Seminar Report
On

REVIEW OF E-WASTE MANAGEMENT STRATEGIES AND FUTURE PROSPECTS

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by

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APPROVAL SHEET

This seminar report entitled "**Review of E-waste Management Strategies and Future Prospects**" prepared by **Rajaryan Kuvelkar** (Roll No. 19D180023) is hereby approved for submission.

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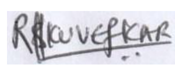
Full Signature of the Student with Date:  20/04/2022

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ABSTRACT

E-waste, also known as waste electrical and electronic equipment (WEEE), refers to discarded items that run on electricity. The Indian market is currently flooded with large amounts of electrical and electronic products and devices, which are in great demand domestically. As a result, the volume of E-waste created in the country is increasing at an alarming rate, despite the fact that management methods and regulatory measures are still in their infancy. E-waste storage, processing, recycling, and disposal procedures currently used in India have the potential to harm human health and the environment. Furthermore, India's governmental measures on E-waste are very new and insufficient to solve the problem. The purpose of this paper is to assess the present state of E-waste management in India. The informal sector's dominance in the E-waste recycling market, with all of its socio-economic, health, and environmental ramifications, is examined in depth, as is the country's sluggish advancement of formal recycling facilities. E-waste composition, categorization, global and Indian E-waste scenarios, prospects of recoverable, recyclable, and hazardous materials found in E-waste, Best Available Practices, recycling, and recovery processes used, and their environmental and occupational hazards are all discussed in this paper. Various obstacles for E-waste management, particularly in India, are identified as a result of the overview.

Keywords: E-waste management; Extended Producer Responsibility (EPR); India; Transboundary Movement; Informal Sector; Global Practices.

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Chapter 1

Introduction

1.1 What is e-waste?

The StEP(Solving the e-waste Problem)-agreed definition of e-waste is as follows: "E-Waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use." E-waste has become an urgent and long-term worry, similar to hazardous waste, because its unchecked buildup and recycling may cause serious environmental concerns, jeopardising human health. Information technology has transformed the way we live, work, and communicate, providing a plethora of advantages and prosperity to all of its users.

People's lifestyles have changed dramatically as a result of the development of creative and new technology, as well as the globalisation of the economy, which has made a wide range of items available and cheap to them. New electronic goods have become a vital part of our everyday lives, offering us with more convenience, security, and the ability to acquire and distribute information more easily and quickly. However, it has also resulted in unfettered resource use and worrisome waste production.

E-waste management is a concern in both developed and developing countries, such as India. The electronics sector is one of the fastest increasing waste streams in the world, consisting of end-of-life electrical and electronic equipment goods, due to rapid technological advancements, technical advances, and a high rate of obsolescence. Refrigerators, washing machines, computers and printers, televisions, mobile phones, i-pods, and other electrical and electronic devices, many of which contain harmful compounds, are included. Many consumption and production patterns are unsustainable, posing a major threat to the environment and human health. Optimal and efficient use of natural resources, waste minimization, development of cleaner products, and environmentally sustainable recycling and waste disposal are just a few of the issues that must be addressed by all parties involved in order to ensure economic growth and improve quality of life.

The European Union (EU) and other industrialised nations have tackled the issue of e-waste to some extent by implementing policy efforts and employing scientific recycling and disposal technologies. 'Waste Electrical and Electronic Equipment,' as defined by the EU, is a new waste stream (WEEE). The key aspects of the WEEE, according to its directive, are the definition of "EEE," its classification into ten categories, and its scope based on voltage ratings of 1000 volts for alternating current and 1500 volts for direct current. Components, sub-assemblies, and consumables have been added to the EEE classification system. Because there is no definition of WEEE under Indian environmental rules, it is merely referred to as "e-waste."

EEE becomes e-waste when it is disposed of as rubbish by its owner with no intention of reuse. Each product contains various materials, is disposed of and recycled in different ways, and is damaging to the environment and human health in diverse ways if not managed properly. EEE is made up of a wide range of items. EEE, on the other hand, is classed for statistical purposes based on similar functions, material composition, average weight, and end-of-life characteristics. EEE is therefore divided into 54 separate product-centric groups by the E-waste Statistics Guidelines on Classification Reporting and Indicators – Second Edition (Forti, Baldé, and Kuehr 2018). The 54 EEE product types are categorised into six broad

groups based on their waste management features, namely, Temperature exchange equipment, Screens and monitors, Lamps, Large equipment, Small equipment, and Small IT and Telecommunication equipment.
WEEE is divided into three categories based on consumption and supply-demand: White Goods (large household or domestic appliances such as air conditioners, driers, washing machines, freezers, refrigerators, stoves and ovens), Grey Goods (information and communication appliances such as CD ROM, disc drivers, computers, Liquid Crystal Display (LCD) monitors, keyboards, mice, typewriters, telecommunications equipment, telephone, fax, modems, pager) and Brown Goods (audio or visual appliances, such as television, mobile phones camera, sound equipment, recorders, and projectors).

1.2 Components of e-waste

All trash from electronic and electrical appliances that have reached their end-of-life term or are no longer fit for their original intended use and are headed for recovery, recycling, or disposal is referred to as e-waste. It includes computers and their peripherals, such as monitors, printers, keyboards, and central processing units; typewriters, cell phones and chargers, remote controls, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators, and other household appliances; and typewriters, cell phones and chargers.
E-waste is classified as 'hazardous' or 'non-hazardous' depending on its content. Ferrous and non-ferrous metals, polymers, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber, and other materials are all included. About half of the trash is made up of iron and steel, with the rest consisting of plastics (21%), non-ferrous metals (13%), and miscellaneous materials. Non-ferrous metals include metals such as copper and aluminium, as well as precious metals such as silver, gold, platinum, palladium, and others. E-waste is dangerous in nature because it contains metals such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants in excess of threshold levels. It includes about 1000 distinct compounds, many of which are poisonous, and when disposed of, it causes major contamination. Among the e-waste, obsolete computers offer the greatest environmental and health risk.
Aluminium (Al), Copper (Cu), Cobalt (Co), Iron (Fe), Manganese (Mn), Tin (Sn), Nickel (Ni), Germanium (Gr), Gallium (Ga), Indium (In), Vanadium (Va) are present in Printed Circuit Boards (PCBs), cables, housing, heat sink, cooling fans, connectors, Cathode Ray Tube (CRT) and power supply in Large Household Appliances (LHA) and Small House While valuable metals like Palladium (Pd), Gold (Au), Platinum (Pt), and Silver (Ag) are abundant in ICT devices, precious elements like Palladium (Pd), Gold (Au), Platinum (Pt), and Silver (Ag) are not (ICT).

