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SUSTAINABILITY OF AN ELECTRONIC WASTE RECYCLING PLANT IN KENYA

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Project contains no material previously published or written by another person except where due reference is made in the Research Project itself.

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This Research Project has been submitted for examination with my approval as the Supervisor.

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List of Abbreviations

EU – European Union

GDP – Gross Domestic Product

ICT – Information Communication Technology

PC – Personal Computer

TV – Television

UNEP – United Nations Environmental Program

USD – United States Dollar

WEEE – Waste Electronic Electrical Equipment

CRT – Cathode Ray Tube

LCD – Liquid Crystal Display

Abstract

The rise of technological innovation has brought with it an increase of electronic waste which causes environmental and health problems. This paper highlights the informal electronic waste recycling practices mostly used in developing nations and the dangers that come with it. The paper first investigates the amount of mobile phone electronic waste generated in Kenya annually. This is done through a questionnaire to find out the rate at which people change their mobile phones. It then seeks to investigate the sustainability of an electronic waste recycling plant in Kenya by modelling costs and revenues of such a plant over time as to whether such a plant can be self-sufficient. In order to test sustainability of the plant, an excel model is developed comprising of three major components; collection, recycling and refurbishment with relevant costs and revenues stated at each stage. This research will provide a foundation for establishment of an electronic waste recycling facility.

1. INTRODUCTION

Background

Electrical and Electronic waste, both of which are commonly referred to as e-waste are becoming a greater proportion of the global municipal waste stream growing at a rate three times that of other municipal waste globally according to a press release by the United Nations Environmental Program (Hofstra Law Review, 2012). Estimates indicate more than 45 million tons of e-waste was generated globally in 2012.(Seitz, 2014). Due to the increase in population, urbanization, economic grwoth and lifestlye orientations, it is anticipated that developing countries will tripple their electronic waste in the next few years. (United Nations Environment Program , 2010)

Empirical findings have shown that over the course of time, poorer and weaker countries in the developing world habitually bear the negative consequences such as the dumping of electronic waste produced in developed countries. China and India were the main victims of dumping which has since then heavily affected countries such as Ghana and Nigeria (Olowu, 2012). Many African countries lack appropriate infrastructure to treat e-waste in a controlled manner with most activities being performed by the informal sector resulting in environmental and health issues due to inadequate procedures applied. (Schluep, 2012). Interest over waste electrical and electronic equipment (WEEE) has not grown soley due to environmental and health concerns but aslo due to scarcity of rare earth elements found in electronic equipment. For example, metals such as gold and silver can be obtained at a higher quality with lower environmental impact from electronic products rather than from traditional mining. (Hofstra Law Review, 2012). It is estimated that from recycling one ton of scrap from computers, more gold can be recovered than that from 17 tons of gold ore and up to 40 times more concentrated copper than what is found in the copper ore. Approximately 6000 mobile phones can contain 3.5kg of silver and 340g of gold among other precious metals which can be sold at in the existing commodity market. (Seitz, 2014).

Motivation for Study

In 2008, the Government of Kenya approved the creation of Konza Technology City as a flagship for the Kenya Vision 2030 project. Vision 2030 aims to create a globally competitive and prosperous nation with a high quality of life by 2030. (Government of Kenya, 2016). A flagship project such as Konza Techno City shows the direction the country wants to take as a technological hub in the region which should therefore be accompanied by modern recyling procedures of technological equipment developed by the city. Furthermore, Vision 2030 seeks to improve the quality of life in the Kenya and by doing so research on electronic waste; its effects and how to recycle will go a long way in achieving this by reducing health and environmental concerns from electronic waste and creating employment to the people of Kenya.

The Kenya Environmental Sanitation and Hygiene Poilicy 2016-2030, has recognised the problem caused by elecetronic waste and the opportunities. The policy cites countries such as Taiwan, South Korea and China who have set up multibillion-dollar industries in e-waste recycling and refurbishment. In order a achieve a smilar fete, the policy calls upon stakeholders such as county governments, ministries of Health, Education Science and Technology, Environment and Natural Resources, Trade and Industry in collaboration with manufactureres , retailers and recyclers to come together to create an e-waste value chain (Republic of Kenya, Ministry of Health, 2016).Through vision 2030, the government is setting up a framework to:

Designate specific areas for e-waste recycling, including disassembly, burning and disposal.

Encourage the private sector to invest in responsible and sustainable e-waste recycling ventures and facilitate exchange and benchmarking visits to countries successful in e-waste recycling.

With such a policy coming to place, the study to investigate the estimate the amount of electronic waste in the country and the viability of an electronic recycling plant becomes important.

Problem Statement

ICT sector is one of Kenya's fastest growing as the sector grew by 12.7% in 2014 (Kenya National Bureau of Statistics, 2015).The government has encouraged growth in this sector through removal of tax levies on computers, promoting e-learning in educational institutions for example the laptop project, and the e-government strategy of 2004; all of which have increased the demand for computers and related accessories.

Public Procurement Oversight Authority (PPOA) which oversees the procurement process in public sector is said to have not seriously considered end-of-life effects of products procured. This is the same with many corporate organizations which regularly schedule an overhaul of their electronic devices but without an electronic recycling plan. However, much of the e-waste still resides in homes, offices and storage facilities because of lack of a proper infrastructure, policy and legislative framework guiding the recycling, refurbishment and disposal of WEEE in Kenya.

This meas a lot of electronic waste that could generate income in terms of job opportunities, sale of precious metals and conserving the environment is not being adequately adressed.

A lot of research has been undertaken on the environmental and health issues associated with poor management of electronic waste. However, this paper seeks to investigate the amount of electronic waste in Kenya as well as model the feasibility and sustatainability of setting up an electronic waste recycling facility in the country.

Research Objectives

The objective of this study are as follows:

1. To estimate the amount of existing mobile phone electronic waste in Kenya.
2. To develop a model to test the sustainability of an electronic waste management plant in Kenya.

Research Questions

This reserch study seeks to answer the following questions:

1. How much mobile phone electronic waste is generated in Kenya annually?
2. Does the revenue generated by the recycling plant exceed the costs incurred over time so as to make it self-sufficient?

Importance of the research

Nairobi has become the tech hub of Africa, a niche that could be worth more than a billion dollars in the next few years. The ICT sector is set to contribute up to 8% of the country's GDP by 2017, according to the Kenya ICT Authority's ICT Masterplan.

The Nairobi Industrial and Technology Park is manufacturing Kenya's first laptop computers known as Taifa with 4,000 units already sold. (Wachira, 2015). Though not all the parts for manufacturing the laptops were sourced locally, the project seeks to attaract local innovators to produce parts. The importance of this reserch in estimating the amount of electronic waste in the country can help prodive information on where parts required for technological innovations may be found. Furthermore, this study hopes to provide information required to run a sustainable electronic recycling plant which can be set up by interested investors. By doing so it can provide recycled materials to various technological innovations.

2.LITERATURE REVIEW

Introduction

For many years, management of waste electrical and electronic equipment (WEEE) simply involved choices between disposal options. This has however given way to focus on recycling and reuse due to commercial, social and environmental concerns (Smith, 2015). The literature discussed in this chapter will focus on the magnitude of electronic waste, informal recycling methods and finally legislation and policies put in place to manage electronic waste.

Magnitude of electronic waste problem.

