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Green Computing A Way to Reduce Environmental Impacts of E-Waste in Manufacturing Companies in Meru County

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***Abstract*—** *The constant growth of technology has radically increased the amount of `technology waste' generated causing an increased need in necessary facilities and infrastructure to manage it. Information computing technologies (ICTs) must adopt green computing – principles, policies and strategies which aim at reducing the adverse impact on the environment and minimizing the carbon footprint to increase environmental sustainability. Most companies have not put great emphasis on the need to adopt, assess and report on the impacts of ICTs waste management for environmental sustainability. Issues surrounding green computing are overlooked when it comes to medium or small scale organizations or startup companies. This paper explores E-Waste and highlights the problems caused by E-Waste in the manufacturing sector and presents the recent approaches towards overcoming the same. The study applied a mixed-method research approach using both quantitative and qualitative data. The researchers employed exploratory and descriptive research design to discuss the findings obtained from the four Manufacturing companies in Meru County who filled an online questionnaire which was used as the data collection tool for the study. The preliminary discoveries from the study reveal that ICTs play a greater role in environmental sustainability among manufacturing companies in Meru County. The role of ICTs for environmental sustainability are deemed a necessity in enhancing flexibility and visibility in decision-making as well as in minimizing energy consumption, carbon footprint, and e-waste disposal. To cope with these problems, summarizing the electronic waste recycling practices and experience in businesses, some countermeasures, and suggestions for e-waste recycling have been highlighted in the paper. Scientific methods of disposal of e-waste should be undertaken for reducing the environmental damage. Planting trees can also help the earth recover from its damages. The paper presents green computing as one of the strategies that can be adopted to implement comprehensive E-Waste management by the Manufacturing companies and small and medium enterprises*.

***Keywords*—** *E-Waste, Green Computing, Information Computer Technologies, E-Waste Management.*

I. INTRODUCTION

Electronic waste (E-Waste) is the waste generated after electronic /electrical equipment have been used and reached their end of life or disposal time which implies it no longer fits its original intended purpose and use. These may include items such as computers (personal computer, desktops or laptops), monitors, servers, printers, mainframes, DVDs or CDs, photocopiers, scanners, fax machines, calculators, battery cells, TVs, mobile or cellular phones, transceivers, laminating machines, binding machines, medical apparatus like the (Scanning machine, X-Ray machines) and electronic components like hard drive, flash drives besides other white goods such as refrigerators and air-conditioners used by both companies and individuals(Ni, Zeng, Tao, & Zeng, 2010)

The hazardous impacts of E-waste are not felt by the county after immediate disposal. However, the hazardous elements disposed present in the e-waste is hazardous when such wastes are dismantled and processed, which may take a long period of time, since it is only at this stage that they pose hazard to health and environment (Thakur, Ray, & Goel, 2016).

Electronics and electrical equipment seem efficient, resourceful and environmentally-friendly when in use, but there are hidden dangers associated with them once these become obsolete or e-waste. The harmful materials contained in electronic products, coupled with the fast rate at which we're replacing out dated units, pose a real danger to human health and the environment if not properly processed prior to disposal (Nayab, 2011).

Electronics products like cell phones and computers contain a lot of different toxins. For example, cathode ray tubes (CRTs) of computer monitors contain heavy metals such as lead, barium and cadmium, which can be very harmful to health if they enter the water system. These materials can cause damage to the human nervous and respiratory systems (Ni et al., 2010). Flame-retardant plastics, used in electronics casings, release particles that can damage human endocrine functions. These are the damages that can occur when unprocessed e-waste is put directly into the land (Joseph, 2007).

According to (Balde, Wang, Kuehr, & Huisman, 2014) in the year 2014, it was noted that nearly 41.8 million metric tonnes of e-waste were generated globally by different sectors and this is attributed to increase in market penetration of electronics and electrical products in developing countries, development of a replacement market in developed countries and a generally high product obsolescence (Alireza & Gordon, 2012)

Kenya, being one of the developing countries in the world, faces great competition in industrial revolution followed by high needs of using information technology to increase its competitive advantage (Otieno & Omwenga, 2016). With these growing needs and demands of more advancement of information technology it has led to various problems of electronic waste (Osibanjo & Nnorom, 2008). This calls for

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everyone to look upon environment friendly approaches for disposing electronic waste. Innovation, Invention and Adaptation of environment friendly ways of waste management like green computing are deemed necessary (Arjun Jinachandran, 2015).

