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Procedia Computer Science 46 (2015) 1317 – 1324

Procedia Computer Science

International Conference on Information and Communication Technologies (ICICT 2014)

Go Green with WEEE: Eco-friendly approach for handling e- waste

Anand Jaiswal[a,]*, Cherian Samuel[a], Bharat S. Patel[a], Manish Kumar[a]

[a]*Department of Mechanical Engineering, Indian Institue of Technology (BHU), Banaras Hindu University, Varanasi 221005, India*

Abstract

The rate of EEE put in market and WEEE generated in previous years defines the magnitude of the problem of e-waste handling. Many researches have indicated the potential threat of e-waste and stated the need of proper recycling strategies and global e-waste management policies to confront the growing problem. This study discusses the awareness in people for handling obsolete electronic products and suggests a green framework for e-waste. The study also discusses the role of EPR for e-waste handling, defining the need of green manufacturing and its approaches which can lead to solutions for WEEE.

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)

Keywords: E-waste;WEEE; Extended Producer Responsibility; Green manufacturing; Recycling; Product end-of-life

1. Introduction

With the growing needs and demands of more advancement, we are living into the era, where changes are evitable and are very much required to cope up with the user requirements. When it comes to the information and communication technologies, consistent innovation and up-gradation is the key to remain in market. From the last two decades, this consistent change and dependencies on information and communication technology has led to the serious problem of electronic waste. Waste Electric and Electronic Equipment (WEEE) or e-waste includes a wide and increasing variety of electronic devices ranging from large domestic devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been rejected by their end-users.[1] These electronic goods hold many constituents that require special end-of-life treatment, most prominently mercury, chromium, arsenic, lead, cadmium, and plastics capable of discharging, among other

* Corresponding author. Tel.: +91-9452109605
*E-mail address:*anand.jaiswal27@gmail.com

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
doi:10.1016/j.procs.2015.01.059

compounds, dioxins and furans.[2]

Up to an estimate, 50 million tons of e-waste is produced every year.[3] But when it comes to recycling or re-utilizing of the e-waste generated, the percentage is very less. The developed nations, though, have certain strategies to deal with the e-waste generated but still a major portion of e-waste either goes for land filling or exported to the developing nations of Asia and Africa.

This study aims on understanding the problems of e-waste and the major causes behind the growing concerns of e-waste and after which it suggests strategies to deal with the problem including the concept of green manufacturing under Extended Producers Responsibility. The study also elaborates a survey done on the people to know their understanding about what to do with their electronic products when it has reached its end of life state.

1.1 Electronic waste – a rising global issue

E-waste loosely refers to a term for all the electric and electronic equipment that has reached its end of life state and has been discarded by its end users. StEP, a collaborative organization for solving the –e-waste problem, states that '*e-waste is a general term, it can be considered to cover TVs, computers, mobile phones, white goods (e.g. fridges, washing machines, dryers etc.), home entertainment and stereo systems, toys, toasters, kettles – almost any household or business item with circuitry or electrical components with power or battery supply.*'[4]The e-waste volume is almost increasing at the rate of 5 to 10% annually[3] and within the recent years a major growth in e-waste generation has also seen in developing countries like china and India.

Table 1, taken from the data given by StEP initiative on their website, shows the approximate total amount of electric and electronic equipment put in market in year 2012 throughout the world and in different regions of world. It also gives a brief about the E-waste generated for the year 2012. It can be observed that developing countries are putting a good amount in generation of E-waste but still the European Union and United States are the major producers of E-waste annually. The StEP Initiative predicts that by 2017, the world will produce around 33 per cent of more e-waste, or around 72 million tons annually.[4]

Table 1.Quantity of EEE put in market and E-waste generated in year 2012 worldwide. Source: StEP[4]

Country	EEE Put on Market in Year 2012 (approximately)	E-waste Generated in Year 2012 (approximately)
World	65 million metric tons	49 million metric tons
EU countries	12 million metric tons	9.9 million metric tons
USA	10 million metric tons	9.4 million metric tons
China	11 million metric tons	7.2 million metric tons
India	4. million metric tons	2.75 million metric tons
Japan	3.3 million metric tons	2.74 million metric tons
South America	3.4 million metric tons	2.3 million metric tons