Governments in the European Union, Japan,United states and other indutrialised countries began tigtening regulations on electronic waste in the 1990s. However not every country had the capacity to deal with the steep quantity of electronic and electrical waste they generated. This then led to some countries exporting their electronic waste to developing countries where laws were either non-existenet or not enforced. The reason for exporting electronic waste to developing countries was that it was cheaper to recycle. For example, the cost of breaking down or recycling of electronics in the United States is 26 times more than the cost in Nigeria (Olowu, 2012). As would be expected, a substantial portion of the demand for second-hand electrical and electronic equipment in the developing world is met by discarded equipment from government agencies and companies. In Kenya, for example, this source stream of electrical and electronic equipment was found to contribute up to twenty percent of the stock of second-hand ICT equipment in the country as of 2009.

Globally, estimates show annual production of e-waste to be 45million tonnes of which the United Nations Environment Programme (UNEP) says only 10 per cent is recycled. The European Union, despite strong legislation, is a major source of e-waste which is illegally exported and dumped in developing countries. An estimated 75 per cent of e-waste generated in the EU, equivalent to eight million tonnes a year, is unaccounted for. (Environmental Investigation Agency, May,2011). The UNEP study of 2009 warns that by 2020, electronic waste in South Africa and China will have soared by 200-400 percent from 2007 levels, and by 500 percent in India. Statistics also suggest that the United Kingdom alone is responsible for producing some 1 million tonnes per year of electronic wastes while the United States dumps between 300 and 400 million electronic items per year, and yet, less than 20% percent of those electronic wastes are properly recycled (Olowu, 2012).

Informal electronic waste recycling

In developing countries, informal methods are more prevalent with individuals typically responsible for breaking the component parts down by hand and then extracting the materials using rudimentary processes. These crude techniques involve; physically dismantling using tools such as hammers, chisels and bare hands to separate different materials, removing components from printed circuit boards by heating over coal fired grills, stripping of metals in open-pit acid baths to recover gold and other metals, chipping and melting plastics without proper ventilation, burning cables to recover copper as well as burning unwanted materials in open air, disposing unsalvagable materials in fields and riverbanks and the refiling of toner cartridges. (Xinwen Chi, 2011).

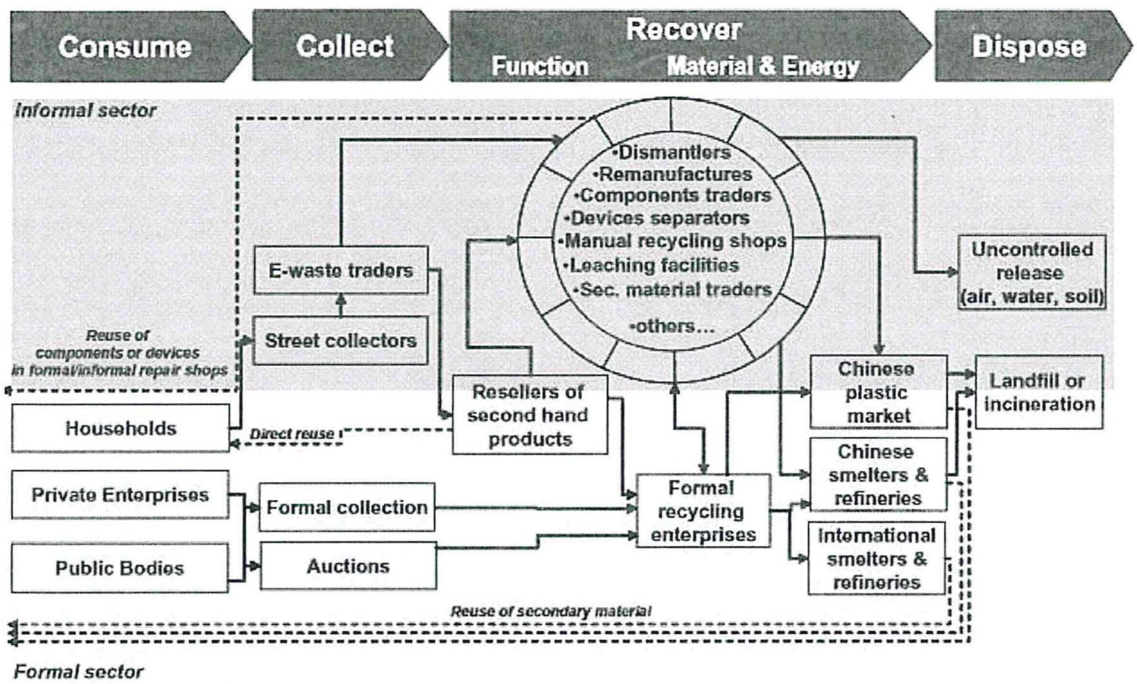


Figure 1. Flow chart of informal and formal e-waste processes in China

Figure 1 shows comparison between informal and formal recycling practices in China. From the chart it can be observed that formal recycling leads to more reuse of secondary materials than informal methods thus more efficient. With formal recycling the there is less pollution as waste materials that cannot be recycled are disposed through incineration; a method of thermal treatment. Informal methods result in more pollution of the air, water and soil.

The informal practices contribute to the release of toxic metals such as lead which is mainly used in Cathode Ray Tubes (CRTs). One monitor can contain between 0.4 kg and 3 kg of lead, whose main effect on humans is on their central nervous system. High exposure of lead could also severely damage the brain and kidneys of the humans and could lead to miscarriage in pregnant women. High levels of lead could also affect the brain development of children and organs responsible for sperm production in men. (ATSDR, 2007).

Most informal waste recycling is carried out by marginalised social groups that resort to waste picking for income. It is estimated that about 2% of the population in Asia and Latin America depend on waste picking to earn their living. (Medina, 2000). Poor wages, absence of environmental regulation and low overhead costs create viable profit margins from collecting and selling secondary raw materials.

Reasons cited for low end management of e-waste and existence of informal recycling sectors in developing countries include; the unwillingness of consumers to return and pay for the disposal of their old electronic equipments, lack of awareness among consumers,recyclers, collectors of the harzards posed by electronic waste, lack of funds and investment to finance improvements in e-waste recycling, absence of recycling infrustructure, absence of law or lax implementation of legislature regarding electronic waste (Xinwen Chi, 2011).

Benefits and challenges of e-waste recycling

The benefits that are achieved through recycling are undisputed; some of which include higher quality extraction of precious metals such as gold and silver compared to the traditional mining methods. Due to a decrease in mining capacity, prices of precious metals have skyrocketed in recent years. (Hofstra Law Review, 2012). Despite these benefits, only a small percetage is recycled; this is mainly attributed to the inconvinience of drop off locations and recycler disposal fees with consumers choosing between storing the waste or disposing it in landfills. As a result most of the electronic waste is still left unrecycled and posses a danger on the environment.

In countries where labor is inexpensive partially due to lack of environmental and worker safety regulations, the electronic recycling industry has seen $72 million in aggregate profits

The value of salvageable materials is not sufficient to cover the costs of collection, processing, transport, and recycling. Recycling fees are used to offset these costs and correct this disincentive (Hofstra Law Review, 2012).