Green computing is the intended approach and practice of using information technology resources efficiently, responsibly and in an eco-friendly way that is environmental friendly (Siddiqui & Syed, 2013). Green technology is one of the major needs for the current industrialization era (Jaiswal, Samuel, Patel, & Kumar, 2015). The modern day depends a lot on Computers and other ICT devices, including tablets, mobile phones and printers etc., all of which consume large amount of energy and results to large amounts of electronic waste with time (Awasthi, Zeng, & Li, 2016). These technological developments along with short innovation cycles have increased the obsolesce rate of these devices, which is contributing to the e-waste stream. The risk associated with dealing with this e-waste call for green technologies for end of life disposal. To manage e-waste (Mathias, Ruediger, Christian, & Federico, 2012) and (Debnath, Roychoudhuri, & Ghosh, 2016) support the use of green computing as a viable approach which ensures a formal recycling process.

According to (Archana, Kumar, Pankaj, & Rakesh, 2011) green computing designs takes the following main stages: green use, green disposal, green design and green manufacturing. This entails use of computing devices in a more environmental friendly manner that consumes less energy. The goal of green computing is to reduce the design and use of materials that cause negative impacts to the environments.

A. Why Is Electronic Waste A Problem?

E-waste is a problem that started since when the first computer and electronic products were manufactured, but the extent of severity and depth of the problem is being experienced by the modern societies (Panda, 2013). In developing countries like Kenya, the manufacturing industries use electronic and electrical equipment which include computers and other cellular devices which are becoming obsolete every year hence presenting new challenges. E-waste poses new challenges that are both long-term and short-term to the environment (Heeks, Subramanian, & Jones, 2015).

In the last three decades, developing countries like Kenya have witnessed the production and consumption of electrical and electronic equipment (EEE) grow due to the affordable pricing, internet usage, and evolution of the equipment's capabilities and features (Otieno & Omwenga, 2016). This has resulted to huge quantities of obsolete e-waste. This has been catapulted by the increased cross-border transportation of these electronic devices as second hand equipment into developing countries with the aim of narrowing the digital divide (Osibanjo & Nnorom, 2008). In Kenya many industries and individuals have a great reliance on imported refurbished devices.

One of the greatest problem in the management of E-Waste is the low-level of citizen awareness on the harmful effects of E-Waste on the environment, their health and safety (Otieno & Omwenga, 2016). E-waste has the effect of polluting the environment when burnt or disposed without due diligence; discharging harmful heavy metals such as mercury and lead; depleting the ozone layer; blocking water drainage channels; and causing harmful effects including cancer to living organisms in an ecosystem (Nayab, 2011). The problem is compounded by the inability of most manufacturing companies and consumers to purchase brand new electronics therefore resulting in a substantial number of consumers going for second-hand or refurbished products which are cheaper but have a shorter life-span (Osibanjo & Nnorom, 2008).

B. E-Waste Toxins And The Human Body Parts Affected

Waste generated from end-of-life electrical and electronic equipment, known as e-waste, is a rapidly growing global problem (Devin, Marie-Noel, Tapiwa, & Peter, 2014). According to (Devin et al., 2014) E-waste contains valuable materials that have an economic value when recycled. However, most of the e-waste is recycled in the unregulated informal sector and results in significant risk for toxic exposures to the recycler, who are mostly women and children, and the environment (Tanskanen, 2012). The table below shows the E-Waste Toxins:

Table 1: E-Waste Toxins and Affected Body parts(Devin, Marie-Noel, Tapiwa, & Peter, 2014)

e-Waste Toxins and Affected Body Parts

Components	Constituents	Affected body parts
Printed circuit boards	Lead and cadmium	Nervous system, kidney, lever
Motherboards	Berillium	Lungs, skin
Cathode ray tubes (CRTs)	Lead oxide, barium and cadmium	Heart, lever, muscles
Switches and flat-screen monitors	Mercury	Brain, skin
Computer batteries	Cadmium	Kidney, lever
Capacitors and transformers	Polychlorinated biphenyls (PCBs)	
Printed circuit boards, plastic	Brominated flame-retardant casings cable	
Cable insulation/coating	Polyvinyl chloride (PVC)	Immune system
Plastic housing	Bromine	Endocrine

In Kenya, recycling of e-waste is almost entirely left to the informal sector, which does not have adequate means to handle either the increasing quantities or certain processes, leading to intolerable risk to human health and the environment (Omari, Mutwiwa, & Mailutha, 2016). The following is a summary of the rate of discarding the Electrical and Electronic items:

Discard Rate of Electronics Items

Item	Discard/replace rate
Mobile telephone	1 to 3 years
PC	Every 2 years
Camera	3 to 5 years
Television	10-15 years
Refrigerator	10-15 years
Washing Machine	10-15 years
IT accessories	Very fast

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The above summary table concurs with what (Tanskanen, 2012) states that electrical and electronic equipment waste is the largest growing waste streams globally. Therefore for a sustainable environment and economic recovery, valuable materials need to be recovered for reuse and electrical scrap be recycled. Tanskanen further states that it is more complicated to recycle electronic products which have reached the end of their life as they contain many different types of material types integrated into each other. Efficient recycling of e-waste is not only a challenge for the recycling industry; it is also often a question of as-yet insufficient collection infrastructures and poor collection efficiencies, and a considerable lack of the consumer's awareness for the potential of recycling electronics for the benefit of the environment as well as for the savings in energy and raw materials (Jaiswal et al., 2015)

II. DISCUSSION

The study was carried out at North Imenti constituency in Meru County in Kenya that is one of the many developing nations. Four manufacturing companies were used in the study. A total of 20 employees were considered as the respondents with five employees per company being sampled and one of the five respondents given the online questionnaire coming from the ICT department. The researchers analyzed the data using SPSS and MS Excel.

All the respondents who were sampled indicated that their respective companies use ICT for their business processes. The study also showed that the sampled companies neither have an E-waste management plan nor policy. The respondents indicated that the old ICT equipment were dumped in a single room which some referred to as an archive, others as store of old computers and others disposed the E-Waste together with other waste from the company to the county garbage collection vehicle. Other respondents also indicated that the old ICT equipment were sorted and sold as scrap metal.

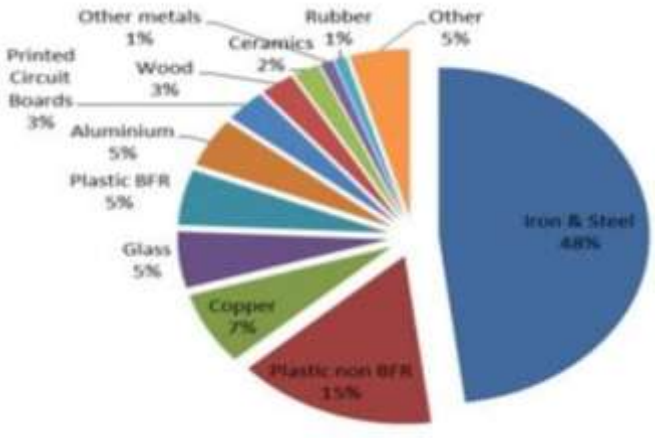

Figure 1: Composition of E-Waste on a Broad Level

This clearly indicates that the highest materials used are made of Iron & Steel which has 48% followed by plastics at 15%, Copper, Aluminium and Glass are at 5% , Printed Circuit Boards follows closely at 3% and the lowest is Rubber which is at 1%.