In all the electronic products that have reached its end of life state, 80 to 85% of electronic goods are discarded in incinerators or landfills that are capable of releasing certain toxics into the air.[5] According to a report from EPA, U.S. generated 3.16 million tons of e - waste in the year 2008 and in this only 13.6 % estimating 0.43 million tons was recycled. The rest were incinerated or dumped in landfills.[6]The report also shows a significant increase in the generation of e-waste from the previous year but the recycle rate remains same as 13.6%.

In earlier days, US and EU were the main collaborators of producing WEEE in the world but with significant growth of economies and development in information and communication technologies, developing nations of Asia are going neck to neck in producing E-waste every year. As per the report of StEP, China, alone, leads the world in putting Electric and Electronic Equipment (EEE) into the market. Over to this up to an approximation, around 4 Kilo tonnes of WEEE are exported worldwide each hour in which near about 80% reach to Asia in which China gets a share of around 90 %.[7] As per the table 1, countries like India, Japan and South American nations are also putting a great share in generation of WEEE in the world.

1.2 WEEE composition and EEE end-of-life

There are several recycling processes and techniques available for handling e-waste but that closely depends upon the material composition and thus it becomes quite important to know about what components comprises the e-waste. WEEE comes with a diversified range of material components and is hard to categories all such constituents into a general set for all the electronic waste generated. In all the e-waste generated, a major portion covers with metals and plastic used in the components. Fig. 1. , adapted from Wildmer et al. (2005)[9], shows the typical material fraction of WEEE. Metals, including ferrous and non-ferrous along with plastics comprises of around 75 per cent of all in WEEE components. With the need of eco-friendly design and encouraging re-usability of products, many countries are imposing policies to reduce the pollutant and plastic contents in the EEE. The use of lead-free soldering is also much in use by the producers as lead is a major pollutant and hazardous for health as well as environment.

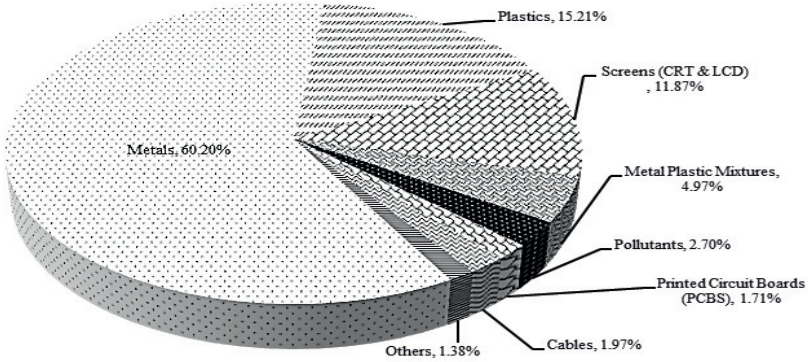

Fig. 1. Typical material fraction in WEEE[9]

Understanding the compositions of EEE helps to recycle the product properly and if we can estimate the end of life state of a product we can re-direct it for recycling process before it can reach to the state of waste. During its period of serving, a product undergoes with several stages that starts from designing and manufacturing and ends to recycle or land filling of scrap. In the end-of-life stage of EEE, the stage of mechanical separation of re-useable components plays the key role in reducing the quantity of e-waste generated. Fig. 2. explains the several stages a product undergoes in its life cycle and end of life cycle.