While there is a need to enforce appropriate legislation which specifically targets e-waste, enforcement is a challenge in areas of the world with limited resources. Most countries lack capacity to implement the policies and regulatory framework. As of September 2010, the Basal Convention on trans-boundary movement of hazardous wastes had 178 signatories, but countries like USA had not ratified the convention (Lipman, 2011).The non compliance to international e-waste management policies by some countries has posed a challenge in the control of movement of hazardous waste to developing countries

The Bamako convention totally bans the import of hazardous wastes into Africa, it however permits the trans-boundary movement of hazardous wastes generated within Africa subject to very stringent regulatory control, and this is a major setback towards sustainability as more developed countries within Africa can willingly transport e-waste to less developed countries within Africa. (Muhani, 2012)

Producers of electrical and electronics equipment's are not taking responsibility of the products they produce, this has contributed to the escalation of the problem. Producers should also take responsibility by reducing and eliminating hazardous substances in their products, producing long-lasting products which are simple to recycle and putting in place effective take-back programmes (Joseph, 2007).

E-waste imposes many challenges on the recycling industry as it contains many different materials that are mixed, bolted, screwed, snapped, glued or soldered together. Toxic materials are attached to non-toxic materials, which makes separation of materials for reclamation difficult(Muhani, 2012).Hence, responsible recycling requires intensive labour and/or sophisticated and costly technologies that safely separate materials.

Regulations and Policies on Electronic Waste

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is one of the most important steps taken in recent times towards the international regulation of hazardous wasteAs of September 2010, the Convention had 178 signatories it was implemented in order to impose a stronger message about trade in hazardous waste and management within Africa. (Basel Convention, 2011)

Article 4 of the Basel Convention calls for an overall reduction of waste generation, by encouraging countries to keep wastes within their boundaries and as close as possible to its source of generation, the internal pressures should provide incentives for waste reduction and pollution prevention. Parties are generally prohibited from exporting covered wastes to, or import covered waste from, non-parties to the convention.

The Bamako convention on the ban on the import into Africa and the control of trans-boundary movement and management of hazardous wastes within Africa is a treaty of African nations prohibiting the import of any hazardous waste. The convention was negotiated by twelve nations of the organization of African unity at Bamako, Mali in January 1991, and came into force in 1998 (Muhani, 2012). Impetus for the Bamako convention arose from the failure of the Basel convention to prohibit trade of hazardous waste to developing countries, and from the realization that many developed nations were exporting toxic wastes to Africa.

Article 69 (a) of the new constitution, states '*The State shall ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits*' (Government of Kenya, 2010).The constitution of Kenya plays a crucial role in environmental management by acknowledging the importance of environmental sustainability, which will go a great mile in ensuring conservation of the environment.

Public involvement is critical to for environmental conservation; all parties involved in environmental matters are brought together hence ensuring success in matters of environmental conservation as is clearly highlighted in Article 69 (d) of the new constitution.

The National Government is responsible for protection of the environment and natural resources with a view to establishing a durable and sustainable system of development. The County Governments are responsible for implementation of specific national government policies on natural resources and environmental conservation appropriate within their jurisdiction (Government of Kenya, 2010).

Another challenge is the that environmental regulations which are not specifically designed for e-waste. These include the waste management regulations of 2006 enforced by the National Environmental Management Authority; the institution that implements all policies relating to the environment. These laws help in controlling generation, handling, transportation, storage, or disposal of waste that threatens public health, the environment or natural resources. (Asiimwe). These laws are not specifically designed to tackle electronic waste management and recycling thus creting loopholes within the law.

3.METHODOLOGY

Data Type and Sources

In order to estimate the amount of electronic waste generated in Kenya, data will be collected from existing electronic waste recycling companies such as East Africa Compliant Recycling and WEEE Centre. The later will mostly provide data in regard to refurbishment of electronic waste since the organization is primarily focused on providing computers for schools at not for profit. The East Africa Compliant Recycling will provide data on the recycling process such as metals extracted, equipments needed for recycling, recycling efficiency, wages, labour,collection and transportation costs. Other sources of data are from the Kenyan Economic Survey 2015 and Kenya National Bureau of Statistics and the to provide information on volumes of electronic equipment imported and the growth of Information Communication Technology sector.

Comodity prices for metals such as gold, silver , iron and aluminium will be collected using 2015 average prices provided by the World Bank. This will enable calculation of revenue from selling the extracted metals from recycling at global prices. Volatitlity of comodity prices will also be calculated in order to carry out a sensitivity analysis of the plant's revenue to these global commodity prices.

Questionnaire

This will be used to collect data on how often and why people changed their mobile phones in the last 10 year. The rate at which people change their mobile phones will serve as a proxy for the rate at which mobile phones become obsolete and therefore end up as electronic waste. The data collected together with the number of mobile subscribers in Kenya, which as at September 2015 stood at 37.8 million (Communications Authority of Kenya, 2016), will estimate the amount of mobile phone electronic waste in the country.

Data will be collected based on these age groups;

16 - 25
26 - 35
36 - 45
46 - 55
56 - 65

Table 1 Age groups to be surveyed

Model Set Up on Excel

The purpose of this excel set up is to give a rough estimation of all relevant financial cash flows in the recycling and refurbishment of electronic waste in Kenya.

The excel model is based on assupmtions and experiences of a similar project carriend out in Dar es Salaam, Tanzania (Schluep, 2012).

Electronic waste management involves three components;collection, refurbishment and recycling, all of which will be incorporated in the model in the followig way;

Collection

This is the preceeding statge to recycling and refurbishment which constitutes the acquisition of waste electrical and electronic equipment through puchase of collected material. The model will assume 60:40 ratio of electronic waste items coming from businesses and households. Other than acquisition costs, this stage will also includes transportation cost, cost of setting take back points and labour costs. The electronic waste is collected in bulk comprsing of materials to be refurbished and recycled. Out of the materials collected from businesses; 60% is recycled while 40% is fit for refurbishment, on the other hand those collected from households and informal sectors 75% is recycable and 25% fit for refurcbishment. The expenses incurred in the model will be divided between the two revenue streams of recycling and refurbishment. The flow chart below shows a theoretical example on the appropriation of costs per revenue stream that shall be used in the model.

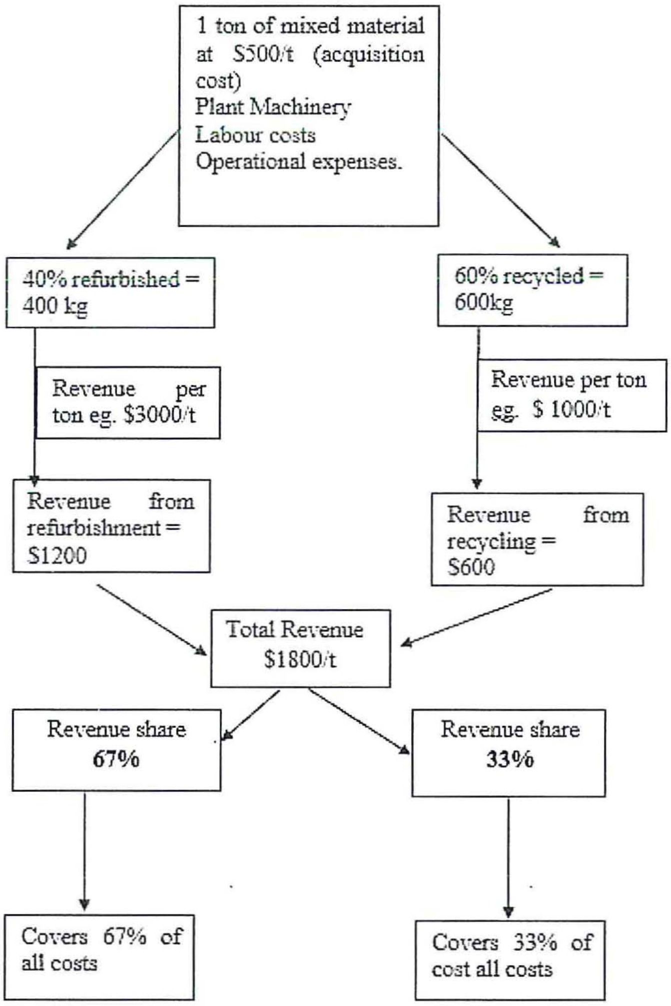


Figure 2 Flow chart describing cost appropriation

The scope of collected items to be included in the model will include laptops, printers, desktop personal computers (Liquid Crystal Display and Carthode Ray Tube moniters) and Television sets.