As the Figure- 1 above, the results indicate that the E-waste consists of a larger amount of iron and steel along with aluminium, rubber, ceramic, copper and other chemically composed materials, the challenges will arise since the methods to extract them out from the obsolete items and recycle them will also be different. Heavy materials from the disposed items will be taken out separately as they are easy to pick up by use of hands and naked eyes while the tiny one needs special attention and special equipment to extract. In addition, the chemically harmful substances from the electronic items need to be taken care by using special chemical deposition techniques to avoid any harmful effect on the handler's human body and environment. Most electronic and electrical waste goes through a recycling system called a WEEE (Waste Electrical and Electronic Equipment), which not only recycles 95-98%, by weight, of all E-waste passed through it, but ensures that any data left on hard drives and memories are thoroughly destroyed too.

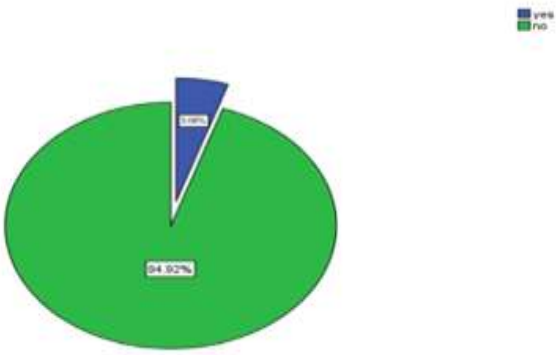

Figure 2: E-waste generator responsibility

The manufacturing companies gave varied reasons as to why they did not separate e-waste before disposal. 92% of the respondents did not find it important to separate e-waste from general waste before disposal, 5% claimed there was no provision for separation as the company did not provide separate litter bins. 3% of the respondents generally didn't care how the waste was disposed an this is indicated in Figure 3 below

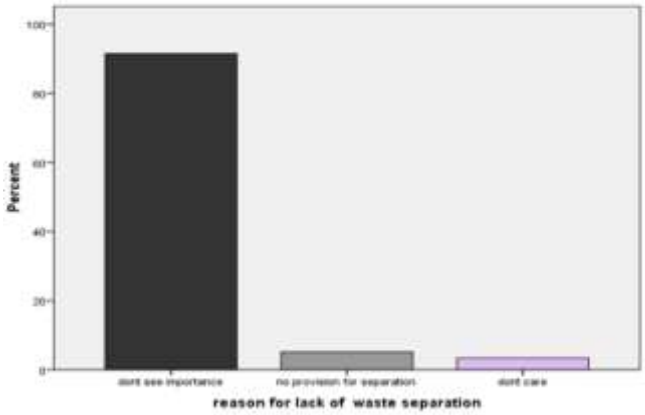

Figure 3: Reasons for lack of waste separation

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Company Disposal Mechanism or Policy

The study established that all the sampled manufacturing companies did not have any environmental policy nor e-waste policy as shown in Figurers 4 and Figure 5 below:

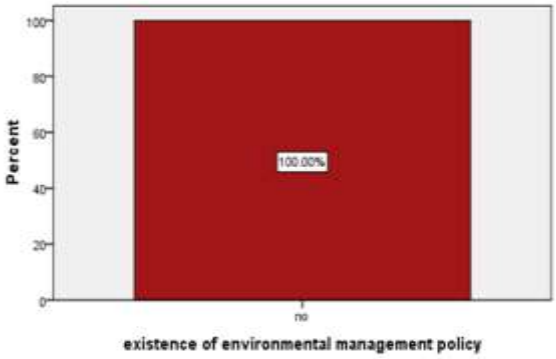

Figure 4: Environmental Policy

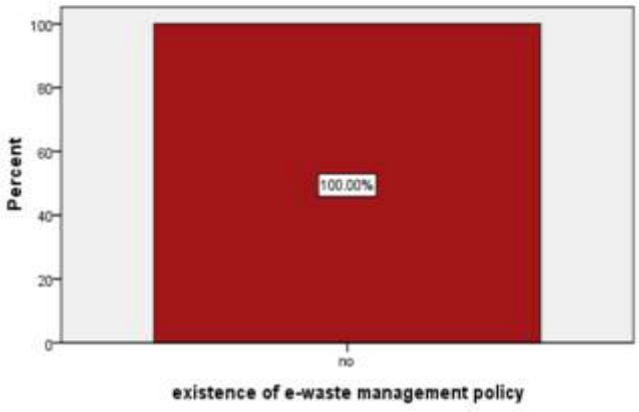

Figure 5: E-Waste Policy

Health and Environmental Impacts of E-Waste

E-waste has a number of both health and environmental impacts, the negative health impacts including kidney problems, brain damage, skin ulcers, lung cancer, birth defects and death that come from water contamination and soil contamination. The study results are however alarming that only 25% of the respondents could highlight the negative effects of e-Waste. This could be explained by the fact that only 10% of them could tell what happens to the e-waste they dispose away and only 14% cared what happens to the e-waste discarded. Of those who did not care what happens to the discarded e-waste, 16% felt that it had no serious health or environmental effects, 8% felt that it was not their responsibility while 76% of the respondents did not care since e-waste just like general e-waste is of no value to them as shown in Figure 6.

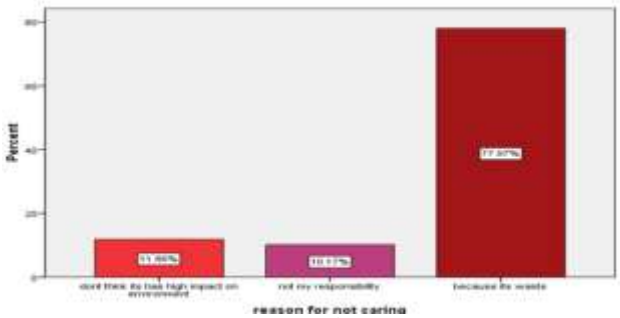

Figure 6: Reasons for not Caring

Of those who cared what happens to the e-waste they dispose every day, 3% percent cared since they knew it was harmful to the environment and 3% felt it was harmful to human health as shown in figure 7:

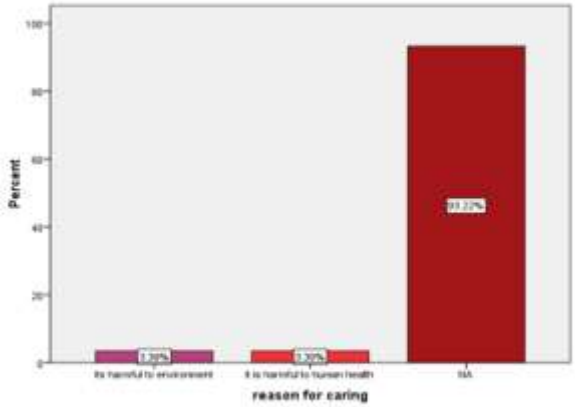

Figure 7: Reasons for Caring

This study indicates that electronic appliances are composed of hundreds of different materials that can be both toxic and equally of high value when being used before they are disposed. While majority materials such as aluminium, iron, plastics and glass account for over 80 weight % of E-waste, whereas valuable and toxic materials are found in smaller quantities but are still of high importance as explained by (Thakur et al., 2016). The material composition of different appliances is often similar, but the percentage of different components can vary a lot. The precious metals such as Gold, silver, copper, platinum etc., turns recycling of E-waste into a lucrative business opportunity. On the other hand, the recycling of hazardous E-waste which possesses carcinogens such as lead and arsenic is critical and cause serious health risks and environment dangers if not properly handled.

The amount of e-waste being generated is increasing rapidly and is compounded by both illegal exportation and inappropriate donation of electronic equipment, especially computers, from developed to developing countries. The use of electronic devices results to various effects on the environment. These environmental issues result from the gases emitted which includes carbon dioxide and other toxic materials. These effects cause serious health issues including respiratory diseases, global climate changes and acid rain (Archana et al., 2011).

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Computers affect the environment at different stages in their life cycle from manufacturing, use and disposal. Developed nations have methods of dealing with e-waste however that is not the case for most developing nations. The adoption of green computing methods will help in reducing these negative effects, whether in developed or developing nations (Jaiswal et al., 2015).