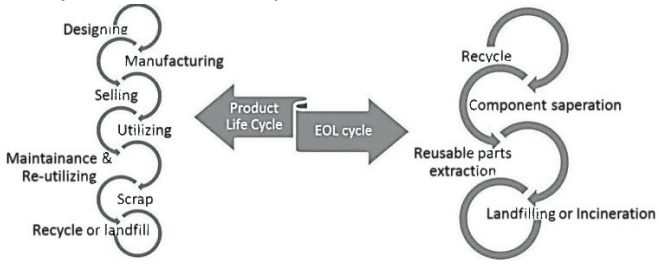

Fig. 2. Different stages of EEE life-cycle and EOL cycle

1.3 Effect of e-waste on environment and health

EEEs are prepared from a number of components, some containing toxic ingredients that have an adverse effect on the environment and human health if not handled properly. These threats arise because of inadequate recycling and disposal procedures used.[10]

The e-waste comprises of many hazardous and toxic components including lead, mercury, cadmium, polyvinyl chloride and many others which requires specialized treatment. Such toxic components can't be completely handled by the processes of land filling or incineration and can lead to a number of environment and health impacts if trashed improperly. As per Juliet Duff, Irish Doctors Environmental Association, *'incineration does not solve the problem of waste, it only reduces waste to approximately 30 – 50 % of the original compressed waste mass, and this is converted into an ash that contains some of the most toxic concentrations of substances, such as dioxins and heavy metals.'*[11] These dioxins and other toxins reaches to atmosphere and end up in water bodies, soils through which it gets into crops and animals eventually leading to humanity causing multiple health disorders.

According to a factsheet from World Health Organization, short-term exposure of human beings to high levels of dioxins may consequence in skin lesions, like chloracne and patchy darkening of the skin, and altered liver function. Long-term exposure is linked to damage of the immune system, the developing nervous system, the endocrine organs and functions related to reproductions.[12] Various studies and researches has proved other toxins like lead, barium, hydrocarbons emitted from e-waste incineration or land filling, a health hazard and can lead to many health disorders and even cancer if being in contact for prolong period.

2. E-waste: Reasons behind

Information and communication technology has evolved rapidly in last two decades with number of inventions and advancements in electric and electronic products. As EEE come in market, it also goes obsolete with course of time and gradually handling of these out-dated products has become a global concern. There are several reasons which have raised the potentiality of the complications of e-waste in small time, some of which include:

- Unrestrained growth in information technology (IT) and electronics industry
- Rapid innovation in technology making a number of useable products, non-fashioned.
- Reduced lifecycle of EEE making it obsolete in much lesser time
- Use of non-degradable components such as plastics, which reduces price but a serious threat to environment
- Decreasing cost of products enabling more purchase thus more e-waste
- Limited rate of recycling and re-usability
- Multifaceted processes of WEEE handling
- No fixed protocol throughout the world for e-waste management
- Poor e-waste collection efficiency of organizations
- Use and throw attitude of consumers limiting re-usability of products
- Lack of awareness of end user about what to do with e-waste scrap

One of the main reasons behind the serious issue of e-waste that has emerged globally in little time is rapid growth of technology, enabling the reach of EEE to maximum populaces and no proper and common protocols for handling e-waste in the entire world. Of all the e-waste generated only 12.5% of electronic waste is presently being recycled.[13] Rest of the e-waste goes for land filling, incineration or just exported to under-develop or developing countries.

Another important reason which has raised the magnitude of e-waste problem is low e-waste collection efficiency and limited knowledge of people regarding what to do with their EEE when it goes obsolete. The awareness in people regarding electronic junk handling is limited in most of the countries but it is a real concern in developing countries like India.

A survey was conducted in India on 100 people belonging to different professional background regarding their knowledge about e-waste handling. Most of the people in survey were having possessions of various electric or electronic products among which 99 % were having laptop or tablet pc and 97 % were having cell phones along with other devices. Fig. 3.illustrates their knowledge about e-waste when asked in survey. Only 19 % of survey takers know to handle their electronic scrap properly in which 7 % said to return it to the producer from where they purchased the product and 12 % said to go for recycling to some organization. 21% were of opinion to sell the e-waste to regular garbage collector that ultimately will lead to land filling or incineration. 23% of individuals agreed that they don't have any knowledge about what to do with their e-waste. In another question in the survey, 86% of

individuals asked for protocols or methods that should come from producer, as an EPR, properly guiding about product after its end of life. 97% have felt an urgent need of specific policies to handle e-waste. The survey clearly gives an idea that there is a good need of putting efforts for creating awareness in people regarding e-waste handling and easily accessible and well-defined protocols that promote recycling and re-utilizing of used products are very much required.

