THE ECONOMICS OF AN E-WASTE MANAGEMENT PLANT

Project report submitted in partial fulfilment
of the requirements for the degree of

Bachelor of Technology
in
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by
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ABSTRACT

This project is to understand the economics of an E-Waste management plant, their profitability and the hazards related to the accumulation. The special focus is kept on reusing of the waste and then on recycling. The commencement of the Industrial Era has led to a boom in Electronics department and henceforth a lot of waste which raises a cause of concern because of the harmful effects on the community.

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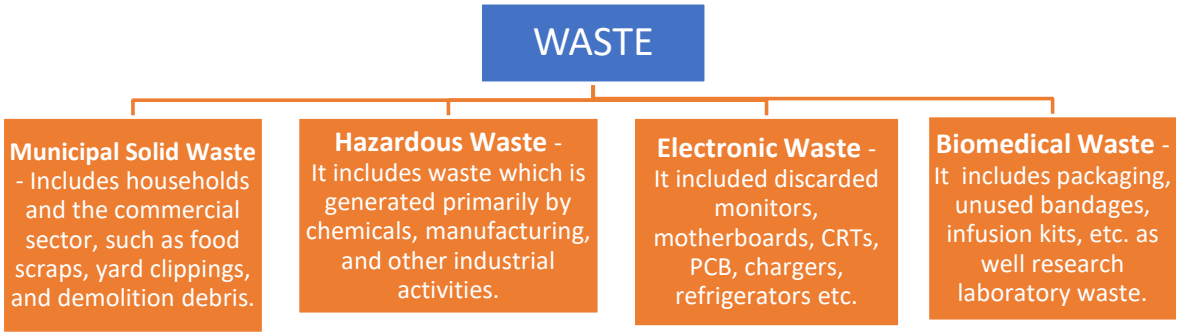
INTRODUCTION

1.1 Waste

'Waste' is simply defined as something that is no longer deemed useful and is discarded. Waste is classified into broad categories, namely - Municipal solid waste (MSW), hazardous waste, biomedical waste, and electronic waste (E-Waste).



1.2 E- Waste

1.2.1 Definition and Classification:

It can be broadly defined as 'any device connected to a power source that no longer satisfies the current owner to the purpose of which it was created'. It comprises of various components which change depending on the region as according to European Union anything which has a circuit is Electronic Waste and according to American norms White Goods (Refrigerator, Washing Machine, Microwave etc.) are not included into E-Waste.

Electronics and Electrical Industry is the World's fastest growing Industry. The new electric and electronic equipment have engulfed all aspects of our daily life providing us with more comfort, health and security. The technological boom has assisted different opportunities to human being like trade, commerce, education, health, welfare institutions and households using electronics as their medium. The increasing affordability and the replacement rate with the speed of technology has also increased. Innovations offer more features, compact size and futuristic design in the market. Given the time lag between the purchase of the product and its end of life means that products purchased a while ago are being discarded now. Most of the products are either out of service or new features have rolled out. The old products are either discarded or either used by other people.

Reference	Definition
EU WEEE Directive	Electrical or electronic equipment which is waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding. Some define "waste" as any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force. [1]
Basel Action Network OECD	E-Waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users.
SINHA	"Any appliance using an electric power supply that has reached its end-of-life."
StEP	"An electrically powered appliance that no longer satisfies the current owner for its original purpose." [2]
	E-Waste refers to "the reverse supply chain which collects products no longer desired by a given consumer and refurbishes for other consumers, recycles, or otherwise processes wastes."

[3]

1.2.2 Statistics:

There are varying estimates as to the amount of domestic, regional, and global E-Waste produced. For instance, between 1993 and 2000 in India, the growth of personal computers was 604%, compared to the world average of 181% [4]. The United Nations Environmental Program (UNEP) approximated that the amount of E-Waste produced in 2012 is enough to fill 100 Empire State buildings and averages to more than 6.8 kg for every living person. In 2012 alone, China reportedly generated 11.1 million tons of E-Waste and the United States produced 10 million tons. This means, on average, each American generates 29.5 kg of E-Waste compared with the less than 5 kg per person in China [5]. In India, there are 178 dismantling/recycling units with a capacity of 441085.6 metric tonnes per annum. In Karnataka there are 57 recycling/dismantling facilities but recycle only 44620.5 MT of waste, while Uttar Pradesh just has 22 facilities with capacity of 86130 MT combined[6]. The State-wise detail of installed recycling/dismantling facilities operating in the country is:

Sl. No.	State	Number of registered Dismantler and Recycler	Registered Capacity in tonne per Annum
1.	Chhattisgarh	2	1650.0
2.	Gujarat	12	37262.12
3.	Haryana	16	49981.0
4.	Karnataka	57	44620.5
5.	Madhya Pradesh	3	8985.0
6.	Maharashtra	32	47810.0
7.	Odisha	1	3000.0
8.	Punjab	1	150.0
9.	Rajasthan	10	68670.0
10.	Tamil Nadu	14	52427.0
11.	Telangana	4	11800.0
12.	Uttar Pradesh	22	86130.0
13.	Uttarakhand	3	28000.0
14.	West Bengal	1	600.0
	Total	**178**	**441085.6**

Source: http://pib.nic.in/newsite/PrintRelease.aspx?relid=159975#

1.2.3 Components and Composition:

E-Waste comprises of computer and its accessories, monitors, printers, keyboards, central processing units, typewriters, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators and other household appliances. The composition of E-Waste is diverse and falls under "Hazardous" and "Non-Hazardous" categories. Moreover, it consists of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items. Computer equipment account for almost 70 per cent of E-Waste, followed by telecommunication equipment-phones (12 per cent), electrical equipment (8 per cent) and medical equipment (7 per cent) with remaining from household E-Waste [7]. Iron and steel constitute about 50% of the waste, followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals like silver, gold, platinum, palladium and so on. The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants beyond threshold quantities make E-Waste hazardous in nature[8]. It contains over 1000 different substances, many of which are toxic, and creates serious pollution upon disposal. Obsolete computers pose the most significant environmental and health hazard among the E-Wastes.

As per the European Council the E-Waste is classified into the following categories:

S. No	Category	% of total E-Waste	Sub-Categories
1.	Large household appliances Washing machines, dryers, refrigerators, air-conditioners etc.	**49%**	Large household appliances, Cooling and freezing, Smaller items.
2.	Small household appliances Vacuum cleaners, coffee machines, irons, toasters etc.	**7%**	--
3.	IT and telecom equipment PCs, Laptops, cell phones, telephones, fax machines, copiers, printers etc.	**16%**	IT and telecom. Equip, CRT monitors LCD monitors.
4.	Consumer electronics Televisions, VCR/DVD/CD Players, Hi-Fi sets, Radios, etc.	**21%**	Consumers electronics excl, CRT TV's 13.3. Flat Panel TV's. Luminaries**.** Lamps.
5.	Lighting equipment fluorescent tubes, sodium lamps etc. (Except: bulbs and halogen bulbs)	**2.4%**	--
6.	Electrical and electronic tools Drills, Electric saws, sewing Machines, lawn mower etc. (Except: large stationary tools/machines)	**3.5%**	--
7.	Toys, leisure and sports equipment Electric train sets, coin slot machines treadmills, etc.	**0.1**	--
8.	Medical devices	**0.1**	--
9.	Monitoring and control equipment	**0.2**	--
10.	Automatic dispensers	**0.2**	--

*Source:*https://www.researchgate.net/publication/269954517_E-Waste_characteristic_and_its_disposal

1.2.4 Foul Practices:

The practice of developed countries exporting E-Waste to developing countries has become traditional routine. High labour costs and draconian environmental regulations for precarious waste disposal in developed countries lays path for the exportation of E-Waste to less developed and less regulated countries. However, the shortcomings arise as developing countries lack the technology, facilities, and resources needed to properly recycle and disposal. Recyclers in developing countries that receive E-Waste from other countries frequently rely on rudimentary techniques to extract valuable materials from E-Waste: [5]

- It is physically dismantled by using conventional tools such as hammers, chisels, and screw drivers.
- PCBs are heated, and components are detached.
- Precious metals are recovered from the stripping of metals in open-pit acid baths.
- Plastics are chipped and melted without necessary and protective ventilation.
- Burning electrical cables, in open pits and at relatively low temperatures to retrieve copper is one of the most eminent crude recycling practices.

Persistant organic pollutants	Component of electrical and electornic	Ecological source of exposure	Route of exposure
Brominated flame retardants Polybrominated diphenyl ethers (PBDEs) Polybrominated biphenyls (PBBs)	Flame retardants for electronic equipment	Air, dust, food, water, and soil	Ingestion, inhalation, and transplacental
Polychlorinated biphenyls (PCBs)	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Air, dust, soil, and food (bio-accumulative in fish and seafood)	Ingestion, inhalation or dermal contact, and transplacental
Dioxins			
Polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs)	Released as combustion byproduct	Air, dust, soil, food, water, and vapour	Ingestion, inhalation, dermal contact, and transplacental
Dioxin-like polychlorinated biphenyls	Released as a combustion byproduct but also found in dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Released as combustion byproduct, air, dust, soil, and food (bioaccumulative in fish and seafood)	ngestion, inhalation, and dermal absorption
Polyaromatic hydrocarbons (PAHs)	Released as combustion byproduct	Released as combustion byproduct, air, dust, soil, and food	Ingestion, inhalation, and dermal contact
Elements			
Lead (Pb)	Printed circuit boards, cathode ray tubes (CRTs), light bulbs, televisions, solder, and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact
Chromium (Cr) or hexavalent chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion
Cadmium (Cd)	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Inhalation and ingestion
Mercury (Hg)	Thermostats, sensors, monitors, cells, printed circuit boards, cold cathode fluorescent lamps, and liquid crystal display (LCD) backlights	Air, vapour, water, soil, and food (bioaccumulative in fish)	Inhalation, ingestion, and dermal contact
Zinc (Zn)	Cathode ray tubes and metal coatings	Air, water, and soil	Ingestion and inhalation
Nickel (Ni)	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental
Lithium (Li)	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, and dermal contact
Barium (Ba)	Cathode ray tubesmand fluorescent lamps	Air, soil, water, and food	Ingestion, inhalation and dermal contact
Berylium (Be)	Power supply boxes, computers, x-ray machines, ceramic components of electronics	Air, food, and water	Inhalation, ingestion, and transplacental

Source: https://www.researchgate.net/publication/268821960_E-waste_A_global_hazard

These recycling approach emits large amounts of deadly dioxins, lead and acid fumes into the environment. Due to exposure, workers in the electronics industry have been suffering from severe illnesses. Recent reports tell of explosions and exposure to

n-hexane at the workplaces of raw material suppliers of electronic goods manufacturer[9]. In addition to this, continuous reports of occurrence of diseases such as malignant cancer[10] among the electronics workers are being reported across the world. In some instances, these diseases have been fatal. Electronics, therefore, pose hazards to workers from the beginning to the end of the product life cycle.