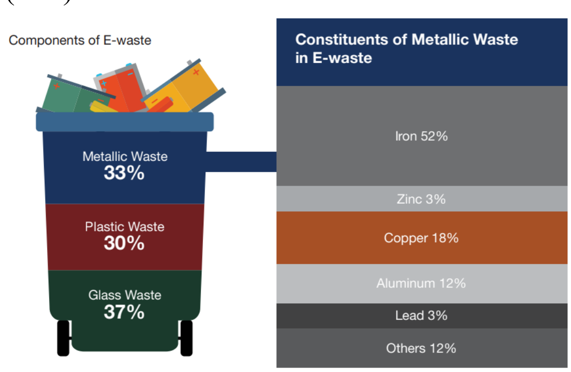

Figure 1.1: Components of e-waste

1.3 Sources of e-waste

The government, public, and private (industrial) sectors are the primary contributors of electronic trash in India, accounting for almost 70% of total waste creation. Individual homes contribute just around 15% of the total, with manufacturers contributing the remaining 85%. Individual homes do not contribute much to computer waste, but they consume vast quantities of consumer durables and are thus potential trash producers. In 2009, an Indian market Research Bureau (IMRB) assessment on 'E-waste generation at Source' indicated that televisions and PCs including servers accounted for 68 percent and 27 percent of overall e-waste volume in India, respectively. Imports and cell phones each accounted for 2% and 1% of the total.

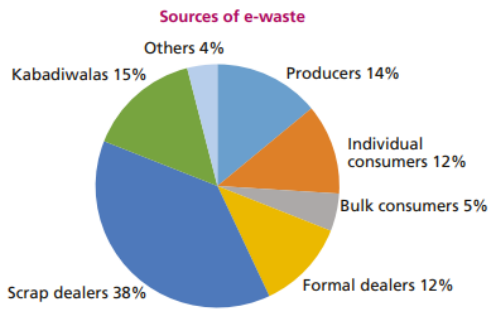

Figure 1.2: Sources of e-waste in India

1.4 E-waste in the global context

Every year, more than 50 MT of e-waste is anticipated to be created globally, making it the fastest increasing component of municipal garbage. In other words, this would fill a train with enough containers to travel around the world once. As a result, with rising consumerism and expected increases in electronic device sales in nations experiencing rapid economic and industrial expansion, the larger percentage of e-waste in municipal solid trash will become a severe concern. According to a UN estimate, e-waste from outdated computers in China would increase by 400% above 2007 levels by 2020, while in India it will increase by 500%. Furthermore, by 2020, e-waste from abandoned mobile phones would be seven times larger than it was in 2007, and 18 times higher in India.
The overall weight of global EEE usage rises by 2.5 million metric tonnes each year on average (excluding solar panels) (Mt). In 2019, the globe produced a staggering 53.6 Mt of e-waste, or 7.3 kg per person. Since 2014, worldwide e-waste creation has increased by 9.2 Mt, and is expected to increase to 74.7 Mt by 2030, nearly doubling in only 16 years. Higher EEE consumption rates, short life cycles, and limited repair choices are all contributing to the rising volume of e-waste. Asia produced the most e-waste in 2019, with 24.9 million tonnes, followed by the Americas (13.1 million tonnes) and Europe (12 million tonnes), with Africa and Oceania producing 2.9 million tonnes and 0.7 million tonnes, respectively. With 16.2 kg per capita, Europe ranked #1 in the world in terms of e-waste generation. Oceania came in second (16.1 kg per capita), followed by the Americas (13.3 kg per capita), with Asia and Africa coming in third and fourth, respectively, with 5.6 and 2.5 kg per capita. Germany has the greatest per capita E-waste creation, with 22.7 kg/person/day.
China now generates roughly 2.3 million tonnes of e-waste on its own soil, second only to the United States, which produces over three million tonnes. During this decade, the EU and the United States will generate the most e-waste. According to the UNEP's Inventory Assessment Manual from 2007, the total e-waste created in the EU is projected to be around 14-15 kg per

capita, or 5MT to 7MT per year. Annual generation per capita in nations like India and China is less than 1 kilogramme. E-waste accounts for up to 6 million tonnes of solid garbage in Europe each year. The creation of e-waste in the EU is predicted to increase at a pace of 3% to 5% every year. The Asian countries together contributed roughly 40.7 percent (18.2 Mt) of the total E-waste created in 2016, with an average of 4.2 kg/person/year.
E-waste creation has previously climbed by 16 to 28 percent every five years, which is three times faster than the average annual municipal solid garbage generation. E-waste accounts for 1 to 3% of total municipal garbage output in the United States. According to the United States Environmental Protection Agency (USEPA), 2.6 million tonnes of e-waste were created in 2005, accounting for 1.4 percent of total garbage. Households and small companies frequently abandon electronic equipment, particularly computers, not because they are malfunctioning, but because new technology has rendered them outdated and unattractive. When new software is incompatible with outdated hardware, users are left with little choice except to purchase new hardware. More than half of the rejected computers are in good working order, according to data from a single-day recycling collection event, yet they are nonetheless removed to make room for the latest technology. Individuals and small enterprises abandon equipment, which becomes solid trash that is disposed of in landfills or incinerators.