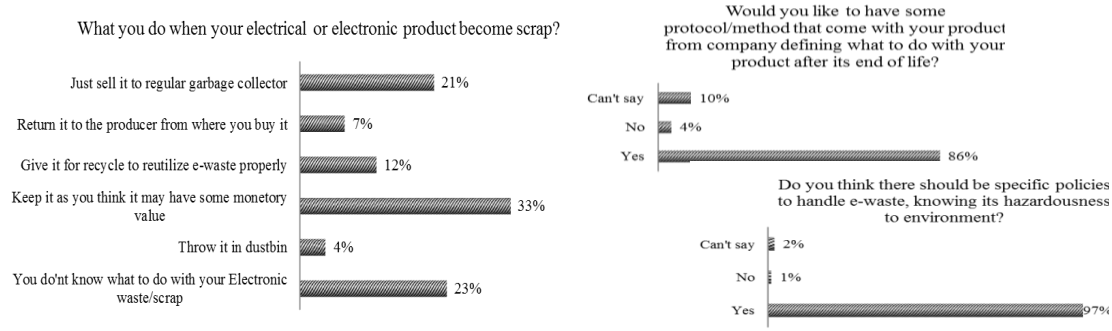

Fig. 3. A survey on understanding about e-waste handling

3. WEEE handling and management: the 'green' approach

A proper WEEE handling require specific strategy that includes appropriate collection and gathering methodology, sorting and segregation techniques, processes of re-cycle through maintenance and left-over should be taken to incinerators or land filling. A 'recycling process' can be described as a sequence of 'process units' aiming at recovering recyclable components and reusable materials.[14] According to a report from EPA, recycling 1 million laptops can save energy equivalent to the electricity used by 3,657 U.S. houses in a year.[15]The WEEE-directive 2003prioritizes the reuse of waste electric and electronic equipment and its components, subassemblies and consumables. Where reutilization is not convenient, all wastes collected discretely should be sent for recovery. Manufacturers have to set up systems to take care of collected e-waste using best available techniques.[14]

Fig. 4. elaborates a 'green' framework for handling and managing WEEE with an environment responsive approach. With course of time, each of the EEE goes obsolete and become an e-waste. Here starts the main work of collecting the e-waste from different sources. Collection and transport of the waste put the major costs on the complete recycling process.[16]In the process of door to door collection of e-waste, main approaches can be considered as A). E-waste collection form households or commercial firms through governmental or non-governmental organizations. B). Collection of electronic scrap from solid waste garbage collectors. C). Collection by the EEE producers from end-users as a corporate social responsibility (CSR).

Many of the countries also have specific WEEE collection policies. In European Union nations, the legislations provide the system for the collection arrangements where consumers free of charge return their used e-waste, whereas in another developed nation-Japan, the e-waste management system is based upon "withdrawal on charge" in which users pay a sum of money while returning their WEEE to the traders.[17]

The next stage of the 'green' framework after the collection of WEEE is the primary operation in which pre-sorting and segregation of electronic junk takes place. In this operation, the main purpose is to sort out such non-functioned products that can be reused after putting maintenance or repair. The re-cycled or repaired products, then are send to re-use and rest is forwarded to the secondary operation.

In the stage of secondary operation, the first step is to dismantle the junk products into components and then separate it into different categories. Many of the recycling plants are based on manual separation and disassembly and it is another main cost entity in any recycling organization.[18]The different electronics components and devices can be separated in a mechanical step into various fractions such as metals (iron, copper, aluminium etc.), plastics, ceramics, paper, wood and devices such as capacitors, batteries, picture tubes, LCDs, printed circuit boards etc.[19]These separated segments can next be treated through maintenance and repair after which it can go to the step of components assembling through which can be used in fresh products.