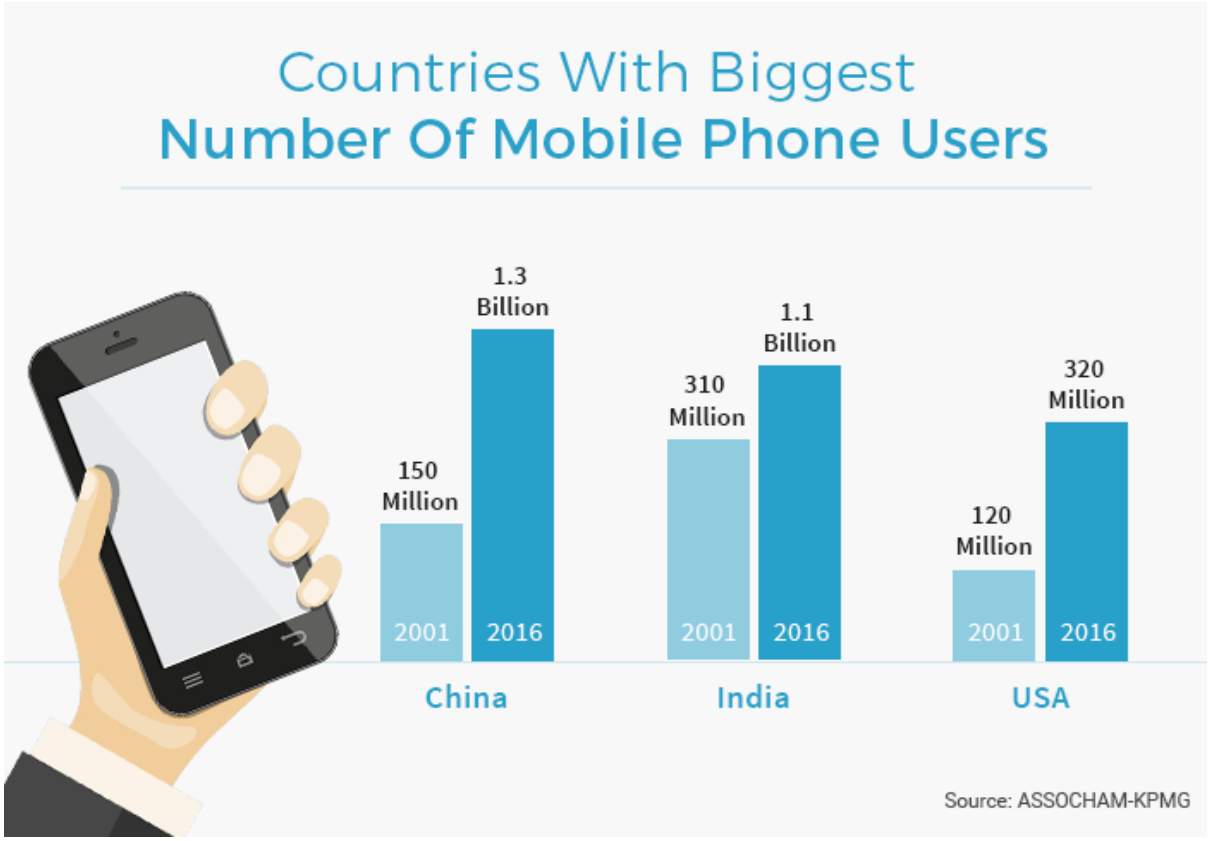
1.3 Facts and Figures

The EPA's E-Waste report shows that:

- USA got rid of 142,000 computers and over 416,000 mobile devices every day.
- In 2012, USA generated 3.412 million tons of E-Waste.
- Out of all produced, only 1 million tons or 29.2% was recycled.
- The rest was trashed in landfills or incinerators. [11]

1.3.1 Discarded Electronics Worldwide

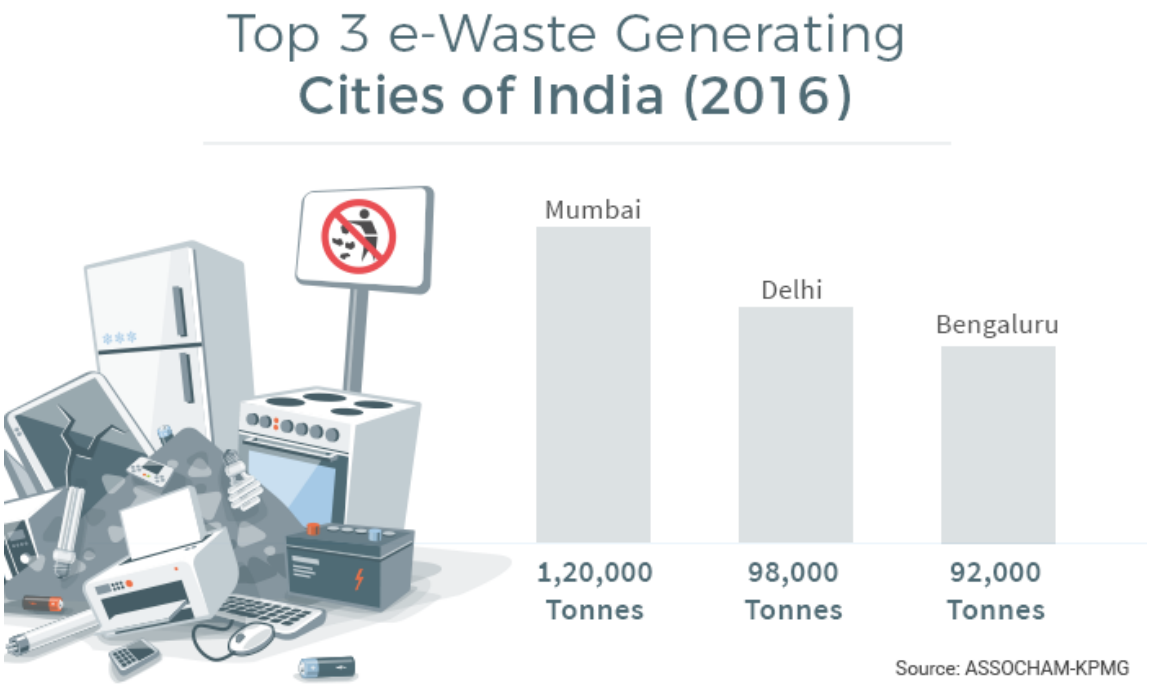
- Some 20 to 50 million metric tonnes of E-Waste are generated worldwide every year.
- When the millions of computers purchased around the world every year (183 million in 2004) become obsolete they leave behind lead, cadmium, mercury and other hazardous wastes.
- From 310 million mobile subscribers in 2001 to 1.1 billion in 2016.
- The number of mobile phone users in India is nearly 4 times that of United States today and is second only to China in the world, which has 1.3 billion subscribers.



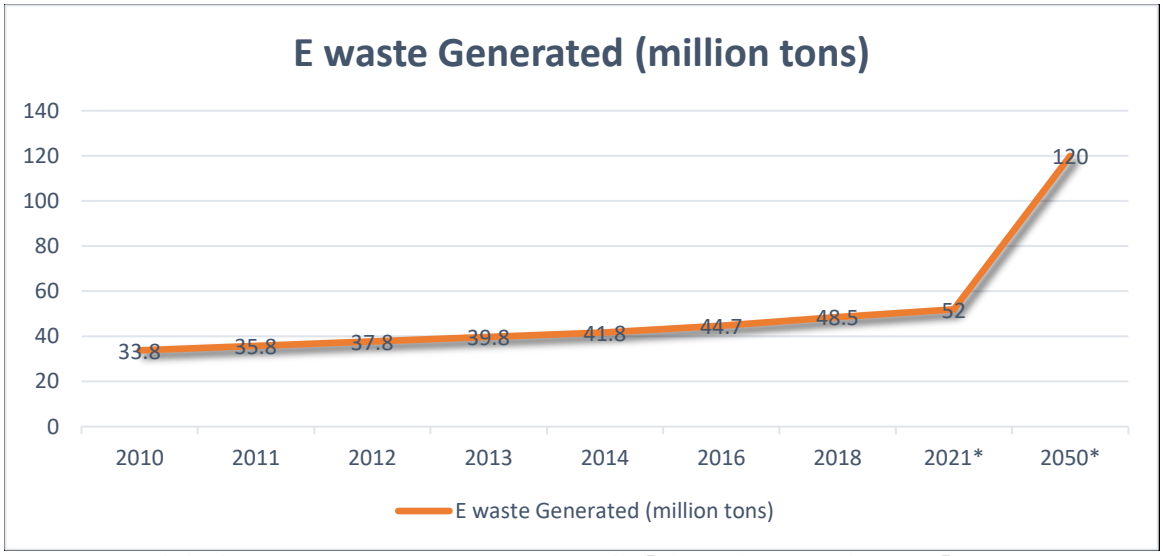
This was just mobile phones, other components include:

- There are 57 million computers in use and plethora of other gadgets and consumer electronics.
- India is now in the global list of highest electronic waste generators, posing grave threat to the environment and public alike.
- In 2016, India was ranked as the fifth largest generator of electronic waste in the world, with an estimated 1.85 million tonnes generated annually.
- Globally, the number is an astounding 40 to 50 million tonnes annually.
- India accounts for roughly 4 per cent of E-Waste generated annually.
- The United States ranked first in E-Waste generation, generating 11.7 million tonnes of E-Waste annually.
- China ranked second with 6.1 million tonnes of E-Waste every year.

- Computers contributed towards 70 per cent of the total E-Waste generated in India.
- Telecommunication equipment accounted for 12 per cent.
- Mumbai topped the list as it generated an estimated 1,20,000 tonnes of E-Waste annually.
- Delhi and Bengaluru ranked second and third, with 98,000 and 92,000 tonnes of E-Waste generation respectively.
- Approximately 70 per cent of heavy metals found in landfills are accounted for by E-Waste.
- Only 1.5% of E-Waste generated in India gets recycled.



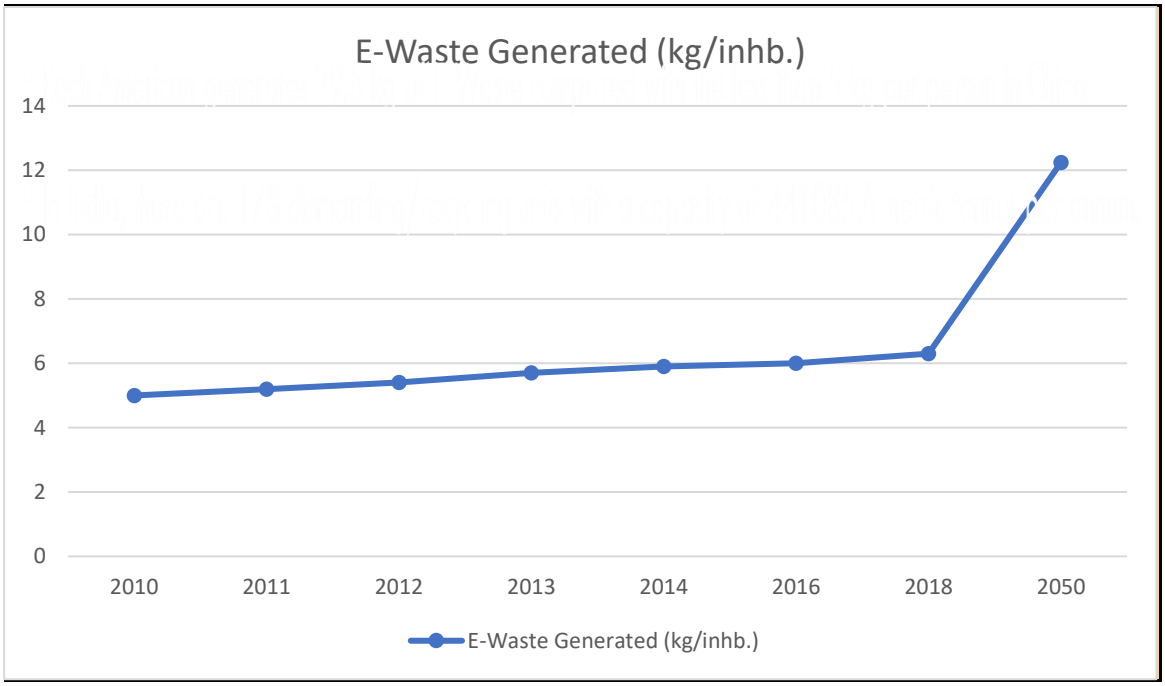
- World generated 48.5 million tonnes of E-Waste in 2018.
- E-Waste is only 2% of Solid Waste but brings in 70% hazardous metals.
- Carbon emissions account for 14% of total Greenhouse Gases.
- Only 20% of it is recycled. [30]



*(UNU-1stGlobal-E-Waste-Monitor-2014-small) [*based on predictions]*

- There is 100 times more gold in a tonne of smart phones than in a tonne of gold ore itself! But the precious metal is virtually thrown away due to poor recycling of E-Waste.
- Due to poor recycling standards mean that 80 per cent of the E-Waste lands in landfills globally, leading to loss of these precious metals.
- Up to 7% of the world's gold may currently be contained in E-Waste.