Refurbishment

All the collected appliances are sorted according to their suitability for being refurbished. It is estimated that 40% of materials collected from businesses and 25% collected from households are suitable for refurbishment. This is followed by triage and testing of the collected materials is carried out to discover which parts of electronic waste are working and can be used to re-assemble the various electronic devices such as laptops and desktop computers. The costs incurred in this process include labour provided by the technicians,rent of the plant premesis and administration fees.

Once testing has been completed, actual refurnishment takes place incurring futher costs as stated above. The refurbished devises are then sold in the market to generate revenue with the following estimated resale price; refurbished PC: 100 USD/unit, refurbished laptop: 200 USD/unit, refurbished printer: 13.4 USD/unit, refurbished TV: 33.4 USD/unit (Schluep, 2012). However if the refurbishment of collected appliances does not contribute to a better financial performance, there is little reason to include this business unit.

The benefit of this business unit is that it extends the life span of some electrical and electronic appliances and therefore contributes additional revenue to the recycing process.

Recycling

This stage of the model focuses on the dismantling and disassembly operation. Equipments that could not be used for refurbishment are broken down to extract parts that can be sold separately. A reduction factor of 25% is applied to cater for obsolete materials that again end up as electronic waste. It is also at this stage that extraction of preceious metals such as gold, solver and copper takes place which will be sold at global market prices to yield revenue.

World Bank Commodities Price Data (The Pink Sheet) 2-Jun-2016

Commodity	Unit		Annual Averages Jan-Dec 2013	Jan-Dec 2014	Jan-Dec 2015	Quarterly Averages Jan-Mar 2015	Apr-Jun 2015	Jul-Sep 2015	Oct-Dec 2015	Jan-Mar 2016	Monthly Averages Mar 2016	Apr 2016	May 2016
Metals and Minerals													
Aluminum	$/mt	b/	1,847	1,867	1,665	1,802	1,770	1,592	1,494	1,514	1,531	1,571	1,551
Copper	$/mt	b/	7,332	6,863	5,510	5,833	6,057	5,267	4,885	4,675	4,954	4,873	4,695
Iron ore	$/dmt	b/	135	97	56	63	58	55	47	48	56	61	55
Lead	$/mt	b/	2,140	2,095	1,788	1,810	1,942	1,717	1,682	1,738	1,802	1,732	1,708
Nickel	$/mt	b/	15,032	16,893	11,863	14,393	13,056	10,579	9,423	8,508	8,717	8,879	8,660
Tin	$/mt	b/	22,283	21,899	16,067	18,370	15,590	15,230	15,077	15,439	16,898	17,033	16,707
Zinc	$/mt	b/	1,910	2,161	1,932	2,080	2,192	1,843	1,612	1,677	1,802	1,855	1,869
Precious Metals													
Gold	$/toz	c/	1,411	1,266	1,161	1,219	1,193	1,124	1,107	1,181	1,245	1,242	1,261
Platinum	$/toz	c/	1,487	1,384	1,053	1,193	1,127	986	907	914	968	994	1,036
Silver	$/toz	c/	23.8	19.1	15.7	16.8	16.4	14.9	14.8	14.9	15.5	16.4	16.9

Figure 3 Commodity prices

The table above shows commodity prices that will be used as a proxy for the seling price of the extracted metals. A senstivity analysis will be also be carried out to show effect of the fluctiating comodity prices on the revenues of the recycling plant.

The costs incurred at this stage include: labour for manual dismantling, transport to from collection to dismantling centre to downstream processing which includes treatment in recovery and disposal facilities to facilitate metal extraction in social and environmentally friendly conditions.

Other factors in the model

The location will be based on Mombasa Road in Nairobi as this area has been designated for industrial activities, therefore rental charges for the site premis will be based on this area.
The number of workers required is subject to the findings on the estimated amount of electronic waste in the country. Workers will be grouped into three catergories with the following estimated productivity per worker: Sorting: 200 units/month per worker, Testing: 100 units/month per worker and Refurbishment: 100 units/month per worker (Schluep, 2012). The gazetted monthly average minimum wage in urban areas, excluding housing allowance, is between Sh12,136 (all other towns) and Sh15,357 (Nairobi, Mombasa, Kisumu). (Government of Kenya, 2015) Therefore the labourers in the three categories above will be paid approximately $180 per month. Other labour costs include: Drivers 200 USD/month , Administration Assistant 900 USD/month and Manager 1,500 USD/month.

4.DATA ANALYSIS AND PRESENTATION

Introduction

This chapter has two main sections; one being an analysis of a survey used to estimate the amount of mobile phone waste produced in Kenya annually while the other section is an investigation as to whether can electronic waste recycling plant can be self-sufficient over time. This is done using an excel model to forecast revenues and expenses of such a plant as well as carrying out a scenario analysis to establish the most sensitive factors in achieving sustainability.

Mobile phone electronic waste producd in Kenya annually

This section examines an electronic waste awareness survey of 131 respondents on their awareness of electronic waste, giving a special focus to the number of mobile phones they have had in the last 10 years. This, together with the number of mobile subscribers is used to approximate the number of mobile phones electronic waste produced annually in Kenya.

Age Group	**Sum of How many mobile phones have you had in the last 10 years?**	**Average per age group**
16 - 25	292	6
26 - 35	414	7
36 - 45	101	7
46 - 55	27	5
56 - 65	16	5
Total	850	6

Table 2. Results of the survey showing mobile phones owned in the last 10 years

In 10 years, 131 people had a total of 850 mobile phones with an average of 1 phone every 20 months. It is important to note that there were different reasons that forced respondents to acquire new mobile devices as shown in **Figure 4.** Therefore in order to estimate the amount of mobile phone electronic waste, we shall only consider mobile phones that got spoilt.

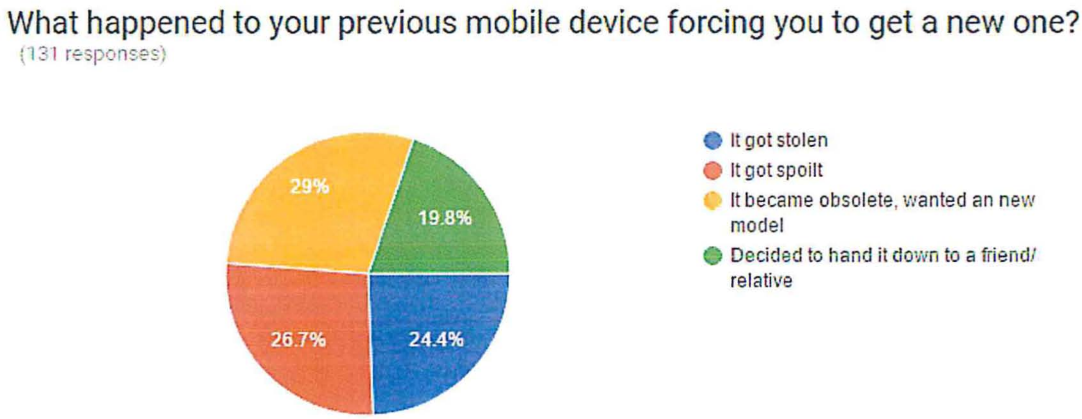


Figure 4. Reasons respondents gave for acquiring new phones in the last 10 years

Mobile phones that got spoilt were 26.7% of the 850 phones 131 respondents had in the last 10 years. Therefore from the survey, 131 people contributed to a total of 227 mobile phones as electronic waste at an average of 23 phones per year.

