.4.2.1. Carbon free charcoal (smokeless) Generation**

As seen in point 5.4.4 the plant will produce carbon free charcoal (smokeless) that will be sold commercially.

The price at which the net energy source from charcoal with in the plant is USD 76,612.28 per month. There for the plant will have an income **USD 919,347.36/year.**

##### **4.4.2.2. Production of liquid bi- product used as a raw material for the production of varnish**

For this CBA, it was assumed that the WTER plant will produce a liquid by-product that can be used as a main source of raw material for the production of varnish after extracting charcoal from solid waste. There for this will be another source of benefit for the plant. The income from producing a liquid by-product which is used as a source of raw material for the production of varnish is **USD 36,840.00/ month**

Total benefit from liquid by-product is **USD 442,063.32/year**

##### **4.4.2.3 Benefit from inorganic parts of solid wastes**

Since the WTER plant will separate inorganic wastes from organic wastes and uses the organic part for the production of carbon free charcoal and a liquid bi-product and sorts, packs and ships the inorganic part to other organization or companies for other purpose.

**The income from exporting the inorganic part of solid waste is USD 24,564.60 /month**

**Total income from the is inorganic part of solid waste is USD 294,775.20/year**

**Total benefit = USD 1,656,185.88/year**

## 4.5 Discount Rate

Calculating the discount rate is the key part in every CBA, therefore the discount rate will be used as a variable in the sensitivity analysis. Therefore two possible scenarios: one is that the project is fully funded by private investment in Ethiopian and a second scenario is that the project is entirely financed in US Dollars.

Case 1: The project is entirely financed by private investment in Ethiopian birr. In this case the discount rate represents the opportunity cost of alternative private sector investment. The discount rate is equal to 9%, which is the available real interest's rate in Ethiopia for long term deposits.

Case 2: The project is fully funded by private foreign investment in dollars, and then the discount rate is the current US discount rate is the current US discount rate of 7% plus the Ethiopian premium risk that is currently 2%. Therefore the discount rate will be 7% +2% =9%. Since both cases showed a discount rate of 9% that is the one for this project as the basic scenario.

## 4.6 Results

Having calculated the major cash flow components of the project—cash outflows (investment and operational costs) and cash inflows (charcoal production ,liquid bi-product production and income from exporting the inorganic solid wastes), it is now possible to evaluate the project using the criteria of Net Present Value (NPV).

The net present value of an investment is the present (discounted) value of future cash inflows minus the present value of the investment and any associated future cash outflows (operational costs and taxes). What does it mean? It is the net result of a multiyear investment expressed in today's dollars.

Several assumptions were made:

1. No inflation. All prices are expressed in US Dollars.
2. Corporate tax rate of 42 %.
3. Plant investment will depreciate on a basis over 30 years. Basic depreciation was used to reduce taxable income. Therefore reducing cash outflows and increasing the expected profitability of the project.

Table 4.5 shows cash flows, for a WTER plant for Nifassilk lafto subcity Addis Ababa, associated with each inflow item (income) and outflow item (expenditures)for each period. Based on the calculated cash flows of the project, the preliminary net present value of the WTER plant for Lafto sub city in Addis Ababa, at a discount rate of 9%, is over **USD 6,496,798.10**.

**Net Present Value = present Value of Net Cash Flows –Initial Investment**

(Years 1 to 30) (Year 0)

**Net Present Value at 9% =USD 9,049,949.00 –USD 2,553,150.39**

**Net present value at 9%=USD 6,496,798.10**







These preliminary calculations demonstrate that a WTER plant at Nifas silk lafto sub city in Addis Ababa, with a capacity of 10 metric ton/day, would be able to generate enough income-through energy sold, income from liquid bi-product and income from inorganic component of the solid waste-to have a positive Net present value. This indicates that the project should be done; the project generates more economic value than its investment and operational costs. The internal Rate of Return is 10.6 %.In terms of its discounted payback, the number of periods in which the project pays its initial investments is 4 years.

#### 4.7 Sensitivity Analysis

For the sensitivity, analysis the tool used was “Crystal Ball.” Crystal Ball is software that performs Monte Carlo simulations in excel spreadsheets. Crystal Ball automatically calculates thousands of different “what if” cases, saving the inputs and results of each calculation as individual scenarios. Analysis of these scenarios reveals the range of possible outcomes, their probability of occurring and which input has the most effect on the model.