- The forecasts show that E-Waste's global worth $62.5 billion annually, which is more than the GDP of most countries! It's also worth three times the output of all the world's silver mines.
- A recycler in China already produces more cobalt (by recycling) than what the country mines in one year. [12]



1.4 International Steps:

EPA and India are also collaborating on global efforts to address electronic waste. India participates in the International E-Waste Management Network (IEMN), which enables environmental officials from around the world to directly exchange best practices related to E-Waste management. Through the IEMN, officials from India have participated in workshops on E-Waste management in the U.S. and Taiwan which enabled them to share experiences related to E-Waste management and learn from others across the region. [15]

1.4.1 International E-Waste Management Network (IEMN) –

According to the United Nations, the growing volume of electronic waste, including mobile phones, laptops, televisions, refrigerators and electrical toys, poses a major threat to the environment and human health. In 2016, only about 20 percent of all E-Waste globally was recycled. Certain components of electronic products contain materials that are hazardous when not disposed of correctly and can leach lead and other substances into soil and groundwater. Many of these products can be reused, refurbished, or recycled in an environmentally sound manner so that they are less harmful to the ecosystem and reduce the need to extract or manufacture virgin materials to fabricate new products. [14]

The United States Environmental Protection Agency (U.S. EPA) and the Taiwan Environmental Protection Administration (Taiwan EPA) have

collaborated through the International Environmental Partnership since 2011 to build global capacity for the environmentally sound management of waste electrical and electronic equipment (WEEE), which is commonly called E-Waste. To support this goal, U.S. EPA and Taiwan EPA coordinate the **International E-Waste Management Network (IEMN)**. [14]

1.4.2 ORGANISATIONS:

The organisations which supported the preparation of the report included International Labour Organization (ILO); International Telecommunication Union (ITU); United Nations Environment Programme (UNEP); United Nations Industrial Development Organization (UNIDO); United Nations Institute for Training and Research (UNITAR); United Nations University (UNU), and Secretariats of the Basel and Stockholm conventions.[13]

According to the report, North America, Western Europe, Japan, South Korea and Australia are the regions which send most of the E-Waste to other countries while India, China, Vietnam, Brazil, Mexico, Senegal, Ghana, Nigeria, Ivory Coast and Egypt are the regions receiving the bulk of E-Waste as many as 67 countries have legislation in place, including India, to deal with the E-Waste they generate which involves the 'extended producer responsibility' (EPR) aspect. As per this, any electronic/electrical E-Waste producer is supposed to have designated collection centres in a city where the customers can drop their products. And they must ensure that those dropped products are recycled. Every producer must ensure that the product reaches a designated dismantler or recycler. Every producer has a certain target of recycling of its products which is directly proportional to the weight of the total annual production of their products. Regarding the implementation of the law, the report says, "In many regions of Africa, Latin America or Southeast Asia, electronic waste is not always high on political agenda, and (law is) often not well-enforced." [16]

1.4.3 SUCCESS STORY:

- Sonia Garga, Project Manager, Sahaas Zero Waste, a start-up that converts waste into resources.
- Pranshu Singhal, founder of Karo Sambhav, an organisation working to integrate the informal sector with formal, says that even the authorised recyclers are outsourcing their E-Waste to the informal sector. [17]

1.5 E-WASTE MANAGEMENT IN INDIA

1.5.1 DELHI -

"The Municipal Corporation of Delhi (MCD) was inefficient and corrupt as was proved by the accumulation of garbage across the city" as said by Delhi's chief minister, Sheila Dikshit. There are approximately 150000-200000 waste workers in Delhi. [18]

A scrap dealer purchased an irradiator which was not in use, since past 25 years, in the chemistry laboratory of Delhi University, India. The irradiator was dismantled by the dealer in late March 2010 and was kept in his shop at Mayapuri, New Delhi. Within a week, he observed skin hyper-pigmentation of the hands and forearm, loss of scalp hair, nausea and fatigue. He came to emergency Department of AIIMS, New

Delhi for treatment. Subsequently teams from Bhaba Atomic Research Centre (BARC), Mumbai and Narora atomic power plant, Narora, reached the spot and the article emitting harmful radiation was detected. The article was identified as a Gamma irradiator & the radioactive material as Cobalt-60. The Gamma irradiator was purchased by the Delhi University from Canada in 1968 and was condemned in 1985. [19]. Resulting in seven radiation injuries and one death. All five patients suffered from the haematological form of the acute radiation syndrome and local cutaneous radiation injury as well. While four patients exposed to doses between 0.6 and 2.8 Gy survived with intensive or supportive treatment, the patient with the highest exposure of 3.1 Gy died due to acute respiratory distress syndrome and multi-organ failure on Day 16 after hospitalization.[20]

However, radiation exposure from Cobalt-60 in civilian set up is rarely reported. An accident involving Cobalt-60 (tele-therapy heads) was reported in Thailand during year 2000, in which total 10 persons were affected and 3 died, due to acute radiation sickness. [19]

MUMBAI -

Municipal Corporation	Total e-waste	Percent
Greater Mumbai	31622.40	66.62
Thane	3598.59	7.58
Kalyan-Dombivali	3282.73	6.92
Ulhasnagar	1769.15	3.73
Navi-Mumbai	3254.11	6.86
Mira-Bhayandar	2006.64	4.23
Bhiwandi-Nizampur	1935.18	4.08
Total	47468.80	100.00

Source: [21]

Above table shows that annually –

- Mumbai city has 31622.4 Metric Tons (MT) E-Waste. It is highest in terms of all other municipal corporations in region. It is high because total population, shops, hospitals, malls, educational and small industrial units in city. There are many software and IT industrial units generating E-Waste in city.
- Thane Municipal Corporation, the estimated E-Waste is 3598.59 MT. It is again because of growth of population and other units in the corporation area.
- In Kalyan-Dombivali, the estimated E-Waste is 3282.73MT.
- In Ulhasnagar, the E-Waste is 1769.15 MT per year. In Ulhasnagar Corporation area, there are IT and software companies. Traditional industries such as textile, food articles, cosmetic, automobile, and chemical industries do not produce much E-Waste. Therefore, E-Waste is moderate in corporation area.
- In Navi-Mumbai municipal corporation area, the estimated E-Waste is 3254.11 MT per year. The city is modern, but density of population is low. Therefore, E-Waste generated is low. But in future population and E-Waste will rise.
- In Mira Bhayandar Municipal Corporation, the annual estimated E-Waste is 2006.64MT.

- In Bhiwandi-Nizampur Municipal Corporation, the estimated E-Waste is 1935.18MT per year. Bhiwandi city is famous for the textile units. Such units do not produce much E-Waste.
- Total annual E-Waste estimated in Mumbai metropolitan region is 47468.8 Metric Tons (MT) per year. [21]

It is further separated according to different components of each municipal corporation.

Constituents	E-waste (MT) annual	Percent
Population	20214.00	63.92
Slums	5122.80	16.20
Academic institutions	464.76	1.47
Industry	486.00	1.54
Theaters	133.20	0.42
Shops and malls	4359.60	13.79
Hospitals	298.80	0.94
Welfare and government institutions	543.60	1.72
Total	31622.76	100.00

Source: [21]

1.5.2.1 In Mumbai Municipal Corporation:

- Population contributes 20214MT E-Waste. People are using the various electronic items such as mobile phones, television, washing machine, refrigerators, computers and laptops. The replacement of electronic items is higher in city. It depends on the income of households.
- The annual E-Waste by slums is 5122.8MT. The solid waste is not regularly collected in slums of Mumbai city. Therefore, data of E-Waste generated by slums and collection is not available.
- The E-Waste from academic institutions is 464.76 MT annually in Mumbai Municipal Corporation. There are many schools, colleges, and other educational institutions which use computers, LCD, laptops, fax machines, printers for different purposes. Now e-learning and new methods of teaching are based on the technology. Most of the electronic items are used in the academic institutions.
- We have also estimated the E-Waste generated by the industry which is 486MT.
- The E-Waste by the theatres is 133.2 MT.
- Shops and malls are also contributing to E-Waste and it is 4359.6MT. Hospitals also contributing the E-Waste which is calculated as 298.8MT.
- The welfare centres and government institutions are also contributing the E-Waste and it is 543.60MT. There are different government departments in the city which are using the electronic goods. When grants are given, the old electronic products are replaced with new products. The old products are discarded in the dust bins.

- Total annual E-Waste generated in the city is 31622.76 Metric Tons (MT). [21]

1.5.2.2 FUTURE ESTIMATION OF E-WASTE –

Municipal Corporation	2021	2031	2041	2051
Mumbai	46663.20	63163.20	79663.20	96163.20
Thane	4969.94	6406.34	7842.74	9279.14
Kalyan-Dombivali	4466.52	5686.52	6906.52	8126.52
Ulhasnagar	2825.46	3897.86	4970.26	6042.66
Navi-Mumbai	4202.31	5154.91	6107.51	7060.11
Mira-Bhayandar	2961.02	3907.12	4853.22	5799.32
Bhiwandi-Nizampur	2797.27	3670.27	4543.27	5416.27

It is important to consider E-Waste for different Municipal Corporations and periods. In 2012, the E-Waste generated in Mumbai city is 31622.40 MT but in 2041, it will reach up to 79663.20 MT. In 2051, it will be 96163.20 MT. [21]

There has been exponential increase in the numbers since the onset of IT sector and it continues to dominate the hazardous waste hierarchy. Mumbai, being the most densely populated city in India and a lavish lifestyle generates huge amount of accumulated waste in this sector which can eventually be threat to the people residing.