Year	Number of Mobile Subscribers	Waste per year
2005	3,935,000	690,878
2006	6,484,791	1,138,551
2007	9,304,818	1,633,670
2008	12,933,653	2,270,794
2009	17,362,257	3,048,335
2010	20,119,304	3,532,397
2011	25,279,768	4,438,433
2012	29,703,439	5,215,108
2013	30,549,422	5,363,639
2014	32,246,393	5,661,580
2015	36,113,121	6,340,472

Table 3 Mobile phone electronic waste based on mobile subscribers

Based on an average of 23 spoilt phones per year per 131 subscribers, the estimation of the amount of mobile phone electronic waste produced yealy is shown in **Table 3** above.

Smartphones, which accounted for 58% of mobile phones sold in Kenya in 2015 (Zab, 2015), have an average life expectancy of 4.7 years according to the Consumer Technology Association which surveyed 1,013 adults (Ely, 2014). However, life expectancy depends on usage and can therefore range from 2.5-4.7 years. Therefore with a mobile phone penetration of 88.1% according to the Communications Authority of Kenya as at September 2015, the amount of mobile phone electronic waste in Kenya is set to grow at a faster rate.

Other Electronic Waste Equipment

The survey also sought to investigate the presence of other electronic waste devices that were present in their homes. These were devices that could not be fixed and therefore lay in homes as waste.

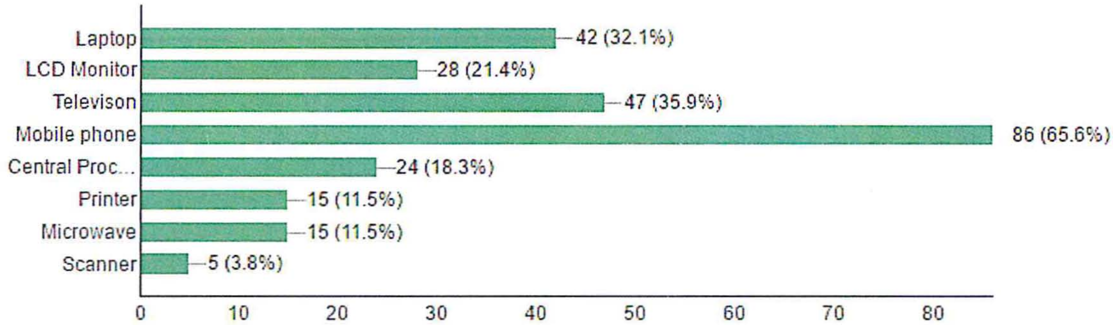


Figure 5 Electronic waste in households

Those surveyed had a total of 262 electronic waste equipments with mobile phones being the most prevalent accounting for 65.6% of electronic waste in households.

The information in **Figure 5** will also be the basis for choosing which equipments will be included in the model in to establish whether an electronic waste recycling plant in Kenya can be self sustainable.

Other Aspects of the Survey

By acknowledging the ownership of electronic waste equipment in their households, the respondents were then asked about their willingness to donate their waste material for recycling. 57.3% were willing to donate while 23.7% preferred selling their equipment for recycling. The rest who were 19.1% of the sample size preferred to keep their waste.

From the survey, one can imply that electronic waste recycling plants need to improve marketing as 58% of those surveyed did not know where to donate despite.

Model Results

This section contains four subchapters regarding the baseline scenario of the model, recycling, refurbishment and a sensitivity analysis of the recycling business unit to world commodity prices in the past.

Baseline Scenario

This section describes in detail the results obtained from the baseline scenario.

In every 100t of mixed electronic waste, the table below shows the composition by weight of each electronic device.

Item	PC	Laptop	Printer	LCD Monitor	CRT Monitor	CRT TV	LCD TV
Composition by weight	19.9%	1.1%	7.6%	1.7%	22.7%	42%	5%

Table 4 Composition by weight of electronic items in 100t of mixed electronic waste

Based on **Table 4** above, an estimation is made on how much of each item can be obtained per metric ton of mixed electronic waste based on the average weight of each item above. The items are then purchased from businesses and households at the following prices.

Item USD/kg	PC	Laptop	Printer	LCD Monitor	CRT Monitor	CRT TV	LCD TV
Household	0.45	2.86	0.51	0.45	0.45	0.21	0.45
Businesses	0.53	3.34	0.51	0.53	0.53	0.21	0.45

Table 5 Purchase prices

The prices in the table above together with the estimated number of electronic items in the mixed waste forms our acquisition cost. Labour and transport charges are added on to the acquisition cost to obtain the total collection cost which stands at Ksh. 6,925,794 per 100t of mixed waste.

The total income in **Figure 6** reflects accumulated income of refurbishment and recycling operations. Refurbishment, which is the most profitable business unit breaks even at volume 259 tons of electronic waste collected per year per year, while total income and recycling breaks even at 285.3t and 382.5t respectively. At 1000t per year, recycling generates an income of Ksh. 4,572,932 and refurbishment Ksh. 20,227,885, adding up to a total income of Ksh. 24,800,816.

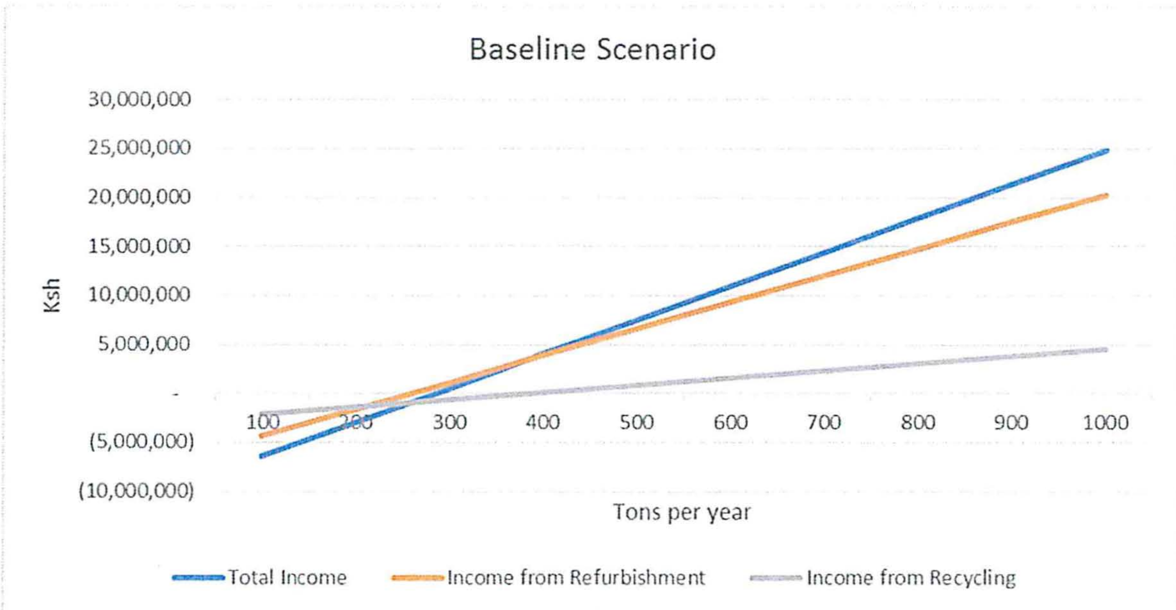


Figure 6 Income from baseline scenario

Refurbishment income catered for 71% of the total revenue therefore incurring 71% of administration, collection and rent charges while recycling catered for 29% of the costs.