Four Key variables were tested:

- **Calorific value of the waste:** The heating value of municipal solid waste varies a lot from season to season and even from different income levels. Different heating values have different charcoal outputs. For the basic scenario 9,500 kJ/kg was used as calorific value. The sensitivity analysis was tested with the values seen in Table 4.6.

Table 4.6: heating value with respective energy out put

<b>Heat Value (kJ/kg)</b>	<b>Net charcoal output (kg/ton)</b>
7,000	350
8,000	450
9,000	550
10,000	650
11,000	750

This is considering the net charcoal to be sold commercially

Source; Municipal Solid Waste incineration, Requirements

For a Successful Project, T, Ramd, J. Haukahi, U. Maraxen,

The World Bank, 2000.

- **Discount rate:** Since this rate is not exact and could fluctuate, a sensitivity analysis was made for different cases, in a range from 7% to 13%. The base scenario is 9%.

- Benefit from liquid bi-product and inorganic part of the solid waste: It was interesting to evaluate the option of charge less than the actual dumping site or in the worst situation charging more. A sensitivity analysis was made from a range of USD 123 to USD 150. The base scenario is USD 140.
- charcoal price; charcoal prices in Addis Ababa have increased by more than one-third since 2004. Prices could continue to tend upward, it is for seen that Ethiopia's majors utilities plan to build several charcoal plants and diversify its charcoal generation sources so, may be in the future, charcoal prices will drop again. Therefore it was evaluated the effect of both price increases and decreases, in the range of 1.33Birr/kg and 2.33Birr/Kg. The base scenario is 1.94Birr/Kg.

Figure 4.8 shows the effect on the NPV of changes in any one of these variables, holding the rest constant at the base values. The chart shows that the project breaks even under almost every scenario.

The WTER facility could be cheaper than current dumping system and the project still has a positive NPV. With a higher discount rate of up to 10.6% we still have a positive present value. Another important factor to consider is the heating value of the waste. The sensitivity analysis showed that this variable is very susceptible to small changes in it in the NPV. The minimum heating value for the project to be positive is 8,500 kJ/kg (500 Kg/metric-ton as charcoal generation) and this is not far away from the basic scenario 9,500 kJ/kg.

As said before this value can vary a lot so this is something to take in to consideration

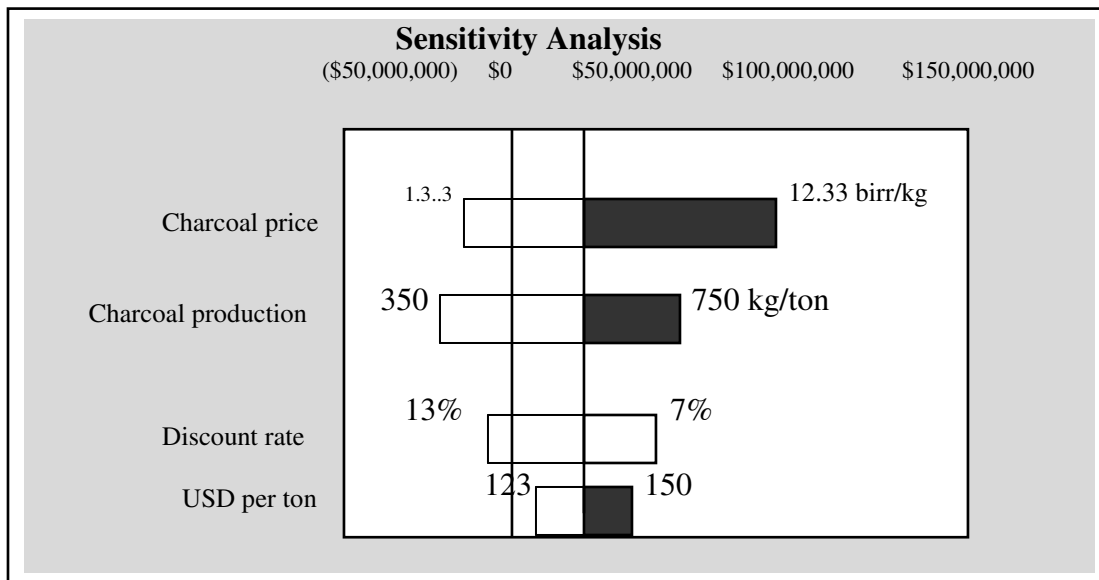


Figure 4.5 Results of montecarlo simulation

Figure 4.9 shows how predominant the variables are in the project. The most important factors determining project's viability are heating value output (charcoal production) and the discount rate.