Rank	Country and rank in e-waste generation	EEE placed on the market (kg/capita)	E-waste generation (kg/capita)	E-waste collection rate (per cent)
1	China	13.3	7.2	16
2	USA	25.3	21	15
3	India	5.8	2.4	1
4	Japan	21.3	20.4	22
5	Germany	18.2	19.4	52

Table 1.1: Statistics of top e-waste generating countries in 2019

1.5 Objectives of this paper

This paper will deal with the management of e-waste in India, legislation and current statistics, looking into the informal sector as well, and possible options for the future. It will also look into the concept of Extended Producer Responsibility (EPR) which will deal with recycling and implementation of a possible circular economy. There will also be a section on transboundary movement of e-waste and the best global practices followed internationally along with a few case studies. This will be followed by the environmental, health, and economic implications of e-waste management on a global scale.

Chapter 2

Management of e-waste in India

2.1 How much e-waste does India generate?

After the initial wave of economic liberalisation in India, about 1990, problems with e-waste began to emerge. The electronic and consumer durable sector in India expanded as a result of fierce rivalry in the market for brand, quality, price, and services supplied by many Indian and foreign enterprises. There was also a major boom for the electronic products business in India during the post-liberalization era, notably for household appliances (TV, refrigerator, washing machine, AC, ovens, etc.), communications, IT, and computers, due to lower rates and increased purchasing power of citizens.

The CPCB estimates that 708,445 tonnes (0.7 mMT) of e-waste was created in 2017–18, although these statistics are based only on sales data from 244 registered companies. They do not contain numbers for imported e-waste. Based on sales data from 1,168 registered companies, the CPCB projected that 771,215 tonnes (0.77 mMT) of e-waste was created in 2018–19. This, too, excludes data for imported e-waste. India, on the other hand, created 3.2 million metric tonnes (mMT) of e-waste in 2019, according to the Global E-waste Monitor, 2020.

As of 2020, India ranked third in the World when it came to net generation of E-waste, behind only China and the United States of America. Having produced nearly 4.1 million tonnes of E-waste in 2020, this number was expected to hit 5 million tonnes for 2021. This number has grown nearly two and a half times over the last six years. The issue however, is the low collection rate which was only about 3.5% for 2018 and hovering around 10% for 2019. Just 10 states in India account for nearly 70% of the overall E-waste generation in the country, with Maharashtra leading the list, followed by Tamil Nadu and Andhra Pradesh. 70% of this waste comes from computer equipment, 12% from telecommunication equipment, 8% from electrical equipment, and 7% from medical equipment, with domestic appliances accounting for the remainder.

India is also the second most populated country globally as well as the second largest producer of mobile phones in the World. According to the Household Survey 'Indian's Citizen Environment and Consumer Economy' (ICE 360) performed in 2016, roughly 88 percent of Indians have easy access to a mobile phone rather than other vital goods. India's current e-waste creation rate is 2 Mt/year, or 1.5 kg per person every day. Maharashtra generates the most e-waste, whereas Delhi has the greatest per-capita consumption.

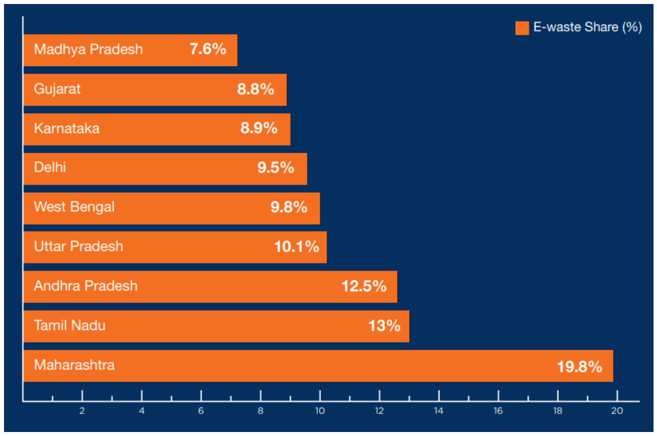

Figure 2.1: Top e-waste generating states in India

Year	E-waste generation (million metric tonnes)
2015	1.97
2016	2.22
2017	2.53
2018	2.86
2019	3.23

Table 2.1: Annual e-waste generation in India

2.2 E-waste Legislation in India

The informal sector's prominent position, as well as the health and environmental risks associated with informal e-waste treatment, prompted the adoption of legislation in the shape of the E-waste (Management and Handling) Rules in 2011. These regulations went into force on May 1, 2012. However, due to flaws on several fronts, the execution of these Rules proved ineffective. E-waste (Management) Rules 2016 were notified in March 2016 to fix the flaws and make the legal framework more effective and functional. They took effect in October 2016, and they replaced the 2011 Rules. These rules were changed in March of 2018. The major goal of the 2016 Rules is to guarantee that e-waste is managed in an ecologically responsible manner. The Rules also aim to protect against the negative consequences of improper e-waste processing and management. When comparing the legislation revolving around E-waste and its management, India is the only country in Southern Asia so far to have any.

Among the specific objectives of the 2016 rules were: To implement Extended Producer Responsibility (EPR), as elaborated in the 2016 Rules, laying emphasis on producers' responsibility for environmentally sound management of e-waste, even at the postconsumer stage; To promote the establishment of an efficient e-waste collection mechanism, through take-back systems and buy back; To promote environmentally sound technologies through authorised dismantlers and recyclers; To minimise illegal recycling and recovery operations in the informal sector; To reduce the use of hazardous substances in the manufacture of EEE. The rules were amended in 2018 to enhance Extended Producer responsibility, the best global practice to ensure end-of-life product takeback. It was also changed to make it easier to accelerate and execute environmentally responsible E-waste management. All parties were assured of adequate collection and effective treatment procedures employed for the dismantling of e-waste under the impact of EPR and PRO. The E-waste collection system was changed in stages, with the goal of reaching 70% by 2023.