The subsequent section will discuss in further detail the results obtained from each business unit.

Refurbishment

Refurbishment was found to be the most profitable business unit accounting for 82% of total income. This business unit breaks even at 88t needing a total of 259t of mixed electronic waste to be collected. This partially attributed to a reduction factor of 25% of the items meant for refurbishment that end up as waste and are therefore moved to the recycling business unit. **Figure 7** below shows how costs and incomes relate with an increase of the total mixed electronic waste collected.

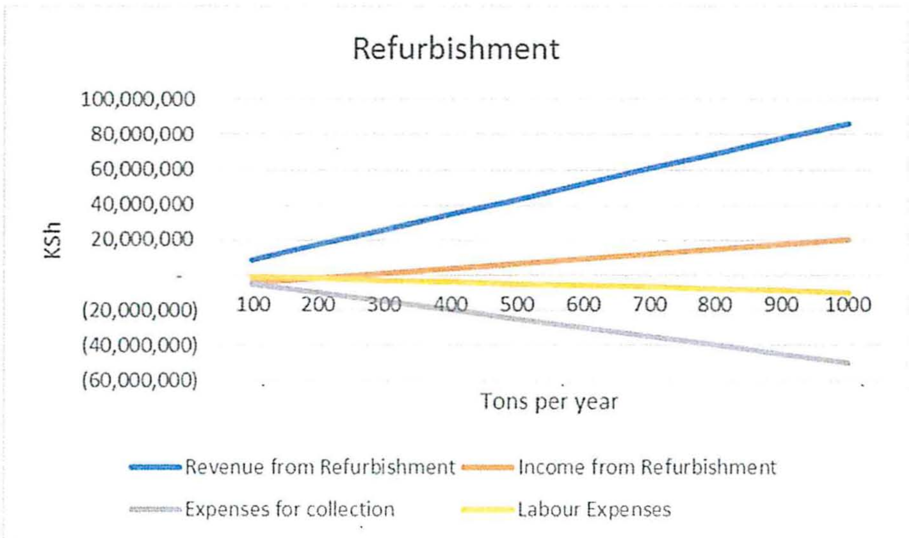


Figure 7 Refurbishment income and expenses

Of the items refurbished, personal computers, laptops and printers account for 92% of the total revenue due to their relatively higher selling price than the other electronics. Personal computers contributed 59% of the revenue from refurbishment making the them the highest income earners of the business line.

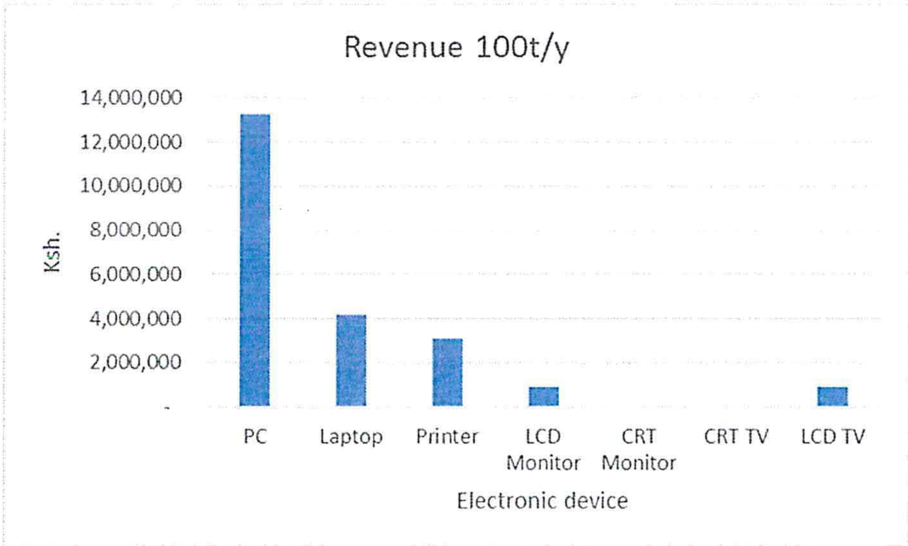


Figure 8 Revenue per electronic device

Concerning expenses for the refurbishment operation, the major shares are attributed to collection and, at lower refurbishment amounts, to administration as shown in **Figure 9**. At higher refurbishment levels, administration expenses become a lesser proportion of the total costs while collection costs rise significantly due to the higher cost of acquiring large volumes of electronic waste. The acquisition cost can be reduced while still being able to collect the same amount of electronic waste if such a plant is able to receive more donations of waste than they need to purchase from businesses and households.

Figure 9 Refurbishment share of expenses

Recycling

This business line contributed 29% to the total revenues thereby incurring the same proportion of costs shared between refurbishment and recycling. As a result, recycling operation accounted for 18% of the total income generated by the business.

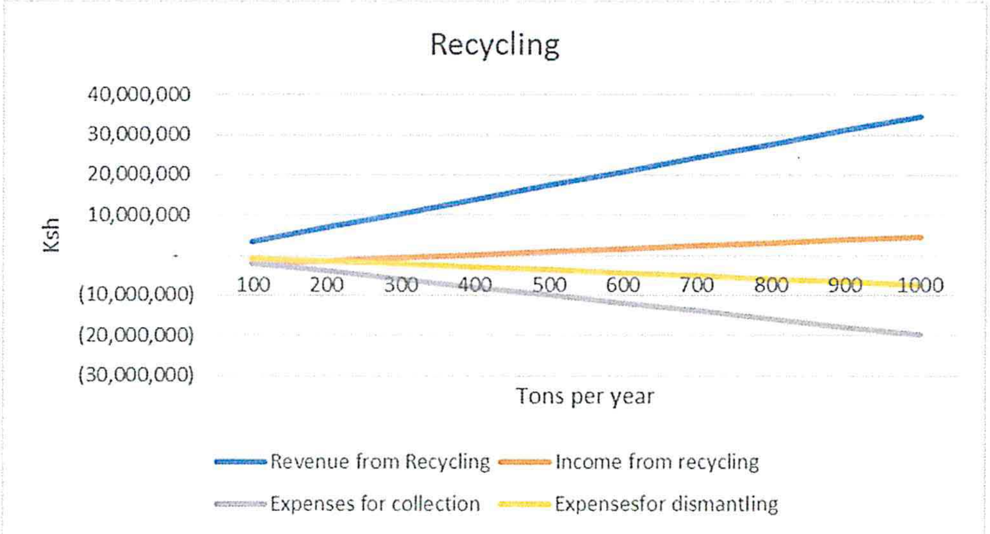


Figure 10 Recycling Income and Expenses

As shown in **Figure 10** above, the business unit breaks even at 382.5t of mixed electronic waste per year making it the operation the requires the largest volume of waste in order to be profitable. This is because only a small amount of precious metal can be extracted from a single electronic device, a large number of electronic waste devices are therefore required for the business line to make a significant amount of income.