The next stage again goes with sorting the junk disassembled components. This manual or automated sorting

involves the removal of hazardous items like batteries and other components prohibited by the WEEE Directive, or the sorting into categories like low and high grade material.[18]The toxic or hazardous components can be treated explicitly by the toxic waste treatment plant and non-toxic components can then be processed so as it can be forwarded for land filling or incineration. This category consists of mechanical processes such as physical impaction, fragmentation/shredding and granulation.[18]After going through the processes of size reduction, the left-over can be treated through the modes of solid waste handling.

The 'green' framework for WEEE handling suggest the 3-tier sorting approach in which at the first two sorting steps the reusable products or components can be taken back into the main stream of utilization and in the last sorting step the toxic waste and non-toxic waste are categorised so as can be treated accurately. This approach can not only improve and increase the recycling of e-waste but also can give an edge to environment by proper dismissal of hazardous waste. Various WtE processes, including landfill and incineration, ultimately operate all the discarded constituents of e-waste produced, that not only helps in environment control but also utilize all the waste generated.

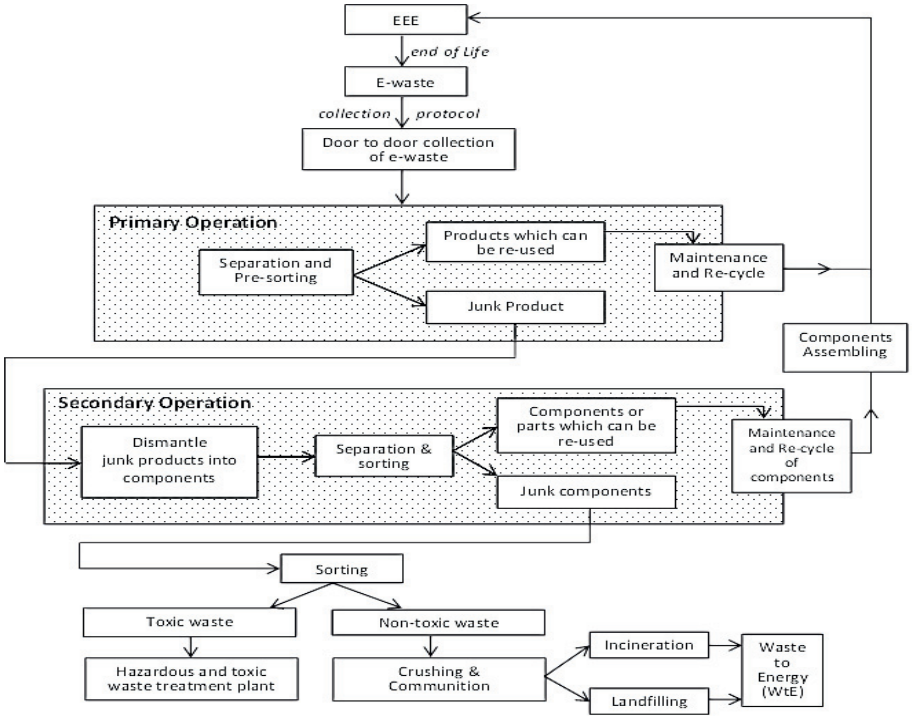

Fig. 4. A 'green' framework for WEEE handling

3.1 Extended Producer Responsibility (EPR): Obligation for environment care

In support to the 'green' framework for WEEE handling, EPR plays the most important role in e-waste management. EPR necessitates producers of electric and electronic equipment to take back and recycle their products once reaching the end of their life.[16]The main concept is that the responsibility and costs of managing, recycling, and disposing of a particular product is to be borne by the producer of that product, rather than society.[5]

As per OECD 2001, EU legislation has proposed the types of EPR approach, provided in table 2, which should be practiced by producers as their social responsibility.

In general, the main roles under EPR can be defined as A). Development of EEE with a 'green' approach and restricted use of components those are hazardous to environment. B). Collection of products after their end-of-life as a take-back process. C). Recycling and re-utilizing of used up products in order to control the generation of e-waste. With proper management of all three above roles of EPR, a good contribution in WEEE control can be achieved.