The results of this study further indicated as little as 25% of e-waste is recycled in formal recycling centers with inadequate worker protection. Over 80% of the respondents did not have enough knowledge on e-waste recycling process. 75% of the respondents had an opinion that e-waste recycling would have a positive effect on the environment.

The study shown that 50% of the ICT staff who were questioned indicated that green computing would be one of the solutions to e-waste management. Some of the green computing benefits that were noted from the study were: It is environmental friendly, energy saving and reduces environmental pollution hence improving people's health. Whereas, green computing was found to have several benefits; various challenges were noted from the study as the main barriers to green computing. These challenges included: The technology being not readily available in the local markets due to insufficient technological infrastructure, High startup, operational and maintenance costs and difficulty of applying green computing by everyone on the company and hence in the society as a result of insufficient technological knowhow among users.

To overcome these challenges, existing laws and policies need to be revised to allow for inclusion of technological advancement approaches in areas of green computing in manufacturing and SME's, and these companies to come up with policies that will enable use of green computing as a method to E-waste management. Training of the members of the society is also necessary to enlighten them on the benefits of green computing. Generally the benefits of green computing will result in saving money, conserving energy, reducing costs, and helping the environment.

The preliminary discoveries from the study reveal that ICT play a greater role in environmental sustainability among manufacturing company in Meru County.

Cloud Virtualization for Greener Manufacturing

Green computing in small and medium scale manufacturing enterprises can be enhanced through adoption of cloud computing and virtualization strategies. In cloud computing, virtualization refers to coming up with software equivalent to hardware. Virtualization can either be full, para, storage, network, platform, or application virtualization respectively. Deployment of virtual instances can be utilized remotely through the use of the internet thin client. This is a solution that results to long term benefits to manufacturing companies with relation to cost cutting and increased revenue (Panda, 2013).

Virtualization of servers within manufacturing companies will in turn result to provision of on demand services that are a trend that is on high demand in the current green computing cloud paradigm. The adoption of cloud computing virtualized services in the manufacturing industry is a feature that will greatly result to the less reliance on electronic devices to benefit the organizations demands both in the short term and long term.

Manufacturing companies can adopt public cloud data center services offered by Amazon, Microsoft, HP and Google who use virtualization in their own data centers. This will lead to virtualization benefits to the companies in a number of ways. Cost reduction of IT staff and equipment required to run and maintain the data center, consequently saving the manufacturing companies on cost. Cloud services in terms of software, applications and services can be setup, embedded and customized to the manufacturing company's requirements. Green computing coupled with virtualization will save on the environmental impact through creation of an ecofriendly environment by reducing the amounts of energy consumed by electrical and cooling manufacturing equipment's (Awasthi et al., 2016).

The government can implement mechanisms to facilitate the collection of all e-waste from the producer therefore ensuring that all e-waste finds its way to a recycling center. These can be; Special collections events, Permanent drop offs sites, Retail stores and as needed come-up with scheduled pick-up in e-waste generating companies.

Open Source cloud solutions exists which can be adopted and customized to specific manufacturing and user requirements that minimizes over reliance on electronic devices by creation of software equivalent solution that are able to function as the electronic devices currently in use. This results to minimal reliance on electronic solutions and enhances the reliance on cloud solutions that result to green computing.

III. Conclusion

In this paper we discuss the effect of the growing need of electronic devices among manufacturing and small and medium scale enterprises with relation to the effect of electronic waste generated and mitigation measures applicable in managing the effect of electronic waste. Management of the electronic waste has been identified as one of the approaches that can be adopted to minimize the effect by adoption of green computing technologies and strategies. Cloud virtualization of the manufacturing processes has been seen as one of the green computing strategies that can be adopted in the developing countries to minimize the effect of electronic waste to the environment and human beings in manufacturing industries. Whereas green computing is becoming potentially beneficial to minimizing of electronic waste, more studies need to be done to enable the adoption of cloud and virtualization solutions among manufacturing companies in the developing parts of Africa.

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