A very small increase or decrease in the charcoal price or heating value can make a dramatic difference in profitability. Monte Carlo analysis on charcoal price shows that variations in it account for 41.25% of the variation in the NPV, on charcoal production accounts for 24.5% and in discount rate for 15.2%.

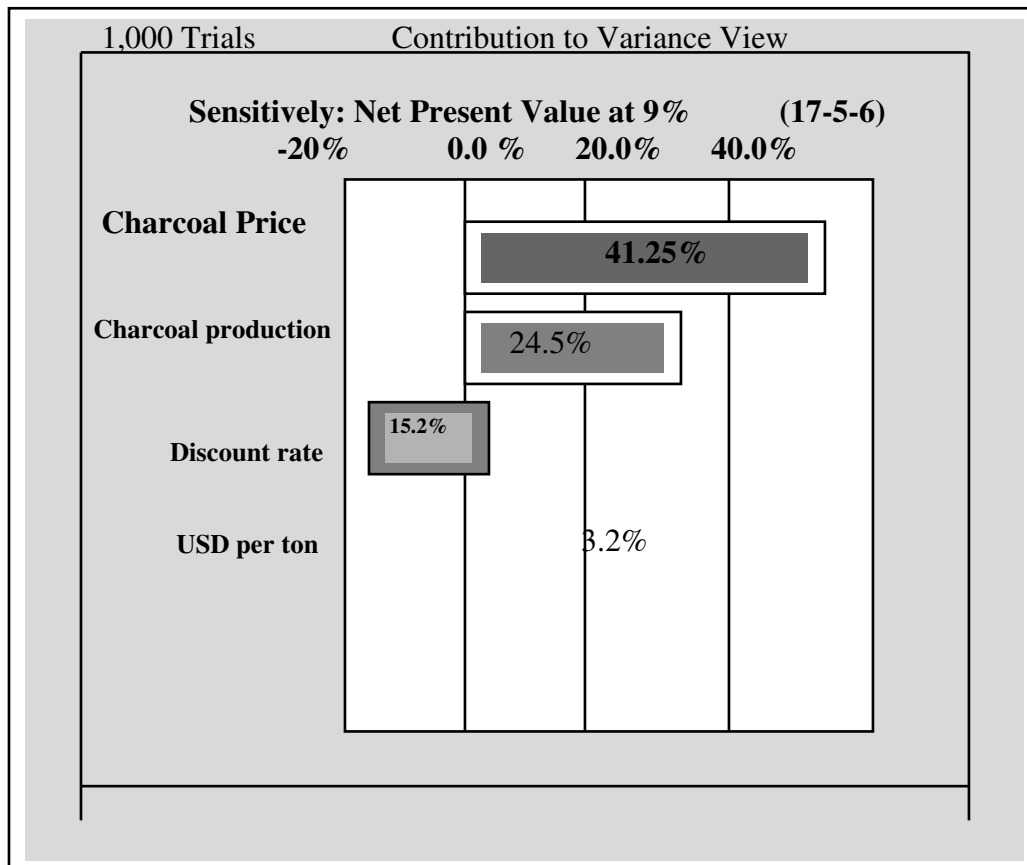


Figure4.6: importance of variables in the WTER plant

#### 4.8 Cost-Benefit Analysis Conclusions

The result of the Cost-Benefit Analysis of a Waste-to-Energy Recovery plant for the municipality of Nifassilk Lafto sub city indicates that the project should be undertaken because it has a positive NPV, thus generating more economic benefits than costs in almost every scenario. However, there is some future analysis that remains to be done the estimation of the heating value variable, as several studies indicates that Addis Ababa's heating value could be lower than the one calculated here.