1.5.3 BANGALORE –

Bangalore is generating approximately 12,000 tons of E-Waste (from computers and peripherals) per year. This estimate is based on information received from recyclers in Bangalore and assuming the fact that 30% of all equipment in IT industry became obsolete every year and end up as E-Waste. Representatives from two governments authorized recyclers Ash recyclers and E-Parisaraa have conducted surveys in the field of WEEE recycling, and the authors participated in this discourse. [22]

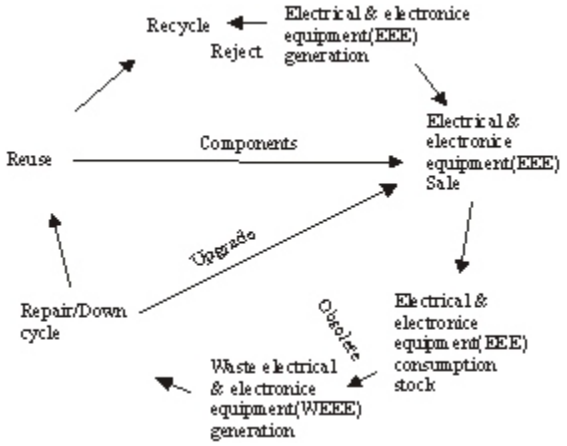


Image Source: [22]

The system is divided into two sections: pre-recycling and post-recycling processes. Five percent of the items produced are rejected and go directly into the "Recycling" process. The field assessment of this study revealed the existence of a vital refurbishing and upgrading industry, dealing exclusively with used personal computers. The flow from the "Repair" to "Traders" processes include the upgrading of PCs with faster processors, increase in hard disk memory or replacement of whole components. The reuse of components (flow from "Reuse" to "Traders") depicts the recycling of components - such as IC processing chips, memory cards, capacitors or other individual components which enter the market by being sold after having their functionality checked. [22]

The post recycling process adopted is simple and having minimum landfill options without incineration. In general, mechanical and recovery operations are being carried out. Mechanical operations include - manual dismantling, segregation, pulverizing and density separation in an eco-friendly manner, while recovery operations are carried out separately for metals, glass, and plastics. [22]

Bharat Electronics Ltd., (BEL) set-up to meet the specialized electronic needs of the Indian defence services, has been the first public sector company to initiate E-Waste management. The segregated waste is recycled at authorized E-Waste recycling facilities in Bangalore. As per government regulations, tenders are called for the sale of this E-Waste. Earlier all authorized scrap dealers were invited to take part in the tender. In the present situation the tender is restricted to only authorized E-Waste recyclers. In depth research on Personal Computers specifically concluded that the precious metal makes up more than 70% of the value. This indicates that the major economic driver for recycling of electronic waste is from the recovery of precious metals and their industrial application. [22]

2 LITERATURE REVIEW:

Numerous studies regarding E-Waste and its management have been done in the past, some of them include:

E-waste Management: Increasing Concern in India [22] quoted that

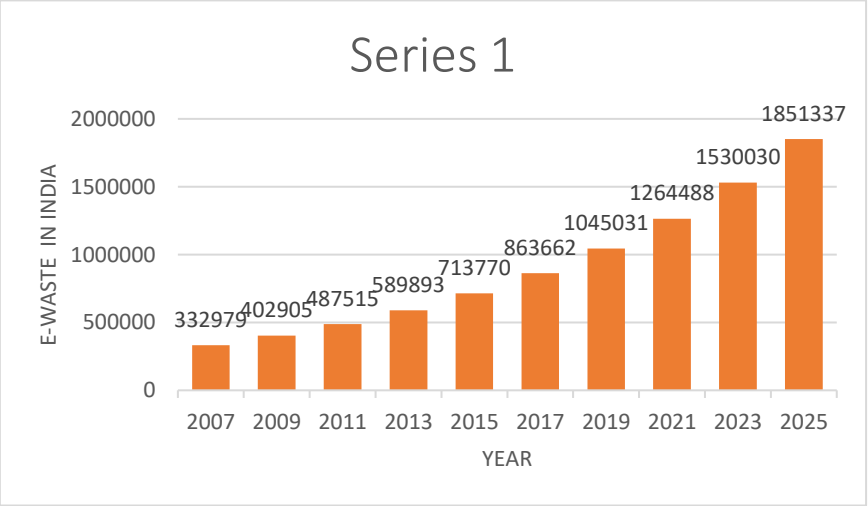
Some important e-waste disposal/ processing methods are:

- **Landfilling**-burying into pits--Is unsafe and poses the threat of chemicals leaching into soil and groundwater and contaminating them
- **Incineration**-mostly open-air burning --If used unscientifically, the process may release toxic fumes
- **Recycling & reuse**--Is an eco-friendly method and can help recover valuable metals etc
- **Bio-remediation**--Productively uses indigenous micro-organisms to detoxify the pollutants --Includes sub-processes such as 'Bio-sorption", "Bio-Leaching" etc
- **Phyto-remediation**--Uses indigenous plants to absorb and degrade pollutants

E-Waste management in Mumbai metropolitan region: constraints and opportunities [21] Defined E-Waste as:

- "E-Waste" is the new by-product of the Info Tech society. It is a physical waste in the form of old discarded, end of life electronics.
- Alternatively, it can be defined as "E-waste is electronic waste. It includes a broad and growing range of electronic devices from large household appliances such as refrigerators, air conditioners, cellular phones, computers and other electronic goods".
- Similarly, e-waste can be defined as the result when consumer , business and household devices are disposed or sent for re-cycling example , television, computers, audio-equipments , VCR.DVD, telephone, Fax, Xerox machines, wireless devices, video games, other household electronic equipments. All the above definitions explain about electronic goods which are used and discarded when new electronic goods are bought.

[23] revealed the statistics that:



[24] mentioned Regulatory Responses to the Electronic Waste Phenomenon, understanding the seriousness of E- waste two conventions have been organized:

1. **The Basel Convention**
2. **The Bamako Convention**

It also stated the various Organization Processing e- Waste in India which are stated below.

[25] talked about the different shortcomings and drawbacks of an E-waste management plant in India, which are:

1. Volume of E-waste generated
2. Involvement of Child Labour
3. Ineffective Legislation
4. Lack of infrastructure
5. Health hazards
6. Lack of incentive schemes
7. Poor awareness and sensitization
8. E-waste imports
9. Reluctance of authorities involved
10. Security implications
11. High cost of sourcing e-waste
12. High cost of setting up recycling facility
13. Lack of research

3 MANAGEMENT POLICIES BY GOVERNMENT:

India figures as one of the regions that receives most of the E-Waste export. India's problems is illegally imported E-Waste. Here too, the government has no record, but as per the Manufacturers' Association for Information Technology, an industry body representing the information-technology sector, the country received about 50,000 tonnes in 2007. A 2015 report by the United Nations Environment Programme says that China, India Malaysia and Pakistan are the main destinations for large-scale shipments of hazardous wastes, including E-Waste, in Asia. [26]

India notified the E-Waste (Management) Rules, 2016, on October 1, 2016, which made EPR mandatory. The phase-wise collection target for E-Waste, which can be either in number or weight was 10 per cent of the quantity of waste generation as indicated in the EPR Plan during 2017-18, 20 per cent in 2018-19, followed by 30 per cent, 40 per cent, 50 per cent, 60 per cent and 70 per cent during second, third fourth, fifth, sixth and seventh year respectively. They must file annual returns with the Central Pollution Control Board (CPCB) stating they have fulfilled their targets. However, CPCB solely relies on the returns filed by them and does not have any independent mechanism to verify those claims. [16]

Union Minister for Environment, Forest and Climate Change, Dr. Harsh Vardhan has said that the Government has amended the E-waste (Management) Rules

in a move to facilitate and effectively implement the environmentally sound management of e-waste in India. Dr. Vardhan highlighted that the amendment in rules has been done with the objective of channelizing the E-waste generated in the country towards authorized dismantlers and recyclers in order to formalize the e-waste recycling sector. He pointed out that the collection targets under the provision of Extended Producer Responsibility (EPR) in the Rules have been revised and targets have been introduced for new producers who have started their sales operations recently.

Some of the salient features of the E-waste (Management) Amendment Rules, 2018 are as follows:

1. The e-waste collection targets under EPR have been revised and will be applicable from 1 October 2017. The phase-wise collection targets for e-waste in weight shall be 10% of the quantity of waste generation as indicated in the EPR Plan during 2017-18, with a 10% increase every year until 2023. After 2023 onwards, the target has been made 70% of the quantity of waste generation as indicated in the EPR Plan.
2. The quantity of e-waste collected by producers from the 1 October 2016 to 30 September 2017 shall be accounted for in the revised EPR targets until March 2018.
3. Separate e-waste collection targets have been drafted for new producers, i.e. those producers whose number of years of sales operation is less than the average lives of their products. The average lives of the products will be as per the guidelines issued by CPCB from time to time.
4. Producer Responsibility Organizations (PROs) shall apply to the Central Pollution Control board (CPCB) for registration to undertake activities prescribed in the Rules.
5. Under the Reduction of Hazardous Substances (RoHS) provisions, cost for sampling and testing shall be borne by the government for conducting the RoHS test. If the product does not comply with RoHS provisions, then the cost of the test will be borne by the Producers.

The E-Waste Management Rules 2016 have been amended vide notification G.S.R. 261(E) on March 22, 2018. [27]

Some changes amended after year 2016 by Indian Government:

1. Manufacturer, dealer, refurbisher and Producer Responsibility Organization (PRO) have been introduced as additional stakeholders in the rules.

2. The applicability of the rules has been extended to components, consumables, spares and parts of EEE.

3. Compact Fluorescent Lamp (CFL) and other mercury containing lamp brought under the purview of rules.

4. Collection mechanism-based approach has been adopted to include collection centre, collection point, take back system etc for collection of e-waste by Producers under Extended Producer Responsibility (EPR).

5. Option has been given for setting up of PRO, e-waste exchange, e- retailer, Deposit Refund Scheme as additional channel for implementation of EPR by Producers to ensure efficient channelization of e-waste.

6. Provision for Pan India EPR Authorization by CPCB has been introduced replacing the state wise EPR authorization.

7. Collection and channelization of e-waste in Extended Producer Responsibility - Authorisation shall be in line with the targets prescribed in Schedule III of the Rules. The phase wise Collection Target for e-waste, which can be either in number or Weight shall be 30% of the quantity of waste generation as indicated in EPR Plan during first two year of implementation of rules followed by 40% during third and fourth years, 50% during fifth and sixth years and 70% during seventh year onwards.

8. Deposit Refund Scheme has been introduced as an additional economic instrument wherein the producer charges an additional amount as a deposit at the time of sale of the electrical and electronic equipment and returns it to the consumer along with interest when the end-of-life electrical and electronic equipment is returned.

9. The e-waste exchange as an option has been provided in the rules as an independent market instrument offering assistance or independent electronic systems offering services for sale and purchase of e-waste generated from end-of-life electrical and electronic equipment between agencies or organizations authorised under these rules.

10. The manufacturer is also now responsible to collect e-waste generated during the manufacture of any electrical and electronic equipment and channelize it for recycling or disposal and seek authorization from SPCB.

11. The dealer, if has been given the responsibility of collection on behalf of the producer, need to collect the e-waste by providing the consumer a box and channelize it to Producer.

12. Dealer or retailer or e-retailer shall refund the amount as per take back system or Deposit Refund Scheme of the producer to the depositor of e-waste.

13. Refurbisher need collect e-waste generated during the process of refurbishing and channelize the waste to authorised dismantler or recycler through its collection centre and seek one-time authorization from SPCB.

14. The roles of the State Government has been also introduced in the Rules in order to ensure safety, health and skill development of the workers involved in the dismantling and recycling operations.