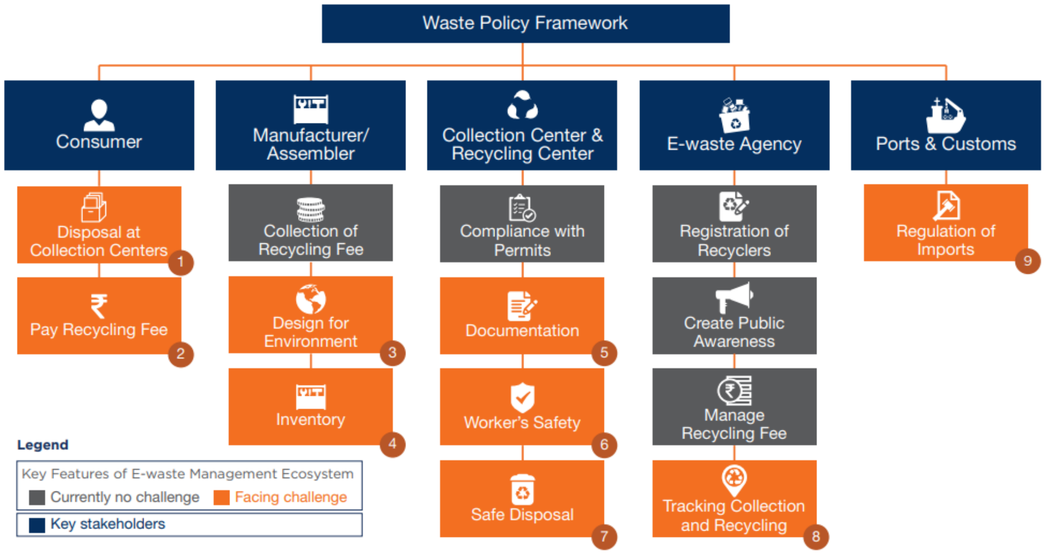

Figure 2.2: Present e-waste management ecosystem in India

2.3 Stakeholders

The Rules have bound a small number of stakeholders—producers, manufacturers, recyclers, dismantlers, refurbishers, dealers, and e-retailers—and outlined the tasks that each of them must carry out, from obtaining authorisation to keeping records and making yearly reports. The majority of tasks, such as collection, transportation, sorting, and disassembly, are carried out manually by unorganised sectors. E-waste is a good source of money production for many individuals in India since it is a rich supply of reusable and valuable materials. A large segment of the Indian populace (rag-pickers) made a living by collecting and selling inorganic garbage such as plastics, polythene bags, glass bottles, cardboards, paper, and other ferrous metals. The informal sector handles about nearly 95% of the e-waste generated in India. The majority of e-waste processes in India are done manually, including collection, sorting, disassembly, recycling, and disposal. Most of the processes utilised for recycling/treatments of E-waste are highly raw and risky in the lack of proper technology and equipment. In India, improper recycling and disposal activities frequently include open burning of plastic trash, exposure to hazardous solders, acid dumping, and extensive general dumping. Pollutants are discharged into the land, air, and water as a result, causing major environmental issues in India. In addition, the labourers and employees in the dismantling and recycling facilities are illiterate and uneducated, and lack fundamental awareness of the substantial occupational and health dangers involved with the activities. The majority of the time, employees execute dismantling and recycling activities without necessary Personal Protective Equipment. The WEEE was mostly dismantled with hammers, chisels, hand drills, cutters, electric torch/burners, and electric drills. These activities occur in densely populated areas such as city centres and slums. The majority of the deconstruction and recycling sites lack adequate lighting and ventilation. Workers and labourers operating in such locations are exposed to substantial occupational health risks due to a lack of appropriate skills and infrastructure.

2.3.1 Manufacturers/Importers

While some manufacturers provide gathering services, they are only available to large corporate clients who create a significant amount of data. Acer, Dell, HCL, Hewlett-Packard (HP), Lenovo, LG Electronics, Motorola, Nokia, WIPRO, Samsung, and Zenith are among the companies that offer take-back services in India. HP is returning cartridges for business reasons rather than environmental concerns, since the corporation wants to limit the growth of cartridge reuse, which is far less expensive than its own original supply. Because multinational businesses frequently have manufacturing operations in India, they are major contributors to the E-waste stream.
They usually dispose of their garbage through a bidding procedure or through the informal recycling industry. Despite the lack of any legally enforceable restrictions, Indian businesses such as HCL and WIPRO are providing voluntary take-back and recycling services to their consumers. From the standpoint of EEE producers, this is a beneficial trend. It's worth noting that worldwide conglomerates with a sizable EEE market share in India have take-back programmes in countries like the United States, but not in India. Despite making some bold statements about producer responsibility, they clearly fall short in India and treat their Indian consumers as second-class citizens. By failing to provide a simple and free take-back service to promote responsible recycling, these businesses indirectly encourage the expansion of informal recycling.

2.3.2 Assemblers

Assemblers are in charge of putting the various components of EEE together. They are a part of the EEE generating process. Assemblers play a particularly important role in the case of personal computers, where they buy locally produced or branded components, assemblies, and sub-assemblies from raw material manufacturers and suppliers, assemble them, and sell them directly to customers. Such constructed PCs are in use in many public-private sector companies, educational establishments, and families across India. This is due to the fact that, in comparison to branded PCs, such items are frequently far less expensive. Because the Indian EEE market is price sensitive, such assemblers give Indian clients the possibility to acquire a used EEE at a lower price.

2.3.3 Retailers

In contrast to the massive formal retail chains in industrialised nations, India's retailing business is still in its infancy and is dominated by individual private stores. Retailers now only play a little and haphazard part in the collection of E-waste, which is restricted to a few high-resale-value items. This typically takes the form of exchange offers, with the buyback or take-back value left to the retailer's discretion. Customers are attracted to EEE exchange offers to a large extent. Such deals now draw attention in major Indian cities, particularly during the festival seasons. People trade in their old items for new ones.

2.3.4 Raw material producers

India has a huge mining industry and industrial smelters that acquire scrap from E-waste dealers and recyclers. The recycler/dismantler dismantles the E-waste and sells the readily reusable/recyclable items, such as plastic, glass, cable-wires, and components, back to the raw material provider for reuse. However, raw material producers' influence on the collection and sorting of E-waste is currently minimal in the country. Steel mills receive just a small percentage of E-waste material such as iron.