Overall, the quantifiable benefits outweigh the quantifiable costs, therefore supporting the construction of a WTER plant for Addis Ababa. The community would have to be educated about these issues.

The approach being taken in this research could be subject to some with regard to some of the assumptions made. However, it is intended to give some useful insights to decision makers by providing a clear picture of the project and the key variables involved. The project is promising as the benefits of energy generation (free carbon charcoal) ,income from liquid bi-product and income from inorganic part of the solid waste and environmentally better waste treatments are expected to be large.

## **CHAPTER FIVE**

### **5. DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Discussions:**

##### **5.1.1 The Integration of Waste management**

The issue of what integrated waste management is, and what is to be integrated is of great importance in deciding the principal foci of the waste management system. Integrated solid waste management has been considered in many different perspectives. The International Energy Association sees integrated solid waste management as an optimized system of waste management practices based on the sound evaluation of environmental, energy, economic and socio-political considerations that includes a combination of two or more components of the waste; the European Resource Recovery Association (ERRA) views Integrated Resource Waste Management as the management of resources and waste in an optimized way, that considers environmental, economic and social aspects (ERRA 1991). Sustainable waste management means that waste is managed at present in a manner that does not leave any unnecessary management or environmental problems for future generations by recognizing the fact that no single method of waste treatment or disposal can deal with all the materials in the waste stream.

As stated in the theory of waste management, the integrated solid waste management in this research is based on waste to energy recovery treatment method. In this approach therefore, wastes can be used as a source of income.

##### **5.1.2 Ways of integrating the wastes**

Collecting the solid waste and separating the organic parts of the wastes from the inorganic part for WTER plant and sorting and packing of the inorganic parts of the wastes to other organization for further process like recycling and composting integration of waste management are proposed here.

##### **5.1.3 Showing the environmental and economical benefits of integrated solid waste management (ISWM) using environmental cost benefit analysis (CBA)**

One way of integrating wastes is to link the collected organic parts of the solid waste materials with combustion in WTER plant and. Waste collection (and the subsequent sorting) plays a vital role in the waste management system since it determines the feasibilities of combusting and recycling in an economically and environmentally sustainable way. It also significantly influences the quality of the recovered materials, and in turn the quality of the recycled products and their market values. Since collection is the contact point between waste generators and the waste management system, this crossing point requires careful management. The householder–waste collector interface is like a customer-supplier relationship where the householder’s solid waste must be

collected with a minimum of inconvenience and the collector must be given the waste in a form well suited with intended treatment methods.

For Addis Ababa that has not much experience in sorting at source, a householder collection of food waste, garden waste textile and paper together; glass, plastic, scrap metals, electric and electronic equipment also together is recommended for the start, else there would be disorder in introducing several containers for different materials. However, those businesses that produce large uniform waste at a spot such as the book binding industry could be linked up with the appropriate recycling industry. This will make it easier and healthier for the scavengers to sort at the deposit site rather than scavenging through decaying matter. It will also reduce the contamination of the recyclable wastes with food and oil and thus improve their quality as well.

Another way of getting good quality recyclable material is to employ financial incentives and educational systems such as deposit-return charges to encourage an increase in the return of valuable waste materials. When for instance poor communities are motivated in this manner, they can recover most valuable items from waste. In this regard, major distributors should become increasingly involved in the separate collection and recycling of products and materials.

Recycling is possible for heavy plastic, plastic bottles, plastic bags, metals, and glass in the city. Plastic waste for instance could be recycled into waste bins to make for the shortage in waste storage containers. What will be needed here is increased capacities for recycling. The organic material collected for recycling can be directly sent to a composting and waste to energy plant because it is pure enough to produce compost for agricultural use and carbon free charcoal. In this regard, it is important to maintain purity because using compost from wastes for the cultivation of food increases the possibility of disease transmission, which would nullify the purpose of its application. The use of compost in urban cultivation in Ethiopia is a potentially powerful, locally responsive approach to addressing waste disposal problems. Promoting the use of organic waste in food cultivation will therefore not only benefit urban cultivators but also minimize the need for expensive imported chemical fertilizers (Ministry of Food and Agriculture 2000) and help to reduce solid waste collection and disposal problems.