Table 2. Approaches of EPR[9,20]

Type of EPR approach	Examples
Product take-back programs	• Mandatory take-back • Voluntary or negotiated take-back programs
Regulatory approaches	• Minimum product standards • Prohibitions of certain hazardous materials or products. • Mandated recycling • Disposal bans
Voluntary industry practices	• Voluntary codes of practice • Public/private partnerships • Leasing and "servicizing" • Labelling
Economic instruments	• Deposit–refund schemes • Advance recycling fees • Fees on disposal • Material taxes/ Subsidies

3.1.1 Green Manufacturing

Green manufacturing is an extended producer responsibility, which broadly refers to development of products with the idea that it will not be a threat to environment after its end-of-life state. Anthony A. Austin, in his article '*Where Will All the Waste Go?: Utilizing Extended Producer Responsibility Framework Laws to Achieve Zero Waste',* states that zero waste can be achieved through complete diversion of municipal solid waste (MSW) from landfills and incinerators, resource conversion, and sustainable product redesign.[5] Green manufacturing concern over development of sustainable products by enhancing the quality of the product along with restricting the use of hazardous components. EU Directive 2002/95/EC, the RoHS (Restrictions on Hazardous Substances) Directive, restricts the use of hazardous substances in EEE. Further, EU Directive 2002/96/EC on WEEE comprises provisions that encourage the design and production of electric and electronic equipment that will support disassembling and recovery, specifically the reutilizing and recycling of electronic equipment.[8,5]The approach of green manufacturing follows following aspects:

- *Lean Design*: It refers to the process of development of components with the approach of systematically reduction of non-value added resources. Lean manufacturing can also decrease the cost associated with applying an Environmental Management System, and thus enhance an organization's environmental performance.[21]
- *Quality Control*: Quality control techniques like Six Sigma give a solution for sustainable product development with longer product life-cycle. Six-Sigma is considered a green manufacturing tool as it remove process variations which leads to lesser defects, reduced waste, less inputs required, and fewer energy is expended.[22]
- R*estrictions on Hazardous Substances:* Limiting and restricting the use of hazardous and toxic substances in EEE manufacturing supports easy handling of WEEE with environment care.
- *Multi-purpose Design:* Multi-purpose manufacturing of electric and electronic equipment limits the number of devices put in market leading to reduced e-waste generation. As an example, now days many of the cell-phone companies are manufacturing mobile chargers that are compatible with cell phones of other companies and models. Such type of green manufacturing initiative can reduce the number of devices ultimately limiting the generation of e-waste up to a significant level.
- *'Green Manual':* Green manual is a new term, which comes from user-manual, that associates with guidance to user about handling of devices after its end-of-life. As per fig. 3. , a survey on understanding about e-waste handling, a number of people are not much aware about proper handling of their EEE when it goes obsolete. In the survey, most of the individuals have shown the need of proper protocol and policies that should come along with the equipment which guide the end-user about what to do with the product when it will become a scrap. The 'green manual' that will come from the producer with the product may contain the take-back policies, information of all the constituents and materials used, list of hazardous components and contact details and procedures for e-waste handling.

4. Conclusion

The raising percentage of WEEE in solid waste and the effect of hazardous and toxic components, used in EEE, over environment is a real challenge against the world to sort out. The need is to come up with specific global strategies to limit the generation of WEEE and ensuring management and re-cycling of e-waste properly.

With raising concerns of environmental effects of hazardous e-waste components, people are also getting aware of the issue and are demanding the eco-friendly products from the producers. This, along with restrictions of use of hazardous components in many countries, the need of green manufacturing is arising with each days passing. Under the extended producer responsibility, the approach of green manufacturing, sustainable product development, creating awareness in people through initiatives like 'green manual', and eco-friendly recycling approach, collectively, can give a suitable solution for e-waste management.

With collective efforts and awareness, the world can achieve the ideal target of hundred per cent recycling of WEEE and zero threat to environment from e-waste.

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