2.3.5 Consumers

EEE's customers are diversified and widespread. As previously said, EEE is used in even the most distant regions of the globe. There isn't a single sector in the city that isn't affected by EEE. IT industries, public and private sector institutions, educational institutes, families, commercial and corporate offices, and so on are some of the key customers or users of EEE. Consumers in India, on the other hand, do not pay for end-of-life equipment while purchasing EEE. Furthermore, once EEE becomes WEEE, consumers in India, whether institutional, commercial, or individual users, do not have to pay for their old equipment to be recycled. Unlike in several industrialised nations, the garbage collector is the one that gives the customers a fair price for their old EEE. Consumers in the country are still hesitant to pay a positive price for E-waste recycling, according to research. E-waste is frequently auctioned in the case of major corporations. Many families and other institutions dispose of their E-waste with other household garbage because they are unaware of the proper disposal processes. Because of a lack of information about how to properly handle E-waste, most of it has been left untreated in various places for years. Consumers, on the other hand, might play a key part in keeping EEE out of the waste stream for longer by opting to repair or pass the item along to various relatives, friends, or colleagues rather than dispose of it outright. On a more positive side, similar behaviours are common throughout India. Because of the widespread perception of E-waste as a commodity, there is a reluctance to dispose of it promptly, and it finds second or even third-hand users throughout the country. Consumer durables in India have been found to have a substantially longer average life than in Western countries. Most homeowners do not sell outmoded E-waste to the scrap market directly, according to research. It is preferable to get it swapped at a merchant when acquiring an EEE, or to give it to relatives or friends. The "Take-Back" policies are also in use in India, albeit they are still in their infancy there. It is the retailer's obligation to properly dispose of end-of-life EEES in the case of Exchange or Take-Back Policies. People in the country, on the other hand, are still reluctant to switch to environmentally friendly items since they are sometimes more expensive than conventional products. Products that are energy-stared are a fantastic illustration of this. Although more stars indicate more environmental compliance, such items are also quite expensive.

2.3.6 Kabaddis and Scrap Dealers

Kabaddiwalas and small and major scrap dealers play an important part in India's E-waste management techniques. The collectors and recyclers are the backbone of India's E-waste management. Consumers' E-waste is collected by collectors and sent to recyclers. On the basis of informal commercial contracts, collectors and recyclers, as well as a slew of intermediates, collaborate. In the country, E-waste is mostly collected by an unorganised sector of scrap dealers/traders, known as "Kabaddiwala" in local language, who buy E-waste along with other recyclable waste or scrap, such as old news papers, books, cardboards, plastics, ferrous-tin material items, glass bottles, and so on, from consumers at a set price and sell it to a wholesaler/bigger trader who segregates and sorts different types of waste. Thus, in India, E-waste is one of the fractions of total recyclable garbage or scrap acquired by Kabaddiwala from a variety of clients such as private homes, workplaces, institutions, government, commercial and industrial entities, and so on. These scrap or reusable/ recyclable products are auctioned in many government and private businesses through newspaper advertising.

2.3.7 Recyclers

Data collecting on this industry is particularly difficult in the lack of a regulatory or monitoring structure, therefore it is unknown how many individuals are involved or how broad the network of collectors and recyclers is in India. Many studies, however, show that the number of individuals engaged in the E-waste recycling industry is rather large. The recycling industry employs over 10,000 people in Delhi alone. More than 2000 unorganised recyclers, as well as 270 medium and large scrap dealers, are expected to be participating in the recycling sector in India. In Delhi alone, an estimated 20,000 to 25,000 unskilled workers are employed in the unorganised sector. In India, recycling techniques are severely limited, posing major risks to human health and the environment.

Other stakeholders include the disposers, the Government, and NGOs.

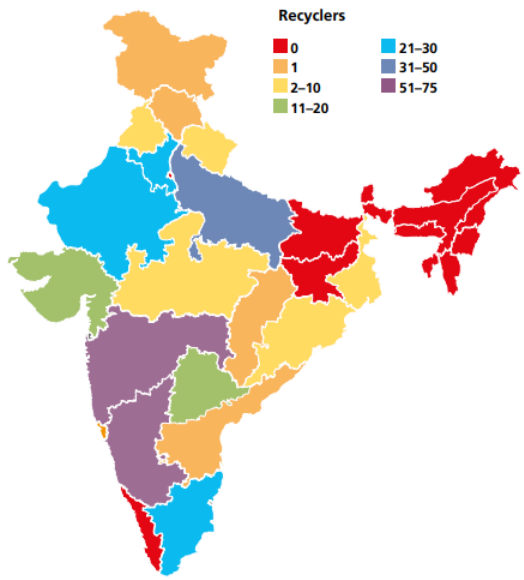

Figure 2.3: Spatial Arrangement of recycling/dismantling facilities in India

Popular brands	Collection targets (in tonnes)					Total brand-wise collection target
	2017–18	2018–19	2019-20	2020–21	2021–22	
Xiaomi	0	0	123	197	344	664
Apple	148	184	294	368	0	994
HP	245	296	367	449	499	1,855
Microsoft	171	232	561	1,314	1,051	3,330
HCL	1,157	1,463	956	1178	759	5,513
Canon	500	766	1,554	2,170	3,079	8,070
Lenovo	1,787	1,829	2,649	3,564	2,283	12,112
Dell	2,939	2,879	4,363	5,096	250	15,527
Sony	3,757	2,090	3,904	3,900	4,506	18,158
Haier	3,159	4,734	6,422	130,581	9,570	36,943
Godrej & Boyce	9,508	11,775	19,528	20,806	24,771	86,388
Videocon	20,912	26,821	36,880	31,928	36,698	153,239
Samsung	36,708	44,121	66,829	64,696	70,078	282,433
Total year-wise collection target	80,991	97,191	144,431	148,725	153,889	625,226