#### **5.1.4 Integration of waste or materials collection and handling with the treatment, processing and disposal methods**

Integration should also be done in which case waste collection and handling is integrated with the treatment, processing and disposal activities. Treatment is of key importance to recover waste or treat it in such a way that in the longer term it only causes insignificant, and therefore tolerable, pollution. Because untreated municipal waste in dumping sites forms leachate and gases over a period of decades and pollutes the infiltrating water over a period of centuries.

The kind of treatment and expected treatment results must be linked to the collection arrangement. The waste to energy recovery treatment of solid waste that is being



proposed in this study is suitable for both sorted and unsorted waste. The market values of the products of the waste to energy recovery plant (namely free carbon charcoal ,liquid bi-product and inorganic part of the solid) in the Ethiopian society cannot be overemphasized. Most city dwellers now use the free carbon charcoal as fuel for domestic cooking. Restaurants, chop bars, hotels and boarding schools use this product for large-scale food preparation as it is estimated to be less expensive than using the hydroelectric power. The free carbon charcoal that would be generated in this treatment process therefore has a high market value.

## 5.2 Conclusions

As presented in this research, it is clear that Addis Ababa waste management system is not that much satisfactory and because of this it faces environmental and social challenges that make this management unsustainable. Unfortunately, most of peoples living in Addis Ababa have only a vague notion of what happen to the waste they produced after it is picked up from their doorstep.

In the coming decades, Addis Ababa is going to runoff dumping space and little can be done with this land after the dumping site is closed.

Therefore, there is an urgent need to educate the population and to move towards an integrated solid waste management approach, in which a WTER plant could play a key role to efficiently address these problems, as was presented in this research. In a “sustainable development” approach, waste should be regarded as a resource for materials and energy recovery and not simply as a product for disposal. It is necessary to create public awareness of the real cost of solid waste management, the importance of waste minimization and what happens to the waste after the waste is disposed.

The result of the cost-benefit Analysis of a Waste-to-Energy Recovery plant for the municipality of Nifassilk lafto sub city indicates that the project should be undertaken because it has a positive Net Present Value (NPV) of USD 6,496,798 under the base scenario, based on discount rate of 9%. The project will pay its initial investment in 8 years and have a useful life of at least 30 years. In addition, the WTER facility would save valuable space, as the WTER plant proposed for Addis Ababa use a total space of 6 hectares.

The WTER facility could charge a significantly lower fee than current dumping system and the project still has a positive NPV. There would still be a NPV with a higher discount rate of up to 10.6 %. However, a very small increase or decrease in the charcoal price or heating value can make a dramatic difference in profitability.

Before the construction of the plant, the none-quantifiable impacts such as the environmental, social and economic factors have to be carefully examined and considered. Potential air pollution and the location of the WTER plant are the factors that could have more weight in creating from the community near by. On the other hand, it is

important to acknowledge that Waste-to-Energy Recovery plants produce dramatic decreases in air emissions, in comparison to dumping sites, and rear emissions, are way below the EPA standards and lower than coal power plants emissions. In addition, the location of a WTER plant will be closer to the municipality than the actual dumping site. This certainly will reduce truck travel and diesel emissions to the atmosphere: consequently, there would be a significant reduction in generating smog. A WTER plant should be located in a site of an old industrial zone or old transfer station and improve the host area. Overall, the non-quantifiable benefits seem to outweigh the non-quantifiable costs, therefore supporting the construction of a WTER plant for Addis Ababa. The community would have to be educated about these issues.

Considering that the current waste management situation in this municipality is almost identical to the rest of Addis Ababa, the possibilities of WTER as a widespread solution for waste management are very promising.

Addis Ababa city government should implement more efficient integrated solid waste management system that will solve the current environmental and social problems arising from solid wastes perfectly. The government has already set a goal for recycling the waste stream: in addition, the WTER plant proposed in this research for Nifassilk lafto sub city could process additional waste stream of Addis Ababa Regarding organic wastes. Under this condition, Addis Ababa's waste to be disposed into dumping sites would be reduced. This could be a major contribution to a solid waste sustainable management and would represent an integrated solid waste management approach.

