E-WASTE MANAGEMENT IN THE WORLD

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ABSTRACT

Electrical waste can be defined as discarded computers, office electrical equipment, entertainment device electronics, mobiles, televisions and refrigerators. This includes used electronics that are meant for reuse, resale, recycling, or discarding or scrapping. Because loads of surplus electronics are frequently commingled or mixed (good, recyclable, and non-recyclable), several public policy advocates to apply the term "electronic waste" broadly to all surplus electronics.

E-waste is an emerging and fast-growing waste with complex characteristics. Its increasing amount has posed a significant challenge to waste management in developed as well as developing countries.
Its toxic emissions mixed with soil and air are causing harmful effects to the entire biosphere either directly or indirectly. Release of acids, toxic compounds including heavy metals, carcinogenic chemicals are the examples of direct impacts and bio magnification of heavy metals is an example of indirect impact. Some of the factors contributing to the growing amount of electronic waste are rapid technology innovation and ever-shortening product life spans. The collection and state-of-the-art treatment of the electronic waste is limited. Moreover, most nations are still without such electronic waste management systems. Global trading of electronics and substandard recycling in developing countries has led to environmental disasters in places like Guiyu, China and Ghana.
The resource potential of recyclable materials, called the “urban mine”, is estimated on the basis of the global quantity of electronic waste. The content of hazardous materials, called the “toxic mine” is similarly estimated. These figures are used by recycling industries for planning the location, capacity and technologies for recycling the E-waste.

Rapid changes in technology, changes in media (tapes, software, MP3), falling prices, and planned obsolescence have resulted in a fast-growing surplus of electrical waste all around the world. This article presents a summary of the problem and suggests a few concrete solutions for tackling the issue.
Moreover, the current and the future production of electronic waste and the potential environmental problems associated with their discarding or scrapping and management practices have been discussed.

KEYWORDS - E-waste, media, electronics, computer, toxic emissions, environment, technologies, recycling, discarding, scrapping, waste management, Incineration, landfills, reuse, export, import

1. INTRODUCTION

Industrial revolution followed by the advances in information technology during the last century has completely changed our lifestyle. Electrical industry is the worlds largest and the most innovative industry and is continuously growing exponentially but the lifespan of the produced products is becoming shorter and shorter. Mobile Phones, Computers, Telecom, Televisions, Calculators, Scanners, Printers, Air Conditioners, Microwaves, Washing Machines, Automobiles, Sensors, Compact Disks, Security Devices etc. are some of the common Electrical appliances being used.

Every year tons of electrical appliances are shipped over oceans, however, after their life is over these items become a complex waste matter consisting of many hazardous heavy metals, acids, toxic chemicals and non-degradable plastics. Many of them are dumped, burnt or exported to recycle and reprocessed. However, about 75% of electronic wastes are uncertain for their use or finding ways to use them which includes refurbishment, remanufacture and reusing their parts for repair etc.

Table 1. Summary of electronic waste definitions by various organisations.

European Directive 2002/96/EC Waste electrical or electrical equipment, including all components, subassemblies and consumables that are a part of the product at the time of discarding. The Directive 75/442/EEC, Article I (a), defines as "waste" "any substance or object which the holder discards or which is required to discard in compliance with the national Legislative provisions".
Basel Action Network (www.ban.org) "E-waste includes a wide and developing range of electronics ranging from large household appliances, like refrigerators, air-conditioners, mobile phones, stereo systems and consumable electrical appliances to computers discarded by their users".
OECOMPACT DISKS (www.oeCompact Disks.org) "Any household appliance consuming electricity and reaching end of its life cycle".

E-waste differs chemically and physically from urban or industrial waste. It contains both dangerous as well as valuable materials requiring special treatment and recycling practices to avoid adverse environmental impacts and harmful impacts on the mankind health. High labour cost and strict environmental legislation have consolidated implementation of these activities mostly in Asian countries like China and India.