Table 2.2: Year-wise collection targets of popular brands

2.4 Treatment and Processing

Manual collecting, sorting, separating, and disassembling are the first two phases of e-waste recycling, followed by mechanical processing, which includes shredding, grinding, and other methods. Recovered materials are transported to appropriate facilities for further treatment and resource recovery. E-waste recycling is a wide phrase that encompasses many different stakeholders. Every player in the value chain has a role to play in ensuring long-term e-waste management. Producers must abandon the 'design for obsolescence' strategy in favour of 'build for reuse.' Authorities must raise awareness of the possible dangers of e-waste among stakeholders. Consumers must begin sending their e-waste to dismantling and recycling facilities that process the garbage with ecologically friendly technology.
The importance of recycling is enhanced by urban mining of numerous precious and valuable elements, which provides access to secondary resource material, job possibilities, and reduces the pressure on virgin assets. The value of recyclable E-waste was projected to be over 55 billion Euros by UNU Germany in 2017, however only a portion of that was recovered through resource recovery. Metals and nonmetals such as Cu, Al, Fe, and steel, as well as precious metals such as Au, Ag, Pd, and Pt, are frequently lost or stolen due to inadequate resource recovery. Due to technological challenges, the most difficult task is dealing with heavy metals such as lead in PCB and monitor glass; Hg in switches; [Cr(VI)] for housing; Americium (Am) in smoke alarms; Cd and Pb in acid batteries; Ba in panel glass and CRT and BFR in printed wiring boards and casings; beryllium oxide in heat sinks, magnetrons, X-rays, and gas lasers. The present treatment choices are primitive and ineffectual, despite the fact that legislation and rules have been in place for the past ten years and have been updated from time to time.
The Ministry of Environment and Forestry (MoEF) (2008) identified ecologically appropriate E-waste treatment methods and claimed that they are applied at three levels. Material movement underpins all three phases of E-waste treatment. From the first to the third stage of treatment, the material flows. Each level of treatment consists of unit operations that process E-waste and feed the output of the first level of treatment into the second level of treatment. The wastes are either disposed of at a Transfer, Storage, and/or Disposal Facility (TSDF) or burned after the third step of treatment. The quantity of residues sent to TSDF or incineration is determined by the effectiveness of activities at the first and second levels. At the first stage of treatment, the input includes E-waste goods such as televisions, refrigerators, and personal computers (PCs), and the unit activities include decontamination (the removal of all liquids and gases), disassembly (manual/mechanised breaking), and segregation. The three unit operations are all dry procedures that do not necessitate the use of water. Inputs are in the form of decontaminated E-waste, which consists of separated non-hazardous E-waste such as plastic, CRT, circuit board, and cables. Hammering, shredding, and specific treatment procedures such as CRT treatment, which includes separation of funnels and screen glass, electromagnetic separation, eddy current separation, and density separation using water, are examples of unit operations at this step. Hammering and shredding are the two key unit activities in this phase, with the size reduction being the primary goal. The purpose of the third phase of E-waste treatment is to recover ferrous and nonferrous metals, polymers, and other economically valuable things. The main recovery activities are centred on ferrous and nonferrous metal recovery, which is carried out either geographically at separate locations or in a single location in an integrated plant. Sorted plastic, CRT, ferrous metal scrap, non-ferrous metal scrap, and other materials are used as inputs. Recycling, incineration/energy recovery, and iron recycling are among the unit's operations.

2.4.1 Formal Sector

The country's formal recycling sector is very limited and in its infancy. In 2016, 178 dismantling and recycling facilities with a capacity of almost 44 thousand Mt/annum were registered, compared to 138 units with a capacity of over 35 thousand Mt/annum in 2014. The number of units had been expanded to 312, with a recycling capacity of about 78 lakh Mt/year in 2019. Currently, nearly 400 such facilities exist with a capacity of 107 lakh Mt/year. MeitY, a government-owned company, has devised a low-cost, ecologically friendly method for recycling precious materials and plastic components in e-waste. It has created two separate prototypes of PCB recycling technologies, one with a capacity of 1000 kg/day and the other with a capacity of 100 kg/batch, all of which meet environmental standards. Both varieties are made to withstand Indian conditions. The 1000 kilogramme PCB/day technology is meant to be a continuous process and is appropriate for large-scale installation. 100 kg, on the other hand, is a batch procedure built specifically for the informal sector. Traditional procedures using diverse techniques such as automated mechanised collection and separation, hydrometallurgical, and pyrometallurgical processing are used. According to the Chinese E-waste management model, dismantling is one of the most favoured approaches for recovering assets from E-waste, followed by reciprocal integration between the informal (collection) and formal (recycling and recovery) sectors.

Furthermore, when it comes to purchasing e-waste from large users, the formal sector has certain financial difficulties. For acquiring any EEE that has achieved end-of-life status, formal sector operators are required to pay a 5% GST. When they sell recovered resources and commodities referred to as scrap, on the other hand, they are charged 18% GST. Many formal recyclers are concerned about the 13% GST difference between incoming and departing revenue. GST and demonetization have also been criticised by the informal sector for a drop in the quantity of e-waste they now receive. They further say that payments to local officials are still required for interstate transportation.

Mechanical separation is the initial stage in most regions of the country's E-waste treatment for metal recovery. Initially, the E-waste item is dismantled and crushed with bare hands, using instruments such as screwdrivers, pliers, chisels, and hammers. It is also subjected to metal and non-metal separation utilising a variety of methods, including magnetic, screening, eddy current, and density separation procedures. It is widely regarded as one of the most effective methods for recovering metals from e-waste on a global scale.

The separated E-waste scrap is subjected to leaching in acid or caustic substance in the hydrometallurgical technique. H_2SO_4, HNO_3, NaOH, HCL, and H_2O_2 are the most common solvents used. In open-pit acid baths, the Au and other metals are removed. Additionally, the leachate is isolated or concentrated to extract the metal using procedures such as solvent extraction, distillation, precipitation, cementation, filtering and ion exchange methods, and particle trading tactics. In India, the method is widely used in the majority of authorised recycling centres. Hydrometallurgy is favoured over pyrometallurgy for a variety of reasons, including a lower risk of toxic and dust emissions, efficient metal separation, and less waste. However, it still has a number of drawbacks, including long procedures that use a large quantity of chemicals and water, resulting in water pollution, unfavourable environmental conditions, and health risks.