Of the metals extracted, as shown in **Figure 11**, revenue from copper was the highest accounting for 33% of the total revenue, closely followed by gold at 31%. Despite gold being the least by volume of the metals collected, its high selling price, compared to the other metals, makes it one of the top income earners in the recycling operation.

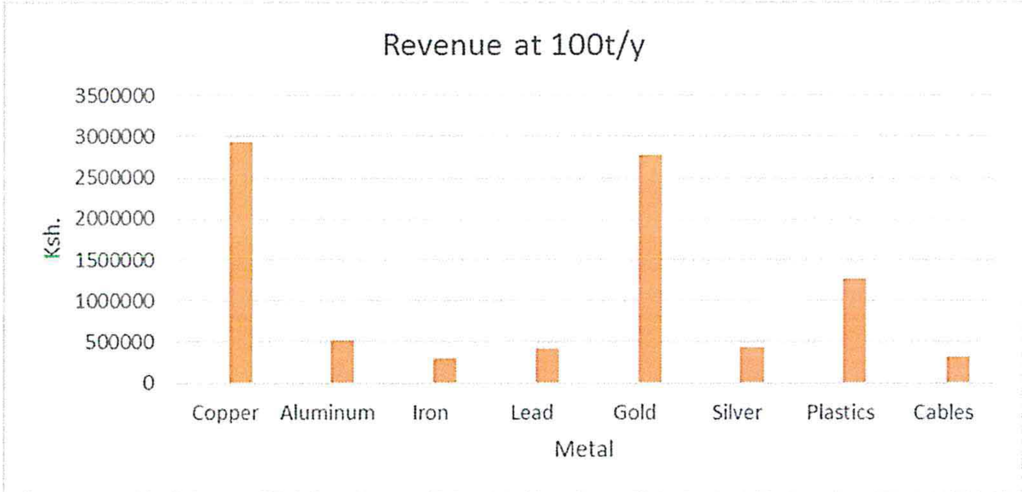
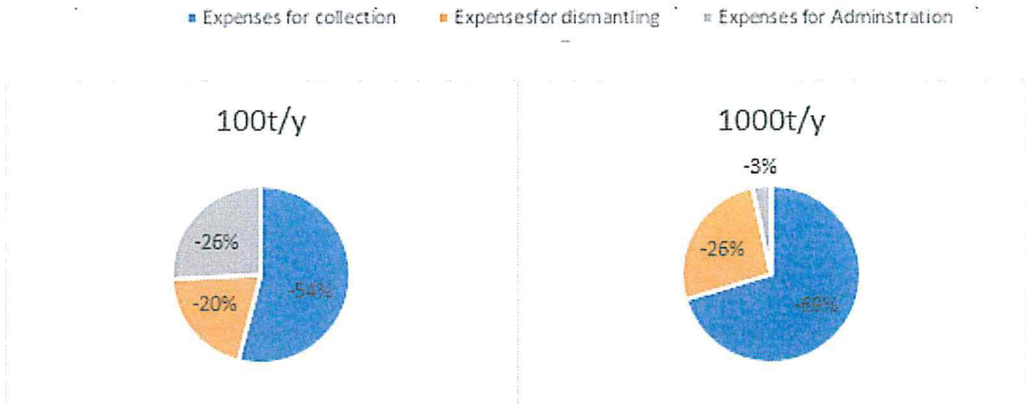


Figure 11 Revenue contribution per commodity

Concerning expenses, their distribution is similar to the refurbishment business line, with a major share attributed to collection followed by administration expenses as shown in **Figure 12.** However, as amount of electronic waste is increased, administration costs become a lesser proportion of the total expenses incurred by the recycling business unit.

Figure 12. Recycling Share of Expenses



Sensitivity Analysis of Recycling Income to Commodity Prices

In the base scenario, May 2016 commodity prices were used to obtained the income generated by recycling business unit. The base case income was the then compared to other incomes based on commodity prices for 2013, 2010 and 2007.

As per the **Figure 13** below, 2010 yielded the highest income of Ksh. 10,698,851 at 1000t of electric waste per year with a break-even of 242t/y. This was followed by 2013 at Ksh. 9,741,792 with a break-even of 255t/y and 2007 at Ksh. 8,282,561 with a break-even of

279t/y. The base case yielded the least income of Ksh. 4,572,932 at 1000t of electronic waste per year with a break-even of 382.5t/y

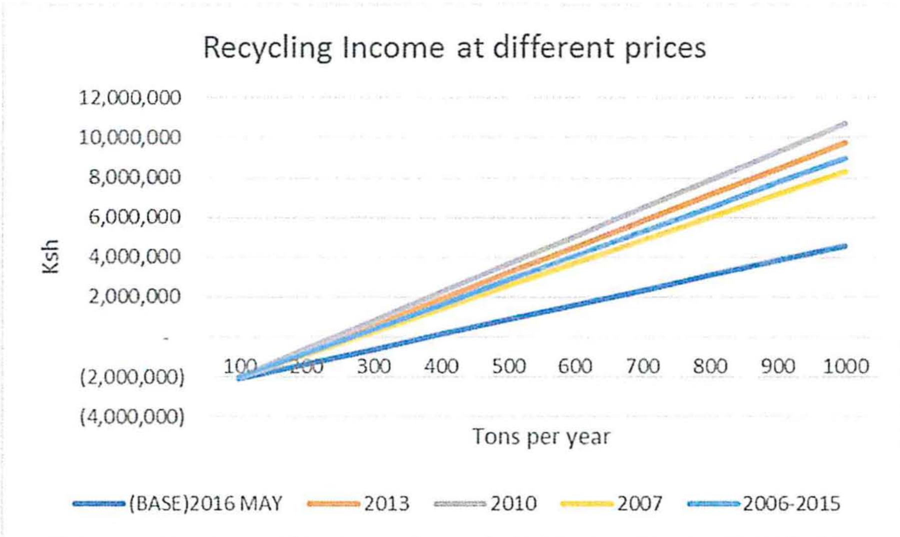


Figure 13. Recycling income at different commodity prices

A decline in commodity prices results in more electronic waste required for the business unit to be more profitable. Since, copper and gold account for the highest portion of recycling revenue, recycling income is most sensitive to their prices.

Commodity Price	2013	2010	2007	2006-2015 Mean
Income in relation to May 2016	213%	234%	181%	196%

Table 6. Baseline Income compared with income from different commodity prices

In **Table 6**, one can observe that the base scenario yields the least income in comparison to previous years, therefore if prices are to rise to the average prices experience between 2006-2015 then an income increase of 96% can be obtained from the recycling unit. The income obtained from the recycling unit therefore follows the volatility of world market commodity prices.

5. CONCLUSION

Results of the financial modelling suggest that under the current local and global economic conditions and if sufficient throughput is guaranteed the recycling operation is a feasible business model by relying on the intrinsic value of the treated material only. Accordingly, the refurbishment operation is feasible by generating sufficient income through the sales of appliances for reuse. However, changing conditions such as wage increases, rise in purchase prices and transportation costs can pose relevant risks to the business, which consequently would require additional income streams.