Television and computer monitors are normally made of hazardous materials like lead, mercury, and cadmium, while nickel and zinc can often be found in the circuit boards. Presence of these substances makes recycling and discarding or scrapping of electronic waste an important issue. While, others are complete junks that occupy usable space at houses, apartments, firms and industries. Dismantling process takes a lot of labour, in countries like China and in some parts of India. The smoke and dust particle consists of carcinogens and other hazardous chemicals that cause severe inflammations and lesions including many respiratory and skin diseases.

Poverty is one of the main reasons for third world countries to consume electronic wastes from Europe and USA. As more electronic waste is placed in landfills, exposure to environmental toxins is likely to increase that result in higher risks of cancer and development of neurological disorders.
The short lifespan of most electrical products i.e. less than two years for computers and cell phones is a major driver of the growing electronic waste problem. The need to adopt a more sustainable approach concerning our consumption habits is highly significant. This trend regards industrial sectors affecting the consumption habits and, especially, electrical industry where the short life cycles and the rapidly developing technology have led to increased volumes of electronic waste.

2. METHODOLOGY

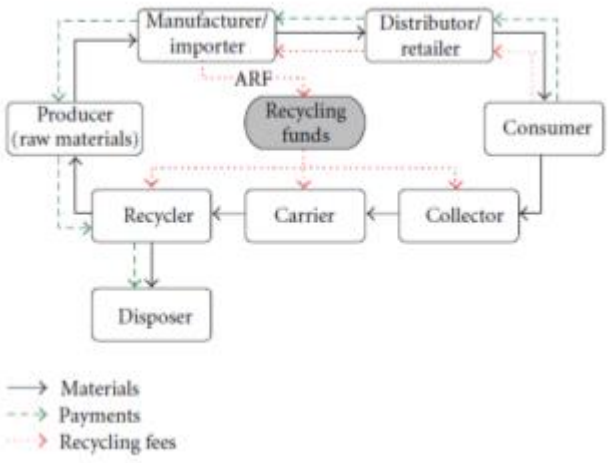
Some of the most successful examples of electronic waste management systems can be found in countries like Switzerland and the Netherlands (in detail in section 3.4.4)

2.1 In Switzerland particularly,

2.1.1 For optimizing the closed loop of material flow, raw materials are first converted into EEE products by manufacturers, then after going through retail and consumption, end-of-life products are collected and recycle and reprocessed to produce new goods. Besides recycling, other materials which cannot be recycle and reprocessd go to incineration for energy recovery, and a small portion (approximately 2%) goes to landfills.

2.1.2 Producer Responsibility Organizations (PROs), like SWICO and SENS, collect Advanced Recycling Fees (ARF) from producers on their sale or import of an appliance. Then, ARF are passed down to retailers who invoice consumers for their purchase of new appliances. This ARF is used to pay for the whole electronic waste recycling system, including collection, distribution, dismantling, sorting, decontamination, and recycling of the disposed EEE products.

Fig 1
Flow of E-Waste in Swiss E-Waste Management System



2.2 Methodology prevalent in Developing Nations

2.2.1 Most countries in Africa lack legislative mechanisms to tackle the problem of e-Waste and have not yet recognized it as a hazardous waste stream. However, several pilot projects have been initiated in Africa to show that recycling can provide both employment opportunities for local communities and act as a step towards a sustainable solution for tackling e-Waste.

2.2.2 A pilot project in Cape Town initiated by HP processed 60 metric tons of electrical equipment in 10 months in 2008, generating an income of about $14,000 and creating direct employment for 19 people. This project also tried incorporating informal processing activities that proved highly effective in dealing with waste. This team is expected to launch the second phase of this project, to engage corporate and government partners to further extend electronic waste management programs to other countries and to tackle the problem in the entire continent.

2.3 ***Conventionally, E-Waste all across the globe is dealt with via the following methodologies –***

2.3.1 ***Landfill****:* More than 4.6 million tons of e-Waste ended up in landfills in 2009. Toxic chemicals in electronics products can leach into the land over time or be released into the atmosphere, impacting nearby communities and the environment.