15. Department of Industry in State or any other government agency authorised in this regard by the State Government is to ensure earmarking or allocation of industrial

space or shed for e-waste dismantling and recycling in the existing and upcoming industrial park, estate and industrial clusters.

16. Department of Labour in the State or any other government agency authorised in this regard by the State Government need to ensure recognition and registration of workers involved in dismantling and recycling; assist formation of groups of such workers to facilitate setting up dismantling facilities; undertake industrial skill development activities for the workers involved in dismantling and recycling; and undertake annual monitoring and to ensure safety & health of workers involved in dismantling and recycling.

17. State Government to prepare integrated plan for effective implementation of these provisions, and to submit annual report to Ministry of Environment, Forest and Climate Change.

18. The transportation of e-waste shall be carried out as per the manifest system whereby the transporter shall be required to carry a document (three copies) prepared by the sender, giving the details.

19. Liability for damages caused to the environment or third party due to improper management of e-waste including provision for levying financial penalty for violation of provisions of the Rules has also been introduced.

20. Urban Local Bodies (Municipal Committee/Council/Corporation) has been assign the duty to collect and channelized the orphan products to authorized dismantler or recycler. [28]

4 PROCESS FLOW DIAGRAMS:

Undergoing recycling is a very sensitive process as dealing with hazardous metal can take a heavy toll. To keep the workflow in an organised manner, we need to follow some simple steps.

Prior to incineration and land-filing the E-Waste undergoes recycling, reuse and recovery options as shown:

The other mechanical processes like shredding, grinding, magnetic and eddy current separation etc. are involved, which are the primary requirement of recovery shown:

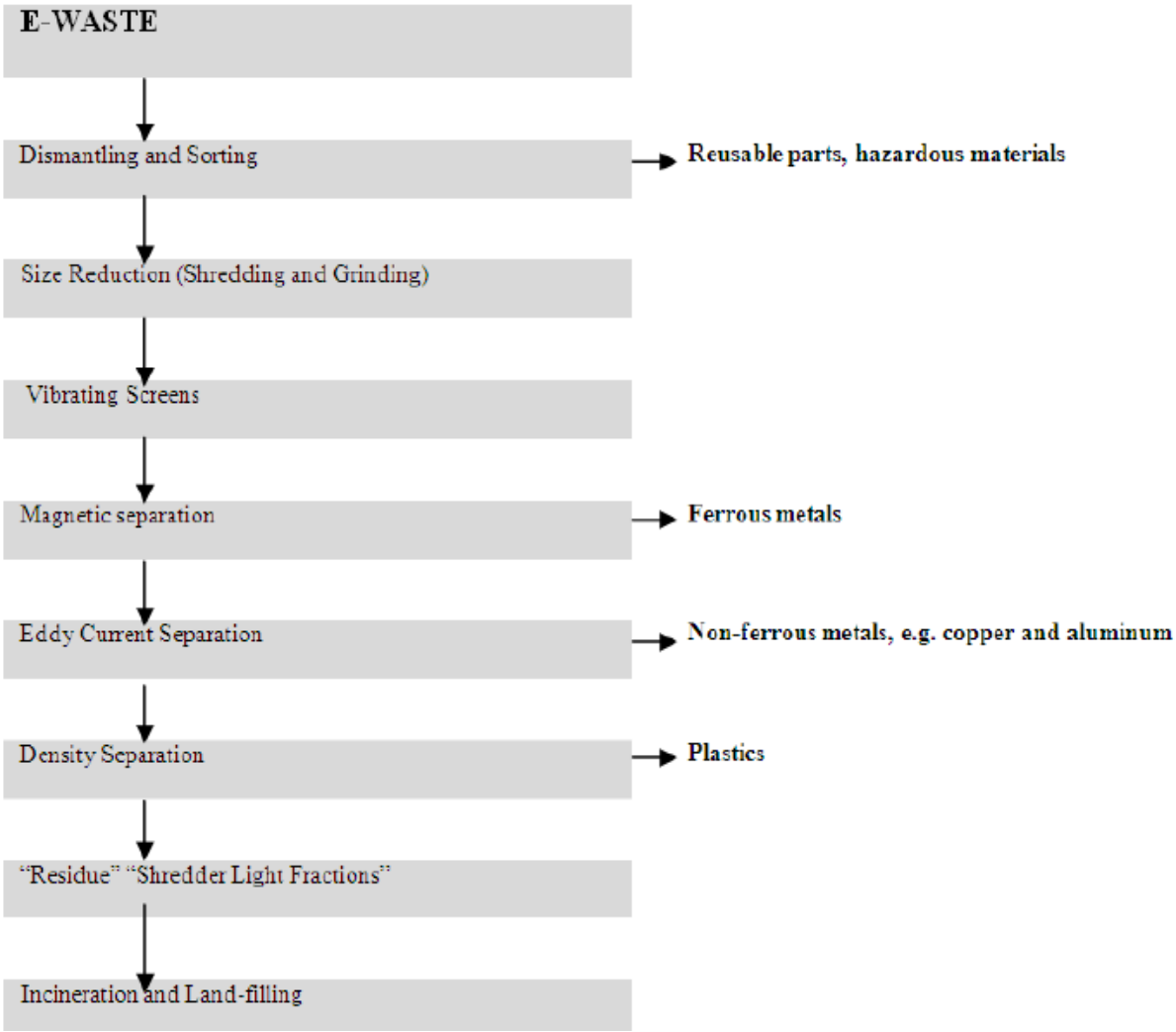


Image Source: [29]

For Further refining of metal fractions, initially the pyro-metallurgical process is used followed by hydro metallurgical processes. Recovering non-ferrous metals and precious metals pyro-metallurgical processes in copper smelter is used and further refining electrolytic process is used. The recovery of metals achieved by this process is 99% and the remaining 0.9% in electrolyte is treated with acidic solution to recover the metals from electrolyte. [29]

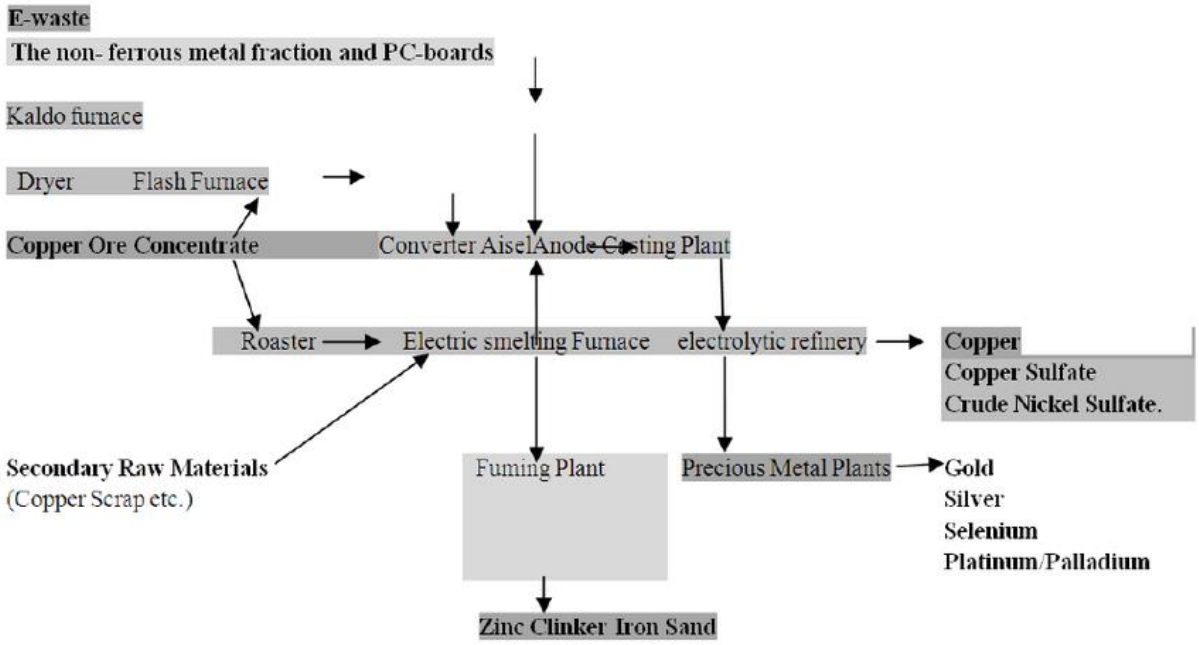


Image Source: [29]

(*Schematic of the processes used to recover copper and precious metals from ore concentrate, copper Scrap and E-Waste)*

The recovery of plastics from E-Waste is also essential like recovery of metals as plastics also have great potential of recycling value. Hardly 25% of plastics is being recycled since the presence of numerous polymers and additives made it very complex materials. The different products and quality of plastics are separated from the E-Waste and subsequent separation is being made by using the following techniques -

- Sieving
- Density separation (in various aqueous or nonaqueous media)
- Electrostatic separation (e.g. triboelectric separation)
- Air-separation

Along with combination of various size reduction steps, such as grinding, milling and granulation. The foreign material in plastics is separated by performing the following techniques magnetic separation, eddy current separation and air-separation. The plastics so obtained are used in the manufacturing of new plastic products. [29]

These treatment technologies are used in three tier system i.e. 1st level treatment, 2nd level treatment and 3rd level treatment.

1. **1st Level Treatment –**
   Plastic is separated and the remaining items like CRT, Circuit boards, cables, hazardous waste, mercury switches are put as input in 2nd level treatment further to extract metals further. [29]

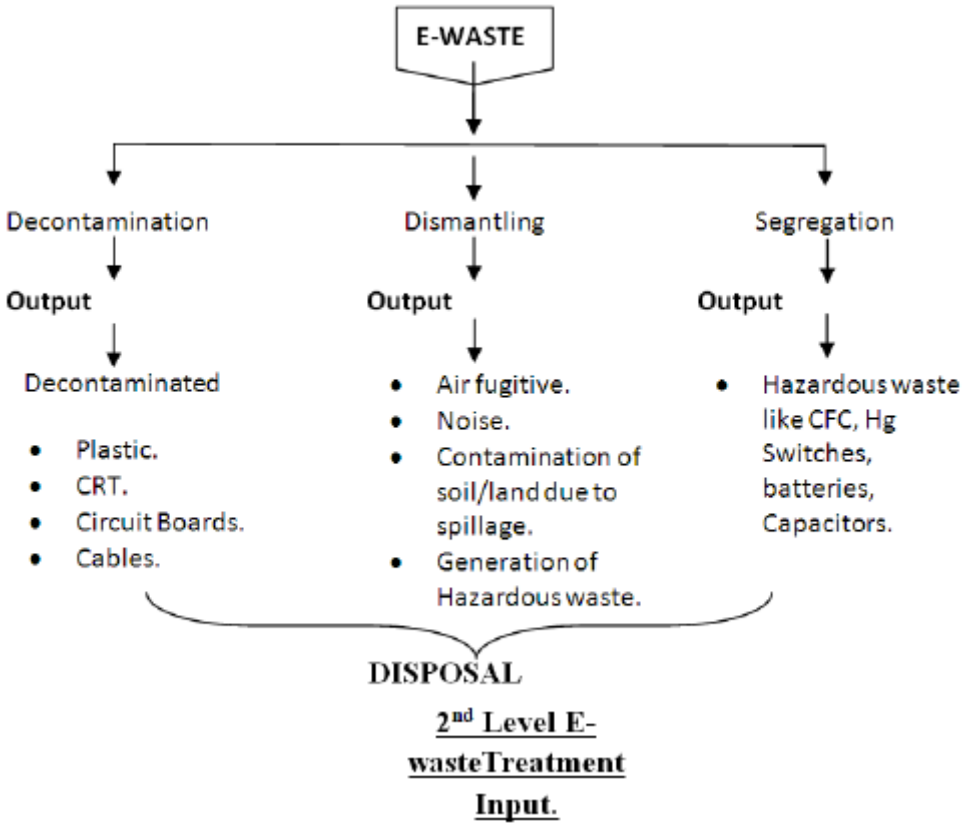


Image Source: [29]

(Flow Chart of 1st Level treatment)

2. 2nd Level Treatment –

From 2nd level treatment the plastic mixtures and plastic with flame retardants, glass, lead, are separated and the other metals are separated by using Magnetic and Eddy current separation of ferrous and non-ferrous metals like Fe and non Fe (Cu, Al, Au, Ag and other precious metals) using the material physical properties like electric conductivity, magnetic properties and density.