Pyrometallurgy is a technique that includes heating a waste sample in an inert gas environment. By heating PCBs over coal-fired grills, the components are removed. Organic fractions like paper, wood, rubber, and plastics, among others, are decomposed at higher temperatures to generate volatile compounds that may be employed as a high-value chemical product like oil or as a source of energy generation in this process. Conventional techniques, on the other hand, are said to affect the environment by releasing secondary pollutants like dioxin and furan and disposing of unrefined and undesired materials in open areas and near water bodies. Such technologies are deemed unsustainable because they produce corrosive leftovers, consume a lot of energy, and have significant capital and operational costs.

2.4.2 Informal Sector

India is heavily impacted as a chaotic location for 95 percent informal recycling, which employs thousands of disadvantaged people in the country's metropolitan and semi-urban areas. It is one of the most vexing challenges that India is now dealing with. Informal recycling, often known as "Backyard Recycling," entails informal collecting, transportation, processing, separating, mending, refurbishing, and dismantling. Several garbage collectors from families, known as "Kabadiwalas" or scrap dealers, gather rubbish and buy and sell it to contractors and traders. E-waste is handled in a crude and unscientific manner, with around 25-30% of it being repurposed and the rest being dumped in open dumps, streams, channels, canals, and open places. Moradabad (Uttar Pradesh), India receives half of the PCBs sent from New Delhi, Mumbai, Kolkata, Bangalore, and Chennai. As a result, Moradabad was dubbed "Peetal Nagri," India's "Brass City." E-waste is typically disposed of in a primitive manner, i.e. in open landfills (UNDP, 2018). In the majority of India's recycling locations, these practices are blamed for a worsening air, water, and soil pollution issue. Seelampur, in Delhi, is the largest dismantling centre in the country.

Due to a lack of knowledge, strict laws, and the absence of cutting-edge innovation and technology, informal groups continue to recycle in tiny, crowded, and dangerous places utilising crude procedures such as open burning, manual cable stripping, acid leaching, and PCB smelting. Risky backyard recycling operations sway vulnerable social groups like children, women, and migrant labourers, resulting in adverse neonatal outcomes in women, reduced vital capacity in children aged 11 to 13, and issues related to thyroid functioning, hormonal imbalance, cancer, a weak immune and reproductive system, and other metabolic activities in the human body, eventually leading to occupational health hazards and also environmental damage.

Though this industry has prevented large amounts of e-waste from reaching landfills while employing millions of people, the environmental and socioeconomic dangers associated with non-scientific e-waste management must be addressed. E-waste from all around the country, as well as from certain Western countries, has been making its way to informal processing yards for a long time. In these informal setups, activities such as e-waste collecting, worldwide, national, and regional trade, disassembly, component separation, mending, refurbishing, metal recovery, and recycling are carried out. Many of them have been in business for more than three decades.

The structure of the informal sector and its inherent flexibility is its greatest asset, but it also poses a severe danger and challenge to the formal sector. Because it catches the majority of garbage created, its ability to retrieve waste from both individuals and businesses is crucial. Its network aids in the large-scale aggregation of garbage, making the trade more dynamic and profitable. While this is seen as a benefit to the industry, it poses a severe threat to the formal sector's capacity to compete, making e-waste legislation exceedingly difficult to execute.

The informal sector has an inherent element of opacity and illegality. Their capacity to vanish and reappear from the gaze of the law on short notice is a benefit to their activities, but this type of economic activity is also seen as a severe obstacle. The operators are forced to wear this veil of invisibility due to the illegality of their operations, which requires resolution and reconsideration by regulation. They are also seen as freeloaders and a societal concern, especially when they bear the brunt of environmental deterioration.

The state's regulatory and monitoring system is ill-equipped to deal with the issues posed by the informal economy. The state does not engage with the sector, despite the fact that it is aware of its existence, which may be due to the urban poor's lack of livelihood alternatives and the state's incapacity to address the issues surrounding urban poverty. The state's incapacity to adequately implement the legislation also encourages the formation of a parallel system that helps alleviate some of the waste management's apparent characteristics. The state's incompetence is further exemplified by its failure to act against some of the most polluting practises, which are openly carried out in clusters and possibly right under the regulators' noses.

The informal sector's improper manner of treatment and disposal has long been a problem. However, because of the informal sector's wide reach, its importance cannot be overlooked. When it comes to electrical and electronic equipment, the informal sector in India plays an important role in collection and classification. The time has come to re-evaluate and implement regulations that will bring this industry into the mainstream of e-waste management.

Low levels of knowledge among consumers and trash providers are one of the most crucial and critical reasons for the regulation's inability to take effect. There is a lack of awareness of the stakeholders and their roles in the e-waste management process. The majority of people are ignorant of how electronic items are managed towards the end of their lives. The producers, too, have been reluctant to fully take on this role. Citizens who are educated can assist in building informal networks by sending garbage to them and preventing them from engaging in some of the more hazardous procedures.

State	Number of authorized dismantlers and recyclers	State-wise capacity (mTA)
Goa	1	103
Jammu and Kashmir	1	165
Andhra Pradesh	1	480
Chhattisgarh	1	600
Himachal Pradesh	1	1,000
West Bengal	3	1,860
Odisha	3	3,680
Punjab	3	4,850
Madhya Pradesh	2	9,600
Uttarakhand	4	19,250
Telangana	11	41,493
Gujarat	16	49,053
Karnataka	71	52,722
Maharashtra	75	78,179
Haryana	28	87,378
Rajasthan	26	90,769
Tamil Nadu	24	97,271
Uttar Pradesh	41	243,627
Total	312	782,080

Table 2.3: Authorised recyclers in India

Parameter	Informal sector	Formal sector
Percentage of e-waste processed	90	10
General practices of e-waste processing	Rudimentary methods: Incineration, breaking, dismantling, dumping, etc.	Industrial recycling and dismantling using technically advanced methods
Current stakeholders	Dealers or retailers, unorganized recycling sector (local pawn shops, recyclers, dismantlers, etc.) contractual labour, localized vendors (kabadis)	Government, consumers, retailers, industries or organizations, registered processing units, NGOs and manufacturers
Binding laws	Not bound by any laws or regulations	Environmental laws, E-waste (Management) Rules, labour laws, etc.
Major functions	Collection, disassembly, extraction and dumping	Disassembly, extraction, recycling, treatment and segregation