2.3.2 ***Incineration*** *(Discussed in Section 3.5)*

2.3.3 ***Reuse:*** This is a good way to increase a product's lifespan. Many old products are exported to developing counties. Although the benefits of reusing electronics in this way are clear, the practice is causing serious problems because the old products are dumped after a short period of use in areas that are unlikely to have hazardous waste facilities.

2.3.4 ***Recycle:*** Although recycling can be a good way to reuse the raw materials in a product, the hazardous chemicals in e-Waste mean that electronics can harm workers in the recycling yards, as well as their neighbouring communities and the environment.

2.3.5 ***Export****:* E-Waste is routinely exported by developed countries, often in violation of the international law. Inspections of 18 European seaports in 2005 found that as much as 47 percent of waste destined for export, including e-Waste, was illegal. At least 23,000 metric tons of undeclared or "grey" market electronic waste was illegally shipped in 2003 to the Far East, India, Africa, and China. In the USA, it is estimated that 50–80 percent of the waste collected for recycling is being exported in this way.

3. RESULTS AND DISCUSSIONS

3.1. Sources of E-Waste

Almost every used electrical appliances is considered as electronic waste like discarded cell phones, cameras, COMPACT DISKS players, TVs, radios, drillers, fax machines, photocopiers, printers, toners, ink cartridges, batteries, re-chargeable, CRT monitors, electric solders, computer mother boards, key board, industrial and house hold electrical machinery like oven, fridge, sewing& washing

machines, fan, air-conditioner, grinder, iron, heater, military and laboratory electrical equipment's, etc.

3.2. Current Situation

2014 saw a record amount of electrical waste discarded across the world, according to a report compiled by the UN University. 41.8 million tons of refrigerators, televisions, washing machines, vacuum cleaners and other electrical appliances were thrown away, up from 39.8 million in 2013. Last year's mountain of electronic waste is equivalent to 1.15 million heavy trucks forming a line 14,300 miles long, according to the report.

Waste that could have been recovered for recycling contained an estimated 16,500 kilotons of iron, 1,900 kilotons of copper and 300 tons of gold, worth $52 billion. The United States and China generated the most electronic waste last year - 32 percent of the world's total. However, on a per capita basis, several countries famed for their environmental awareness and recycling records lead the way.

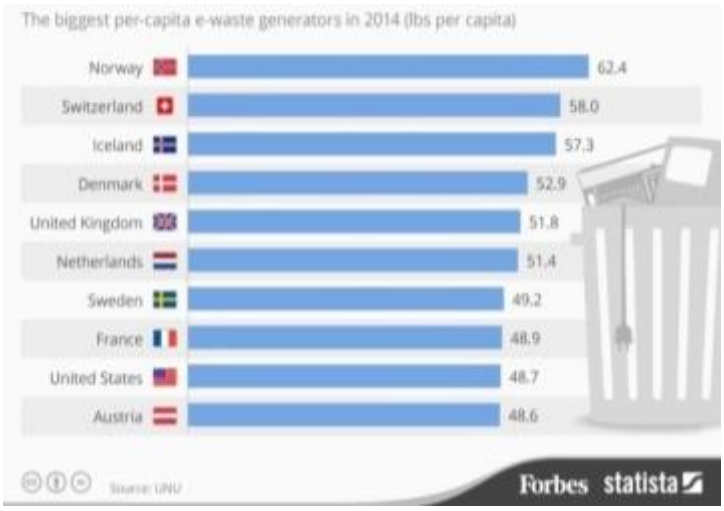
Norway is on top of the world's electrical waste mountain, generating 62.4 lbs per inhabitant. Switzerland is in second position with 58lbs, while Iceland rounds off the top three with 57.3lbs. The United Kingdom comes in fifth with electronic waste per capita amounting to 51.8lbs while the United States is in ninth position with 48.6 lbs.

Each electrical appliances' participation in the annual electronic waste production, E (kg/year), depends on each electrical appliances' mass, M (kg), its quantity (number) in the market and consumption, N, and its average life cycle, L (year).