The pre-communicating of E-Waste is essentially required to prepare a feed stock for magnetic and eddy current separation processes. It includes mill hammering, shear shredding and pulverisation of E-Waste. Further, the material is screened and de-dusted followed by separation of valuable metal fraction of Copper, Aluminium and residual fractions of precious metals by using electrostatic, gravimetric, eddy current technologies. Overall magnetic separation, eddy current separation, electrostatic separation, air tables, gravity air classifiers, air cyclones and shape screens are used among other processes also. For example, eddy current separation for non-ferrous metals is best suited for granular metal of size more than 5 mm and eddy current separator ensures better separation of Aluminium fraction in comparison to the fraction of Copper, Silver and Gold. The grounded material having size less than 2 mm, electrostatic precipitation is used for copper recovery most of time. However, electrostatic separation gives poor separation efficiencies at - 100 μm fine sizes compared with column air separator. [29]

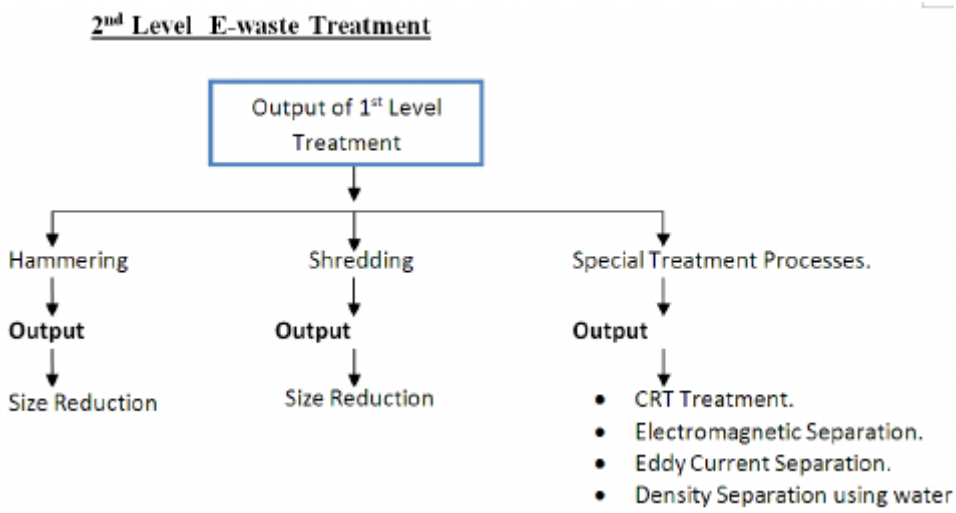


Image Source: [29]

3. **3rd Level Treatment –**
   The 3rd level treatment is based upon the input (residual fractions), technologies used and its final output. Apart from eddy current separation, magnetic separation etc. the E-Waste feedstock is treated with incineration; refining, smelting and distillation to get heat energy and concentrated metals. [29]

Input/WEEE Residue.	Unit Operation/ Disposal / Recycling Technique.	Output.
Sorted Plastic	Recycling	Plastic Product
Plastic Mixture	Energy Recovery/Incineration	Energy Recovery
Plastic Mixture with FR	Incineration	Energy Recovery
CRT	Breaking/Recycling	Glass cullet
Lead Smelting	Secondary Lead Smelter	Lead
Ferrous Metal Scrap	Secondary steel/iron recycling	Iron
Non-ferrous metal Scrap	Secondary copper and aluminium smelting	Copper/Aluminium
Precious Metals	Au/Ag Separation(refining)	Gold/Silver/Platinum and Palladium
Batteries (Lead Acid/NiMH and LiION)	Lead recovery and smelting Re-melting and separation	Lead
CFC	Recovery/ Reuse and incineration	CFC/ Energy Recovery
Oil	Recovery/Reuse and incineration	Oil Recovery/ Energy
Capacitors	Incineration	Energy Recovery
Mercury	Separation and Distillation.	Mercury

Image Source: [29]

This workflow minimizes the waste to be incinerated and dumped into landfills, with recovery of all the necessary ferrous and non-ferrous materials.

5 List of Organization Processing E-Waste in India :

The following organizations are authorized to process e – waste in India.

1. Virogreen, Turn key solution for e-waste by door-door collection service, Chennai, http://www.escrapindustries.com/

2. Ultrust Solutions (I) Pvt Ltd, Services for collection, recycling and safe disposal of electrical & electronics scraps, Chennai, http://www.ultrustsolutions.com/
3. E-Waste Recyclers India, Data security in computer recycling, New Delhi, http://www.e-waste-recyclers.com/
4. Eco Recycling Ltd, Use of mobile shredding vans to control data leakage and client satisfaction, Mumbai, http://ecoreco.com/
5. Cerebra Integrated Technologies Ltd, Most technologically advanced E-Waste Shredding System in India, Bangalore, http://cerebracomputers.com/ewaste-recycling/
6. Attero Recycling, indigenously developed metallurgical unit for metals and plastic extraction, Noida, http://www.attero.in/
7. E-WaRDD & Co, e-Waste recycling services sending zero waste to the landfill, Bangalore, http://www.ewardd.com/
8. Cashify, e waste project management and waste auditing, Bangalore, https://www.cashify.in/
9. Earth Sense Recycle Pvt. Ltd., Collection, Transportation, Dismantling, Segregation & Disposal of e-waste, Chennai, https://www.earthsenserecycle.com/
10. Ash Recyclers, e waste processing for material recovery and segregation of hazardous materials, Bangalore, http://www.ashrecycler.com/index.html
11. E-R3 Solutions Pvt. Ltd, Eco-friendly products and metals recovery from e wastes, Bangalore, http://www.er3solutions.org/
12. E-Parisara Pvt. Ltd, Recycling technology to treat and separate them to glass, metals and plastics, Bangalore, http://ewasteindia.com/
13. Hi-Tech Recycling India Pvt Ltd, e waste recycling, data eraser and logistics services Pune, http://www.hitechrecycling.in/
14. GreenScape Eco, Segregation, collection, storage of materials and recycling of e wastes New Delhi, http://greenscape-eco.com/
15. TES AMM Private Limited, Synchronized electronic waste management solutions with eWTS (Electronic Waste Tracking System), Sreeperumbudur, https://www.tes-amm.com/en-US/
16. INAA Enterprises, Customized solutions for safe removal of the e-waste, Chennai, http://www.inaaenterprises.com/aboutus.html

Source: [24]

6 Plant and Machinery Supplies:

Opening a setup for E-Waste Management plant would require different machinery working in a synchronization to achieve the clean environment with all the hazardous elements treated and metals recovered we are left with 10% of waste which is then dumped into landfills or incinerated under controlled conditions. E-Waste has been bursting out in quantity, to deal with this huge amount of waste Heavy machinery is required with huge capacity so that it can work seamlessly without hinderance.

Table – Composition of Different Elements of E-Waste Sample

Electronic waste	Weight (%)					Weight (ppm)		
	Fe	Cu	Al	Pb	Ni	Ag	Au	Pd
TV board scrap	28	10	10	1	0.3	280	20	10
PC board scrap	7	20	5	1.5	1	1000	250	110
Mobile phone scrap	5	13	1	0.3	0.1	1380	350	210
Portable audio scrap	23	21	1	0.14	0.03	150	10	44
DVD player scrap	62	5	2	0.1	0.05	115	15	4
Calculator scrap	4	3	5	0.1	0.5	260	50	5
PC main board scrap	4.5	14.3	2.8	2.2	1.1	639	566	124
Printed circuit boards scrap	12	10	7	1.2	0.85	280	110	NR
TV scrap (CRTs removed)	NR	3.4	1.2	0.2	0.038	20	<10	<10
Electronic scrap	8.3	8.5	0.71	3.15	2.0	29	12	NR
PC scrap	20	7	14	6	0.85	189	16	3
Typical electronic scrap	8	20	2	2	2	2000	1000	50
E-scrap sample 1	37.4	18.2	19	1.6	NR	6	12	NR
E-scrap sample 2	27.3	16.4	11.0	1.4	NR	210	150	20
Printed circuit boards	5.3	26.8	1.9	NR	0.47	3300	80	NR
e-scrap (1972 sample)	26.2	18.6	NR	NR	NR	1800	220	30
E-waste mixture	36	4.1	4.9	0.29	1.0	NR	NR	NR

(Prospective Scenario of E-Waste Recycling in India)

	%					ppm		
	Cu	Pb	Fe	Ni	Al	Au	Ag	Pd
Computer	7	6	20	0.85	14	16	189	5
Motherboard	14.3	2.2	4.5	1.1	2.8	566	639	50
PCB	15	1.2	12	0.85	7	110	280	50
Plastic CPU	-	-	-	-	10	1500	500	-
Ceramic CPU	-	-	-	-	-	3000	-	-

	$/Ton								TOTAL($)
	Cu	Pb	Fe	Ni	Al	Au	Ag	Pd	
Motherboard	927.7	41	24.7	142.2	59.7	731158	342	2206	734901.3
PCB	973	22	66	109	149	14209	150	2206	17884
Plastic CPU					213.4	193770	268		194251.4
Ceramic CPU						387540			387540

7 ESTABLISHING AN E-WASTE MANAGEMENT PLANT

FINANCING YOUR BUSINESS

Some options given by [31] exist for the financing of your business by different bodies:

1. A small government fund is the first option. The advantage of starting with one's own financial resources allows for full control over the agenda and priorities and does not yet require full cooperation with other actors. Another advantage is that it is easier to arrange in case a pilot collection trial is conducted with equipment from government entities.

2. Funds from the private sector from producers, recyclers, or both. The advantage here is direct involvement of actors later needed for expanding the system. The disadvantage is that later, hesitations may arise to scaling up and providing for more structural financing.

3. Development project funds are an alternative source when limited national resources are available. The advantage here is not just external funding but also the availability of global experts for developing e-waste management who are working directly on these programs. Many of these projects have funding for a variety of topics and are rather different in focus and coverage.