Since purchase of mixed electronic waste is done in bulk, it contains obsolete appliances or scrap material and devices. It is therefore crucial that collection is followed by a triage of the material to recycling and refurbishment for maximal value creation.

The refurbishment operation which breaks even at 259t/y would require approximately 1328 personal computers, 208 laptops 772 printers per year. However, conditions as assumed in the baseline scenario are subject to uncertainties and constant change which can lower or unbalance the business income. Another threat to the business stems from the reduction of the sales prices of refurbished products, which can be triggered through poor quality second-hand products or budget-priced competing products, including low priced new products, such as notebooks.

Breakeven analysis in the recycling operation is attained at collection of 382.5t of mixed electronic waste collected per year as per the baseline scenario. However, this business line can break even at a less amount of electronic waste collected given that prices of commodities present in electronic waste increase. Commodity prices have a strong impact on the business performance. While profit can be generated with the current prices, the budget can readily become unbalanced if the commodity prices fall below that of May 2015. Although the global economic trend points towards rather stable or increasing commodity prices for a longer period, this dependency has to be interpreted as a relevant risk for the business' profitability.

Breakeven for both business lines are not achieved below 100t per year. An effective collection system is therefore necessary for the financial success of the recycling plant. In order to ensure cashflow; seed funding or grants in the initial phase of setting up the business might be required in order to cover expenses until collection has reached the required volumes after which the recycling plant can be self-sufficient.

6. REFERENCES

Asiimwe, E. N. (n.d.). *E-waste Management in East African Community*.

ATSDR. (2007, August). *Toxic Substances portal- Lead.* Retrieved from Agency fot Toxic Substances and Disease Registry.

Basel Convention. (2011). *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* . Châtelaine, Switzerland: Secretariat of the Basel Convention.

Communications Authority of Kenya. (2016). *First Quarter Sector Statistics Report for the Financial Year 2015/2016.* Nairobi.

Ely, C. (2014, September 16). *The Life Expectancy of Electronics.* Retrieved from Consumer Technology Association: https://www.cta.tech/News/Blog/Articles/2014/September/The-Life-Expectancy-of-Electronics.aspx

Environmental Investigation Agency. (May,2011). *System Failure; The UK's harmful trade in electronic waste.* London.

Government of Kenya. (2008). *The Vision; History.* Retrieved from Konza City: http://www.konzacity.go.ke/the-vision/history/

Government of Kenya. (2010). *The Constitution of Kenya.* Nairobi: National Council for Law Reporting.

Government of Kenya. (2015). *THE LABOUR INSTITUTIONS ACT ;Kenya Subsidiary Legislation 2015.* Nairobi: The Kenya Gazette.

Hofstra Law Review. (2012). ECONOMICS OF ELECTRONIC WASTE DISPOSAL REGULATIONS. *Hofstra Law Review*, 152.

Joseph, K. (2007). *ELECTRONIC WASTE MANAGEMENT IN INDIA–ISSUES AND STRATEGIES.* Cagliari, Italy.: CISA, Environmental Sanitary Engineering Centre.

Kenya National Bureau of Statistics. (2015). *Economic Survey 2015.* Naironi.

Lipman, D. Z. (2011). Trade in Hazardous Waste: Environmental Justice Versus Economic Growth. *Basel Action Network.*

Mbuthia, E. (2015). Kenya's statutory minimum wage raised 12 per cent. *Business Daily*, 1.

Medina, M. (2000). *Scavenger Cooperatives in Asia and Latin America.*

Muhani, D. A. (2012). *A FRAMEWORK FOR SUSTAINABLE E-WASTE MANAGEMENT IN MANUFACTURING AND PROCESSING INDUSTRIES, INDUSTRIAL AREA NAIROBI COUNTY, KENYA* .

Olowu, D. (2012). Menace of E-Wastes in Developing Countries. *Law, Environment and Development Journal*, 61.

Republic of Kenya, Ministry of Health. (2016). *Kenya environmental Sanitation and Hygiene Policy 2016-2030.*

Schluep, F. B. (2012). *Economic Feasibility of e-Waste Treatment in Tanzania* . St. Gallen.

Seitz, J. (2014). *Analysis of Existing E-waste Practices in MENA Countries.* Germany: GIZ.

Smith, C. (2015). The Economics of E-Waste and the Cost to the Environment. *ABA Natural Resources & Environment Magazine*.

The World Bank. (2015). *Commodity Markets*. Retrieved from The World Bank: http://www.worldbank.org/en/research/commodity-markets

United Nations Environment Program . (2010). *Waste and Climate Change.* Osaka.

Valuable substances in e-waste. (1996). Retrieved from ewaste: http://ewasteguide.info/valuable_materials_in_e_waste

Wachira, A. (2015). Inside Kenya's silent tech revolution. *African Business*.

Weight. (2007). Retrieved from ewasteguide: http://ewasteguide.info/weight

Xinwen Chi, M. S.-P. (2011). Informal electronic waste recycling; A sector review with a special focus on China. *Elsevier*, 731-742.

Zab, S. (2015). *The Growth of the Smartphone Market in Kenya* . Nairobi.

8. APPENDIX

Table 7. Commodity Prices

Commodity Prices USD/t	Baseline (May 2016)	2013	2010	2007	2006-2015
Aluminum	1,551	1741	2173	2765	2142
Copper	4,695	6913	7535	7459	6998
Iron ore	55	128	146	129	116
Lead	1,708	2018	2148	2704	2032
Gold USD/toz	1,261	1331	1225	730	1145
Silver USD/toz	17	22	20	14	20
Cables	0.38 of copper price				
Plastics	Ksh.35/kg				

*Source;(The World Bank, 2015)

Table 8. Metal composition in electronic devices

Metal composition of electronic devices (% of weight)	PC	Laptop	Printer	LCD Monitor	CRT Monitor	CRT TV	LCD TV
Copper	0.03%	1.50%	3.50%	0.65%	7.00%	3.00%	0.75%
Aluminium	4.92%	3.70%	0.30%	3.10%	2.00%	0.00%	3.50%
Iron	75.06%	29.80%	36.20%	35.25%	10.00%	12.00%	39.75%
Lead	6.30%	-	-	-	-	-	-
Gold	0.0016%	-	-	-	-	-	-
Silver	0.0189%	-	-	-	-	-	-
Plastics	5.80%	14.50%	46.00%	18.50%	13.00%	23.00%	18.50%
Cables	2.75%	1.00%	3.00%	2.50%	0.00%	0.00%	1.50%

*Source; (Valuable substances in e-waste, 1996)

Table 9. Average weight of electronic devices

Electronic Device	Average weight (kg)
Personal Computer (PC)	9.9
Laptop	3.5
Printer	6.5
LCD Monitor	4.3
CRT Monitor	14.1
CRT TV	31.6
CRT Monitor	15

*Source; (Weight, 2007)

Table 10. Selling Price of Refurbished items

Device	Selling Price (Ksh.)
Personal Computer (PC)	10,000
Laptop	20,000
Printer	4,000
LCD Monitor	3,500
CRT Monitor	28
CRT TV	28
CRT Monitor	4000

Table 11. Conversion metrics

USD/Ksh	101.4171
EUR/Ksh	112.4553
Troy ounce to kg conversion rate	0.0283495

Table 12. Other Assumptions in the model

Rent per year	Ksh. 6,600,000
Transport Cost per year	Ksh. 2,084,288
Labor (Dismantlers) per month	Ksh. 15,357
Technicians per month	Ksh 20,000