$E = MN/L$

Electrical computers with an average 3-year life cycle contribute to a greater extent to the total electronic waste flow compared to refrigerators and electrical cook-stoves, having an average life cycle of 10-12 years.

Fig 2: The World's Worst Electronic Waste Offenders



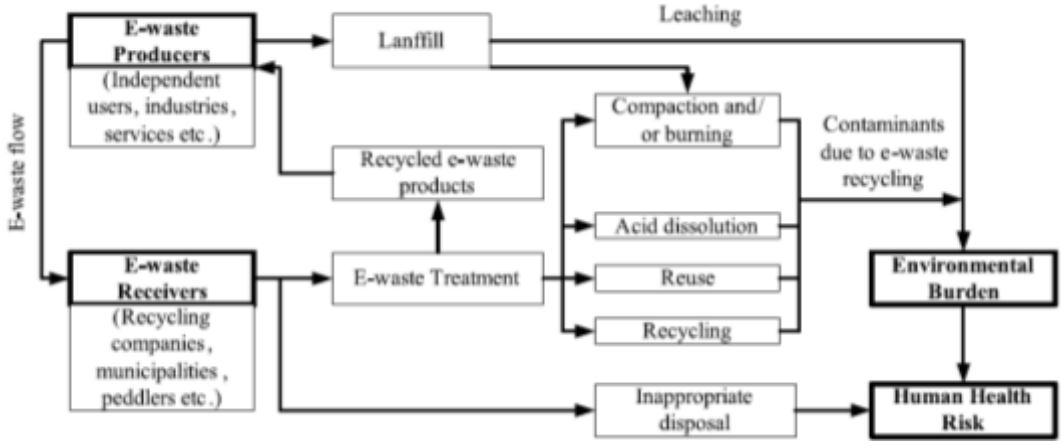
Source - UNU

3.3. Harmful Particles in E-Waste

Phthalates includes PVC in wire coverings and cables, di (2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP), Butylbenzyl phthalate (BBP), DIDP (diisodecyl phthalate) and dibutyl phthalate (DBP) (Otake *et al*. 2001, Butte & Heinzow 2002, Fromme *et al*. 2004).

Heavy metals includes Lead, which is used in electrical solder, batteries, commonly used as alloy with tin, in cathode ray tube lead oxide is used in the glass, used as stabilisers in formulation of PVC. Cadmium compounds are used in switches, solder joints, in batteries that can be recharged, as stabilisers in formulation of PVC (Matthews 1996), Cadmium sulphide are used in interior surface of the CRT screens to produce illumination (Burstall 1997). Antimony is used in semiconductors, flame retardant formulations in plastics (Lau *et al*.2001), also used in lead acid starter batteries and electrical solders (Kentner *et al*. 1995). Air of the electronic waste combusting region may have oxides of these harmful metals. Mercury is used in printed circuit boards, relays and switches, chromium is used as anti corrosive agent in galvanized steel parts, Barium is found in CRT monitors, Beryllium is commonly found in circuit mother boards. Free Carbon (C) radicals obtained from toners of printers is also a form of electronic waste.

Fig 3: Harmful Effects of E-Waste



Source - *G. Gaidajis K. Et al. (2010): Journal of Engineering Science and Technology Review PP. 193-199*

3.4. Country-Wise Overview

3.4.1 India

About 80,000 people working for recycling sector, some villages such as Seelampur has scrap markets where piles of e- wastes are separated for recycling. They separate copper from wires after burning them. Plastic and PVC codes produce noxious smoke which is irritable to eyes and cause respiratory problems. In addition, acid treatment is given to isolate metals; corrosive acids also released from used batteries of cell phones and computers, according to scientists of Greenpeace recycling of a computer in India costs just 2$ while it is 20$ in US. Not only cheap labour but also for the profit from recovered metals of circuit boards such as copper gives earning of 3 to

5 $ per day workers are spending on dismantling e-wastes rather considering their own health. Major issues related to Indian scenario are:

- India's hospitals witness patients with 10 times the expected level of lead in their blood.
- In India, a water sample revealed levels of lead 190 times as high as the drinking water standard set by the World Health Organization.
- Thousands of children throughout the India are attending schools that were built on or near toxic waste sites, with increased risk of developing asthma, cancer, learning disorders and other diseases linked to environmental pollutants.
- Preliminary estimates suggest that total WEEE generation in India is approximately 1, 46,000 tonnes per year.
- About 70% of the heavy metals (mercury and cadmium) and 40% lead, in landfills in India come from electronic waste 22% of the yearly world consumption of mercury is used in electronics manufacture
- More of acid content flow into the land contaminating the soil and land value.
- About 70 percent, of heavy metals in India landfills comes from E-Waste.

3.4.2 Ghana, Africa

About 4 million tons of wastes are brought to Ghana from Antwerp and other parts of western world.
Government of Ghana has signed all international treaties but entry of electronic waste is still there as the population of Ghana cannot afford to purchase new electrical goods due to poverty. And slum children and young men are used as collectors and dismantlers for cheap labour. E-wastes includes camera, computers, TVs, refrigerators, drillers and many used electrical appliances. These wastes are sold for cheap price but there is no warranty for its usage, while unusable items are burned and dumped there. The river has now become a dark muddy stream rich in heavy metal wastes. Fisher men have almost lost their hopes and catch contains heavy metals which can cause long-term impact to the population.

3.4.3 City of Guiyu, China

Guiyu was a peaceful paddy harvesting village in early days, but now it has become a junk yard of much of the electrical discards. Extraction of steel, Aluminium, plastic and Gold occurs in every corner of the village; about hundred thousand of its people are engaged with dismantling electrical appliances. After collecting the metals the inhabitants simply burn the rest, the hazardous smoke spreads and causing variety of respiratory and skin diseases.
Now the surface and well waters of Guiyu has become undrinkable, according to Basel Action Network the content of lead in river Linjaing of Guiyu is between 1.9-24mg/ L whereas the WHO border line is 0.01 mg/ L. Thus the population there have to take water from 30 km away. Open dumping of plastic, and release of dioxins, hydrocarbons and toxic brominated compounds to the soil is a common hazard, In addition circuit boards are burnt which releases fumes consisting toxic lead, tin and mercury, and toxic irritant isocyanides. It was reported that water and soil consist of very high levels of lead.

3.4.4. E-Waste Management in Switzerland

The Swiss e-Waste management system can be viewed as an ERP-based system, where each stakeholder has their own clear definition of role and responsibilities as shown in table 3.1. As shown in Figure 2.1, the solid black line indicates the material flow in the e-Waste management system. In order to optimize the closed loop of material flow, raw materials are first converted into EEE products by manufacturers, then end-of-life products after going through retail and consumption are collected and recycled to produce new goods. Besides recycling, other materials which cannot be recycled go to incineration for energy recovery, and a small portion goes to landfill, approximately 2%. Payments as well as recycling fees, shown as green and red lines, respectively, indicate financial flow of the

system. Producer responsibility Organizations (PROs), such as SWICO and SENS, collect advanced recycling fees (ARF) from producers on their sale or import of an appliance. Then, ARF are passed down to retailers or distributors who invoice consumers for their purchase of new appliance. This ARF is used to pay for the whole e-Waste recycling system, including collection, distribution, dismantling, sorting, decontamination, and recycling of the disposed EEE products.

Table 2: ERP Based system in Swiss E-waste Management system

Stakeholders	Roles & Responsibilities
Federal government	The federal government oversees the whole process and initiates basic guidelines and regulations.
Manufacturers/importers	Manufacturers have the physical responsibilities of managing daily operation of the system.
Distributors/retailers	Retailers are also part of the physical responsibility of the EEE products besides manufactures.
Consumers	Consumers are responsible for returning discarded EEE to retailers or collectors
Collector (collection points)	Collection locations collect all kinds of WEEE free of charge, and are responsible for the safety of the disposed products to prevent illegal exports.
Recyclers	Administration from government is required to operate a recycling facility. Recyclers must follow Minimum standards on emissions and concern employee' health.