To avoid any rudimentary methods due to a lack of economic knowledge, the StEP-Business-Plan-Calculation-Tool [32] supports entrepreneurs in setting up an economically viable e-waste recycling business in an environmentally sound manner. The tool is available at the StEP website.[33]

7.1 PCB Composition

The table shows that the metal content varies from 20% to 40% by weight and averages 30%. The average metal content for the samples analysed in this work was 27%. This variation can be explained by the wide range of board types used, the different characterization methods used by the various authors and the change in the composition of PCBs over the years. The predominant metals are copper, aluminium, iron, tin and lead. [34]

Metal content	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**
Cu (%)	19	20	22	12.5	26.8	15.6	19.66	28.7	27.6	14.6	12.58	19.19	28
Al (%)	4.1	2	–	2.04	4.7	–	2.88	1.7	–	–	2.38	7.06	2.6
Pb (%)	1.9	2	1.55	2.7	–	1.35	3.93	1.3	–	2.96	2.44	1.01	–
Zn (%)	0.8	1	–	0.08	1.5	0.16	2.10	–	2.7	–	–	0.73	–
Ni (%)	0.8	2	0.32	0.7	0.47	0.28	0.38	–	0.3	1.65	0.39	5.35	0.26
Fe (%)	3.6	8	3.6	0.6	5.3	1.4	11.47	0.6	2.9	4.79	3.24	3.56	0.08
Sn (%)	1.1	4	2.6	4.0	1.0	3.24	3.68	3.8	–	5.62	1.41	2.03	–
Sb (%)	–	–	–	–	0.06	–	–	–	–	–	–	–	–
Cr (%)	–	–	–	–	–	–	0.005	–	–	0.356	–	–	–
Na (%)	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca (%)	–	–	–	–	–	–	1.13	–	1.4	–	–	–	–
Ag (ppm)	5210	2000	–	300	3300	1240	500	79	–	450	–	100	135
Au (ppm)	1120	1000	350	-	80	420	300	68	–	205	–	70	29
Pt (ppm)	–	–	–	–	–	–	–	0	–	–	–	–	–
Cd (ppm)	–	–	–	–	–	–	–	–	–	–	–	–	–

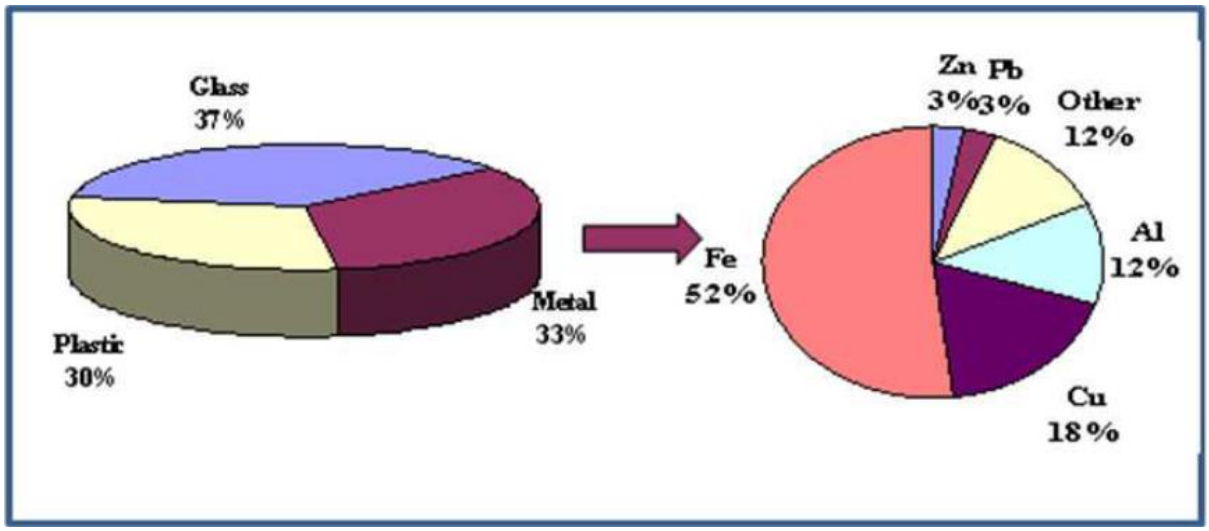
K (ppm)	–	–	–	–	–	–	–	–	–	–	–	–	–
In (ppm)	–	–	–	–	–	–	500	–	–	–	–	–	–
Mn (ppm)	–	–	–	–	–	–	9700	–	4000	–	–	–	–
Se (ppm)	–	–	–	–	–	–	–	–	–	–	–	–	–
As (ppm)	–	–	–	–	–	–	–	–	–	–	–	–	–
Mg (ppm)	–	–	–	500	–	–	1000	–	–	–	–	–	–
Pd (ppm)	–	50	–	–	–	–	–	33	–	220	–	–	–
Co (ppm)	–	–	–	–	–	–	300	–	–	–	–	400	–
Ti (ppm)	–	–	–	–	–	–	–	–	–	–	–	400	–
Total Metals(%)	**31.9**	**39.3**	**30.1**	**22.6**	**40.2**	**22.2**	**46.5**	**36.1**	**35.3**	**30.1**	**22.5**	**39.1**	**31.1**

Table Source – [34]

Non-Metal eg. Epoxy, glass	>70 %
Copper	~16 %
Solder	~4 %
Iron, Ferrite	~3 %
Nickel	~2 %
Silver	0.05 %
Gold	0.03 %
Palladium	0.01 %
Other(Bismuth, Tantalum etc.)	~0.01 %

Table Source – [35]

E-waste is the most rapidly growing segment of the municipal waste stream and the Global E-waste Management Market is expected to reach $49.4 billion by 2020, with compounded annual growth rate (CAGR). E-waste contains many valuable, recoverable materials such as aluminium, ferrous metals, copper, gold, and silver. In order to conserve natural resources and the energy needed to produce new electronic equipment from virgin resources, electronic equipment should be refurbished, reused, and recycled whenever possible. E-waste also contains toxic and hazardous waste materials including mercury, lead, cadmium, chromium, antimony, and many other chemicals. Recycling will prevent them from posing an environmental hazard. *[36]*



[36]

7.2 METHODS OF EXTRACTION

7.2.1 NO MACHINERY

To buy one ton of Ram Fingers – 66rs/ ton [37]

DDR Ram IC Chips..... 1.2 gram gold in 1 kg
DDR 2,3 Ram IC Chips..... 3.75 gram in 1 kg
RD Ram IC Chips..... 5 gram in 1 kg [38]

66 rupees per ton of RAM which will include around 63 pieces of Gold Fingers/kg.[38]
1 ton would have 63000 pieces of Gold fingers.
100 Gold fingers would have 0.6g of gold.
Therefore, 63000 gold fingers would have 378g of gold [39]

7.2.2 THE SCIENTIFIC AND FORMAL WAY

Only 15% of the total waste produced is Recycled in the formal sector. All the mechanical extraction processes have the same objective of enhancing separation and sorting yields of various components, especially the price worthy precious metals. One such layout of machinery is comprising the following stages[35] :

- **Primary coarse size reduction** – this is accomplished with a shredder having multi-use rotational knives.
- **Coarse ferrous metal separation** – accomplished with rare earth magnets sited above an oscillating conveyor belt feed to allow high efficiency ferrous separation across a range of particle sizes.

- **Pulverisation** – circuit board assemblies are pulverised within a hammer mill utilising high abrasion resistance hammers and liners and proprietary grates with the action of the mill inducing a "spherising" effect on the metallic particulates.
- **Classification** – utilising self-cleaning sieves.
- **Electrostatic separation** – virtually complete separation of metallic fractions with recirculation of mid-range particulate fractions.
- **Further size reduction** – secondary pulverisation to effect size reduction on oversized particulates. [35]

  Some machinery used are namely:

  - Primary Shredder
  - Secondary Shredder
  - Eddy Current Separator
  - Vibratory Feeder
  - Vibratory Screen
  - Overband Magnetic Separator
  - Suspension Magnet
  - Belt Conveyor
  - Hammer Mill
  - Drum Separator
  - Electrostatic Drum Separator
  - Magnetic Pulley
  - Shaking Table
  - Air Separator
  - Electro-winning
  - Gyratory Screen Separator
  - Retorts

Reference - [40]

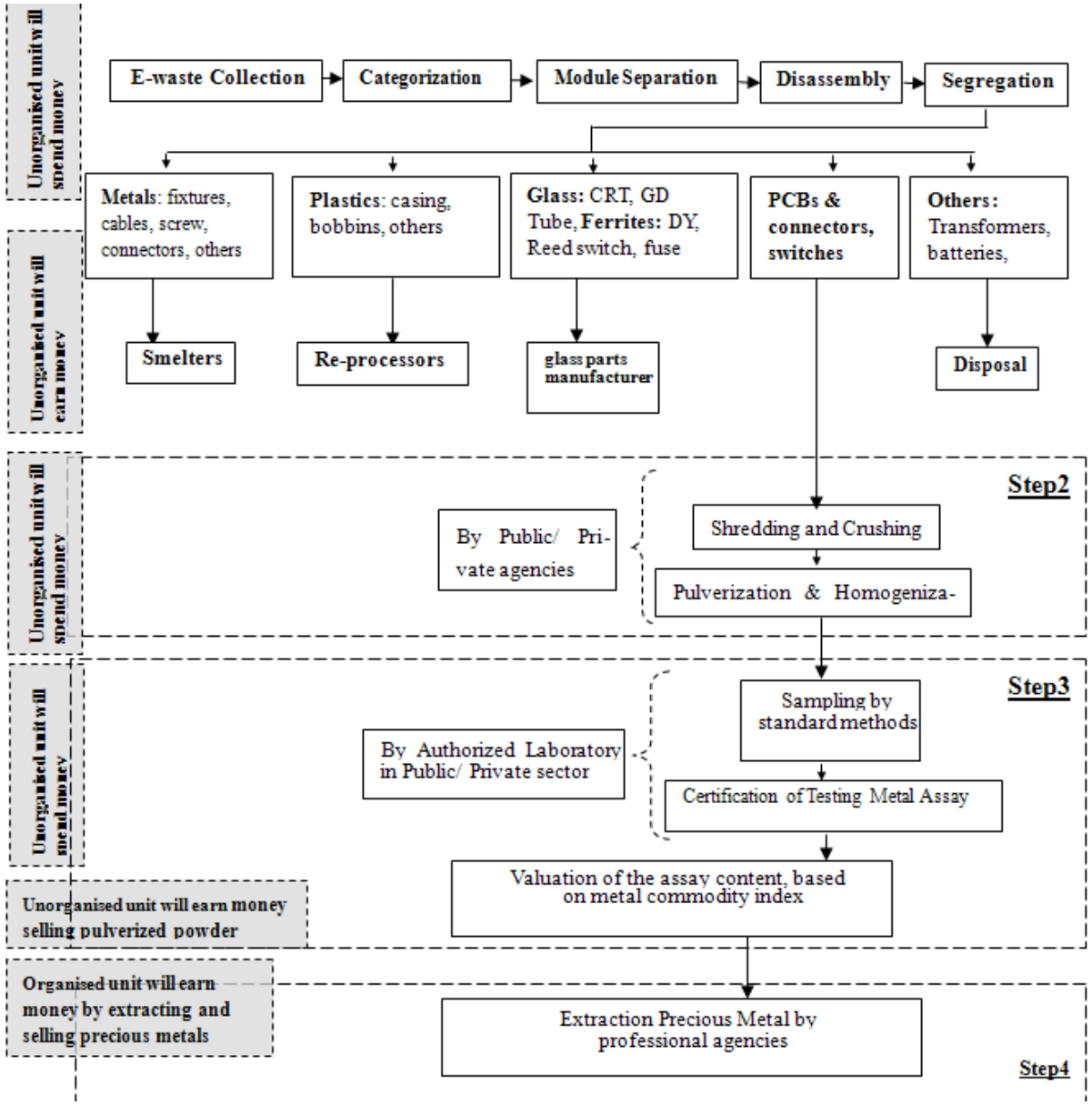


Image Source: [41]