To reach these targets there should be an appropriate framework and regulations. Today, norms that regulate waste management in Addis Ababa are very clear and controlled by Addis Ababa city government environmental protection authority. The authority plays a great roll in controlling environmental and social problems arising from waste streams. However most of the peoples living in Addis Ababa did not understand the environmental social and economical effects of wastes. Therefore it is important to teach the peoples as much as possible regarding effects of wastes in addition to the great activities of Addis Ababa city government environmental protection authority.

Positive experiences with WTER and its widespread use in other countries should provide an encouraging prospect for Addis Ababa too. This was achieved by means of educating the community and convincing the public and other stakeholders of the benefits of combustion for treating the city's waste. This experience not only demonstrates what can be done with WTER, it is an excellent example of integrated solid waste management from which Addis Ababa could derive similar benefits.

### **5.3 Recommendations**

It is recommended here that Addis Ababa city government adapts the ISWM approach outlined here in solving the waste management problem. It is important to know that wastes can be used as a source of income rather than damaging the environment. To do such an important approach in solving environmental and social problems arising from

wastes there must be an integrated method of managing solid wastes. Financial resources and human resources are the fundamental components on which the waste management can be run.

### **5.3.1 Financial resources**

In addition to the great activities done by Addis Ababa city government environmental protection authority in allocating external sources of funds that help to establish waste management programs and different activities that will solve the current environmental and social problems arising from wastes perfectly there must be a program that is planned to internally generate income to support operational maintenance. It is therefore recommended that;

- Waste to energy recovery waste treatment is an important source of obtaining operational revenue and it is recommended here that the existing dumping site be reviewed to operate on this technology. Income from WTER plant and saving of external costs arising from solid wastes must be highly considered in order to have a perfect solid waste management system.
- Direct cost recovery from users should be applied where it is possible to charge a full commercial price covering all operating and capital costs (Paying back of capital, operating cost, indirect cost and hidden cost) for solid waste collection services.
- Assemblies are to encourage private sector service providers to participate in solving the problems, which are to be provided on cost recovery basis.

### **5.3.3 Human Resources**

To overcome the problem of lack of professional man power human resource requirements can be tracked by; ensuring that appropriate training courses are available; collaborating with training institutions on suitable curriculum development; training arrangements through exchange programs with other international institutions. Corporate bodies can also be encouraged to provide sponsorship for training personnel abroad. These arrangements will ensure a constant supply of qualified staff. In addition to professionals and decision makers, the general public's involvement is of importance. The public must be involved in an informed consensus building by educating them on the socio-economic and environmental impacts of improper waste handling and be informed on the values of the waste if properly handled. By so doing, their active participation in effective waste management process is ensured.

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## LIST OF TABLES

Table 1.1: pay back method comparison.....	19
Table 1.2 discounted pay back method.....	20
Table 1.3 Net present methods.....	21
Table 1.4 comparison between NPV and IRR .....	22
Table 1.5 comparing methods of valuation under various scenarios.....	23
Table 3.1 Rate of MSW generation in Addis Ababa	
Table 5.1 stakeholders for construction of a WTER plant in Nifasilk lafto sub city....	40
Table 5.2 non-quantifiable costs .....	44
Table 5.3 non-quantifiable benefits.....	45
Table 5.4 heating value of MSW in Addis Ababa.....	49
Table 5.5 cost of collection and final disposal for the municipality of Lafto sub city...54	
Table 5.6 cash flow of a waste to energy recovery plant in Lafto sub city Addis Ababa.....	56
Table 5.7 heating value with the respective energy out put.....	59

## LIST OF FIGURES

Figure 1.1 integrated waste management hierarchy.....	8
Figure 1.2 a simplified form of environmental economics .....	13
Figure 3.1 composition of the Addis Ababa MSW.....	31
Figure 4.1 a typical waste to energy combustor.....	36
Figure 5.1 secondary market effects of introducing a WTER plant .....	41
Figure 5.2 schematic diagram of the mass burn technology .....	46
Figure 5.3 schematic diagram of Refuse Derived Fuel (RDF).....	46
Figure 5.4 the martin grate combustion system.....	48
Figure 5.5 Results of Monte Carlo simulation.....	60
Figure 5.6 importances of variables in the waste management center.....	61