3.5 Incineration

Incineration also includes pyrolysis; substances generated during incineration are likely to be more toxic than its ordinary form, pyrolysis is heating the substance in the absence of oxygen, here the burning does not occur but the substances are converted to fumes, oils and charcoal. However, in gasification limited air is given to convert the substances into fume, ash and tar. Incineration is a commonly used method of the dispersal of e- waste in China, Africa, India and Pakistan. Heating the plastic or PVC circuit board releases erotic fumes of Polycyclic aromatics (PCA), polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)which are also known as carcinogens. Smoke also consists of minor quantities of oxides of following heavy metal residues antimony, lead, thallium, arsenic, copper, manganese, mercury and nickel, reminder ended up in the ashes.

3.6 Safe Methods of Disposal of E-Waste

Most safe method is recycling materials including metals and reusing them, which includes industry wide system for the collection of electronic wastes. Implementing proper rules to make following as mandatory wearing protective masks and gloves and safety glass when dismantling and avoid easy methods of extraction like incineration (as discussed in section 3.5) which results harmful fumes, avoid dumping and avoid using acid baths, and implementing strict rules against dumping electronic wastes in landfills as it could leach out towards ground water or may be released after long time. Implementing proper storage system for collected and extracted electronic wastes until it is reused as products, strengthen the implementation of agreed legislations of Basel convention and implementing

potent laws to prevent political invasions or pressures. Take action against unapproved illegal electronic waste collectors and dismantlers, encourage research scientists in finding alternatives to hazardous chemicals and carcinogens, banning the electrical products with hazardous ingredients, monitoring the transportation of electronic wastes within the state municipal limits as well as ports and harbours. Consulting with manufactures electronic waste processors, environmental groups like NRDC, Basel Action Network (BAN) have created a certification system for recycling, refining and refurbishing companies known as e- Stewards. E-steward certification assures the recycle and reprocessers keep up the standards which allow the recycling process in a way that protects workers health and the environment. It is also important to educate the public on handling and discarding or scrapping of electronic waste through awareness programs.

4. CONCLUSIONS

Electrical equipment and therefore electronic waste are everywhere in our society. These items are characterized by a complex chemical composition and difficulty in quantifying their flows at a local and international level. The pollution caused by their irregular management substantially degraded the environment mostly in poorer countries, receiving them for recycling and recovery of their valuable metals. As for the consequences on ecosystems, mankind health and environmental restoration of areas burdened by certain polluters generated by electronic waste (e.g. Li and Sb), there are no sufficiently documented scientific studies.

4.1 Indicative Technological Changes

- The replacement of CRT screens with LCD screens (Lead elimination but mercury introduction),
- The introduction of optical fibres (Cu elimination from the cablings, but F, Lead, Y and Zr introduction),
- The introduction of rechargeable batteries (Ni, Compact Disks reduction, but Li increase), etc.

4.2. Elimination of Hazardous Material

- The production of “halogen-free” appliances, not contributing to the production of PCBs and dioxins (but their production is more expensive environmentally),
- The replacement of bromide combustion retarders with more environment-friendly ones based on phosphorus, and
- The introduction of legislative restrictions (Lead, mercury, Cr, PBBs and PBDE up to 1000 mg/kg, Directive RoHS – Restriction on Hazardous Substances).

4.3. E-Waste Management in Industry

Even though some successful stories of e-Waste system currently exist, but several challenges still remain including:

- How to balance the harmonization between manufacturers and recyclers with respect to finance, operations, technologies, and so forth,
- How to deal with different business models of stakeholders from various industries,
- How to determine the amount of policy in law, leaving others to be industrial standards,
- How to ensure that obligations are met by the stakeholders.