ECONOMICS RELATED TO ELEMENTS EXTRACTION:

Market value of metals recovered from 1000 kg of PCBs

Recovered Metal	Weight	Approx. Cost (in US$)
Gold	279.93 g	13207
Precious Metal (Pt, Pd, In)	93.31 g	2622
Copper	190.512 Kg	1095
Aluminium	142.152 Kg	250
Lead and Tin	30.844 Kg	30+232
Silver	450 g	247

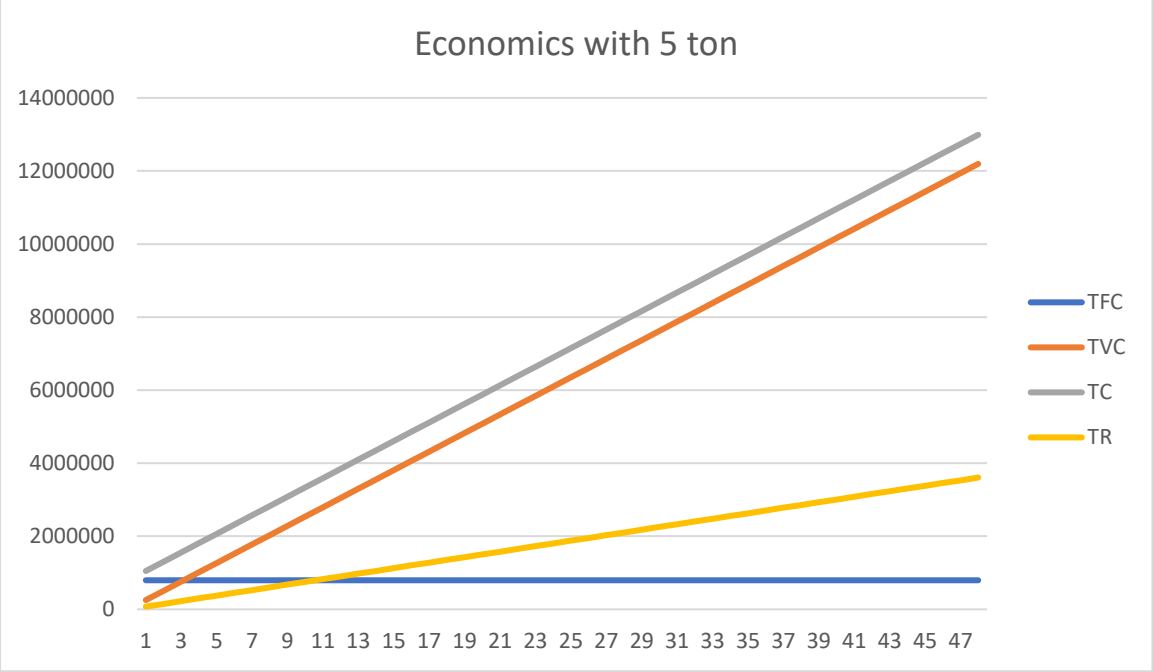
[36]

Total = 17683$

TOTAL VALUE* = 15030$

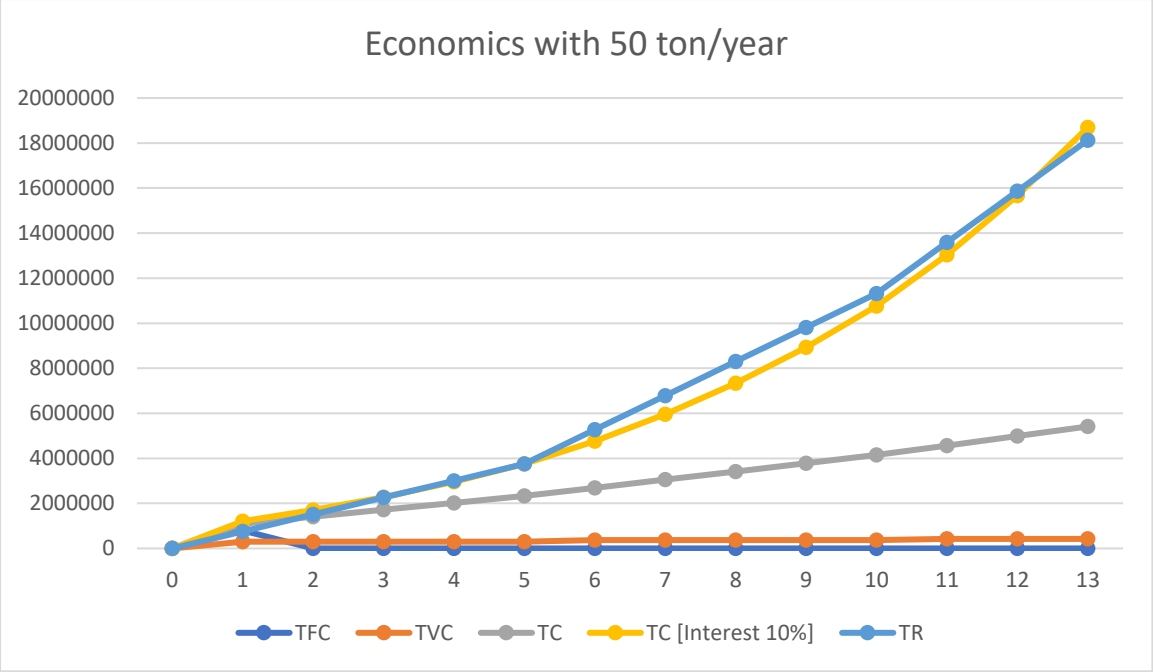
*Considering 85% of extraction of metals is done.

Assuming a model with a demographic location based in Gurugram, Haryana and a Waste Management facility in Manesar, Haryana would sum up for some One-time costs and Variable cost which is iterated annually. The total revenue is generated by selling the different extracted elements on the spot price of 24 carat and assuming only some part of the metal is incinerated or landfilled but most of it is individually sorted out.



The Break-even is never achieved with 5 ton of E-waste per year.
NOT A VIABLE OPTION!

The break-even is achieved just at the immediate end of 4th year marking a no profit, no loss situation.

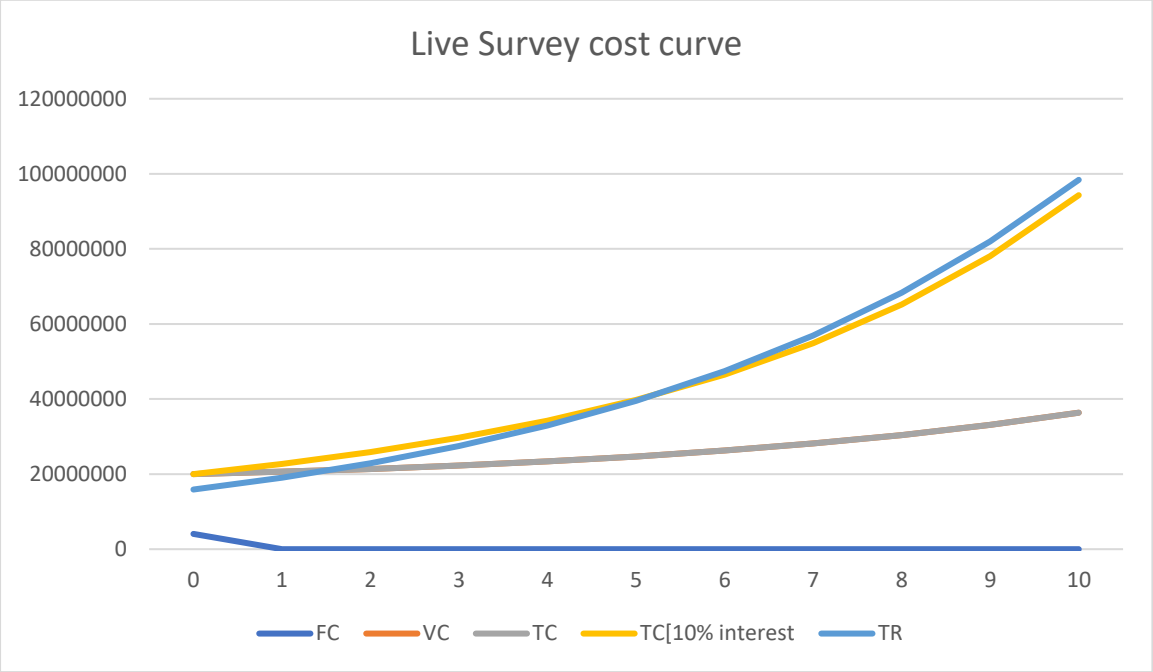


As we can see that if we recycle 5 tons of RAM Scrap per year then the venture would be in loss and even after many years there won't be any break-even but if there is a facility which can handle 50 tons per annum.

If we consider 10% Simple Interest per annum, then also the Break-even is achieved in approximately 4 years, but the instance to keep in mind that if we do not pay the loan in the time period of 4-6 years then the revenue would become less than the Total Cost again as the TC curve[yellow] is an upward curved graph.
The firm would need to increase its capacity from 50 ton to 100 ton after a span of 5 years and continue so on by paying the loan as soon as possible.

The Cost curves given in the above graphs are straight because unlike the case of Manufacturing in which the marginal cost keeps on decreasing first, but here the E-scrap is bought at the same price all over, transported at the same price and metal recovered is also of the same amount. Therefore, as all the variables are a constant value, so the graphs would be a straight line.

ACCORDING TO DATA FROM DESHWAL [LIVE SURVEY]



Assuming the initial fixed cost and a Compound Interest of 10% would sum up the amount and generate an upward facing graph, to counter this hike, the company increases its capacity by 20% every year. Therefore, the company starts generating profits after a span of 5 years only if the loans are paid timely and assuming the plant runs at the constantly increasing pace every year.
Thus, an important aspect to any business model is constant growth with time which would counter the effect of loan and interest added. Though there are various tax redemption schemes by governments of respective countries for motivating such waste management entities, but we as a community of the world fall short of good techniques and scientific disposal techniques.

8 CONCLUSION

There are various permutations and combinations of different techniques, scale and methodologies to take into consideration for setting up an E-waste management plant. Many eco-friendly techniques need to be tested for better metal recovery in an environment friendly manner and churning maximum value out of it. Different variables need to be fixed for testing purpose and many miscellaneous expenses like electricity, employee engagement activities and field trips aren't taken into consideration but adds a bit to the cost. For a model to be successful we can see from the graphs that there is a need of constant growth in a business to sustain itself in the market and generate some meaningful revenue out of it after some years. More than the plan the execution is important and that is what is the deciding factor in many firms of competition with the same business model. The existing firms have already achieved heights in this domain and continue to increase. The motto of this model is to give path to our planning and have a workflow for future. The most important and

motivational entity about this project is that it is a step forward for the environment and saves the normal human being from any calamities from nature or hazardous elements.

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ANNEXURE

Sheet [1] : Based on Costing of E-waste management plant in 5 and 50 ton/year

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Sheet [2] : Based on Live Survey Data of Deshwal Waste Management Pvt. Ltd.

https://drive.google.com/open?id=1cN_eh7H3ePWipNq_ZY5QYXbNAnKqSMjY