4.3 Suggestive Measures to the Government & International Organisations

- Ban on total imports of e- waste.
- The Framework should address the issue of E waste imports for reuse and recycling.
- Creating lucrative investment options for E-Waste Management options.
- Link up activities of informal sector with formal sector
- Promote adequate ESM technologies for recycling
- Incorporate precautionary principles and polluter pays
- Adopt Consultative processes
- Promote recycling units to ease process and to encourage generators to have proper electronic waste discarding or scrapping
- Impart training to generators on electronic waste handling.
- Awareness program on recycling
- Tax incentives for scrap dealers
- Reward and reprimand schemes for performance and non-compliance of electronic waste management
- To make recycling business viable one
- Encroach legal import of electronic waste
- Should subsidize recycling and discarding or scrapping industry
- Incentive schemes for garbage collectors.
- Disposal fee from manufacturers and consumers

4.5 Healthy Consumer Practises

- Buy products made with fewer toxic constituents
- Go for recycled and reprocessed content whenever possible
- Use technology that is energy efficient
- Use products designed for easy upgrading or disassembly
- Opt for items minimal packaging
- Opt for upgrading the computers or other electrical appliances to the latest versions rather than buying new equipments.

Some of the organizations helping the cause are:

www.mineralpolicy.org, www.mpi.org.au,
www.USGS.gov, www.moles.org, www.ban.org,
www.copper.org, www.antigraymarket.org, other links
www.retroworks.com

Our Initiative:

The management system has to be rationally designed so that the environmental benefits from the collection, transportation, management and the financial benefits from the recovery are not set-off by the required resources and energy consumptions for the system operation.

Our Android Application: ***E-Waste Management***

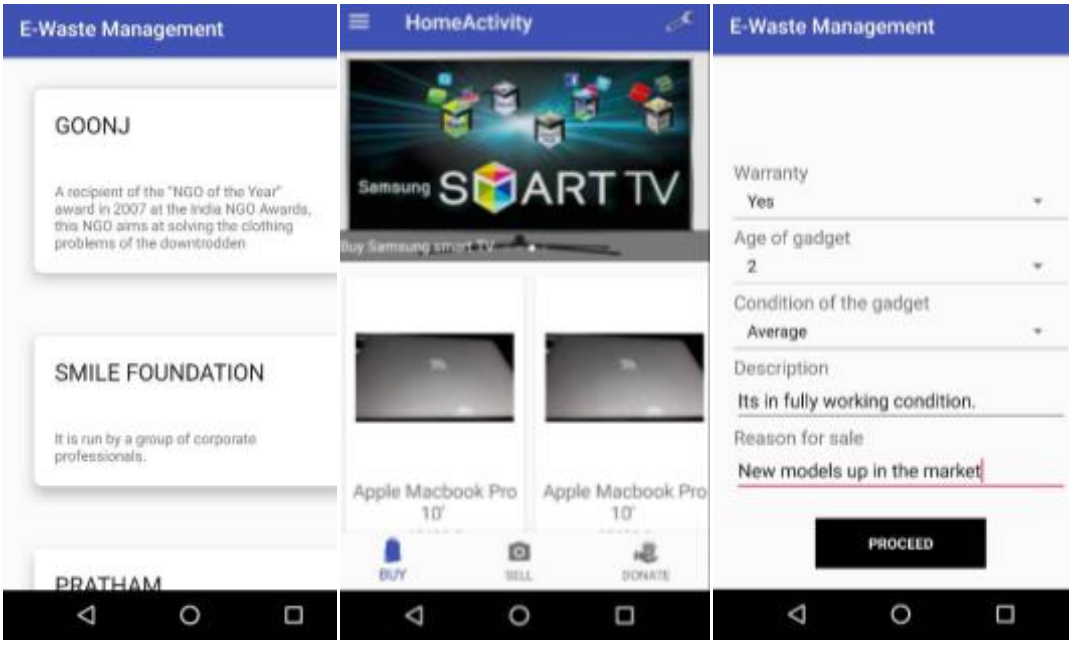
We have also made a basic application which will help in managing E-waste.

What our app offers?

1. It provides user friendly medium to sell and purchase E-Waste online.
2. It has the feature to decide the selling price on the basis of the condition of the product.
3. It also has the feature of donating items to the NGOs free of cost.

This app is still under development because it requires monetary aid for full functionality.

Fig. 4: Glimpse of E-Waste Management App



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