Table 2.4: Informal v/s Formal sector in India

2.5 Issues and Challenges

Inadequate data on e-waste creation rates: The 2012 laws recognised the lack of waste inventories as a restriction and tasked state pollution control boards with compiling state-by-state e-waste inventories (SPCBs). Electronic product sales data, which is a key input in estimating e-waste volumes, is frequently accessible at the national level of aggregation, making state-level inventories difficult to create. E-waste is imported from industrialised economies, frequently illegally, in addition to local creation. There is a lack of knowledge on the type and quantity of e-waste coming into the country. System design for efficient trash collection, transportation, and processing necessitates a reasonable understanding of waste creation, composition, and flows.
Environmentally unsustainable informal sector practises: Despite the official dismantling and recycling industry's (number of such facilities) expansion, the amount of garbage handled in the formal sector remains quite low. According to anecdotal information, most of these formal facilities are running significantly below their allowed capabilities due to a lack of waste sources. Household and institutional customers are less eager to return their garbage to the official sector due to a lack of understanding about e-waste and the price of returning end-of-life equipment to formal collection centres. Most crucially, in comparison to the official sector, which has yet to invest in effective collection and processing systems, the informal sector, via the ease of household pickup and monetary incentives (even if nominal), makes it more appealing for consumers to return their garbage. Millions of individuals, many of whom are members of the most disadvantaged groups, rely on the informal e-waste industry for a living; yet, the sector's waste management techniques pose major environmental and health risks to both employees and the general public. This poses a possible moral issue for policymakers, and the long-term viability of any e-waste management system will be determined by our ability to overcome it.
Market frictions for end-of-life items include: The incapacity of private players, such as PROs, to build up e-waste management systems in the formal sector is hampered by the inability to consistently source e-waste amounts that produce economies of scale. Employing effective e-waste recycling methods, for example, may necessitate considerable upfront capital investments, which may not be justified for private firms in the lack of assurance about e-waste supply. These marketplaces are also hampered by a lack of information. First, because e-waste recycling is such a young industry, a lack of knowledge about cost-effective recycling

methods might be a market obstacle. Second, market functioning is harmed by a lack of consumer knowledge, which is partially due to a lack of credible information on e-waste disposal. Beyond the present e-waste restrictions, public policy may need to play a bigger role in allowing improved e-waste markets.
Inadequate legislative design and enforcement: The required take back system for producers in the 2012 legislation, without associated collection objectives, offered no incentives for producers to take responsibility and hence resulted in minimal progress in e-waste management practises. This was rectified in the 2016 revisions, which offered greater regulatory certainty by establishing progressive and progressively stringent collection objectives. Nonetheless, the regulatory structure throws a substantial strain on regulatory agencies that are already understaffed. Producers' EPR plans are likely to be reviewed by regulators, who will then give authorisation and enforce the plan's conditions. Other entities, including collectors, dismantlers, recyclers, and bulk consumers, were also subjected to detailed rules and protocols, which the agencies were required to implement. Environmental regulatory enforcement in India has long been plagued by regulatory capture by groups that profit from bad enforcement, a lack of transparency, and a refusal to openly share information on compliance and regulatory proceedings, and e-waste policies are no different. This presents a substantial public policy dilemma for the country's future e-waste management.

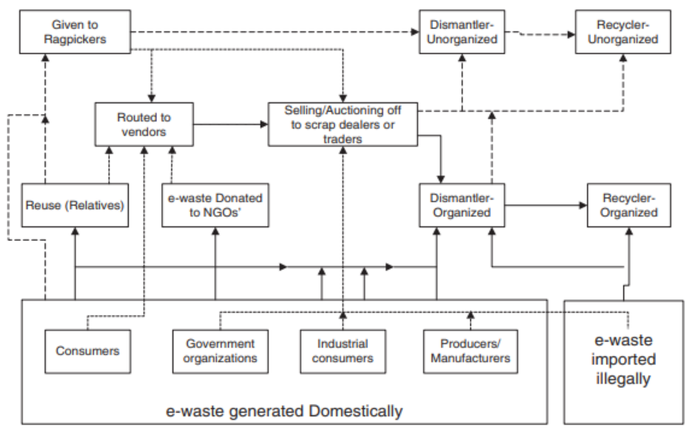

Figure 2.4: Flow of e-waste in India

2.6 What is Extended Producer Responsibility?

One of the most generally utilised ways for regulating e-waste internationally is the Extended Producer Obligation (EPR), which lays the responsibility for product end-of-life management on the makers or producers. EPR was created with the intention of forcing manufacturers to absorb the external expenses connected with their goods' end-of-life disposal. The Organisation for Economic Co-operation and Development (OECD) has two major EPR goals. To begin with, the EPR transfers some of the waste management responsibility from local governments to upstream companies. Second, by requiring the internalisation of the external costs of disposal, the EPR is supposed to offer incentives for businesses to include environmental issues into their product design. For example, if EPR forces manufacturers to absorb the societal costs of disposal after the useful life, they will be more motivated to create items that are more recyclable or less poisonous.
Producers can be held accountable in four different ways under the EPR method. Economic responsibility demands the manufacturers pay, often a tax, towards the expenses of e-waste processing (e.g., collection, recycling, disposal). Physical accountability entails requiring, for

example, that things be returned to users at the end of their useful life. Requirements for product return may also impose collection rate objectives. Information responsibility may entail disclosing product characteristics (e.g., toxicity, recyclability), as well as obligations such as product labelling. Finally, environmental harm and cleanup may be subject to financial liabilities under liability standards. Any one or a combination of these four types of producer duties may be included in EPR rules.

The E-waste (Management and Handling) Rules of 2011, India's first e-waste regulations, used the EPR approach and required electronic product manufacturers to set up collection centres (i.e., physical responsibility) and inform consumers (i.e., information responsibility) on how to return used electronic products to the collection centres. Early review of these guidelines found that while they may have increased demand for new official dismantling and recycling centres, the rules have mainly been ineffectual in changing the current practices. The government has revised the rules twice since then, partly in reaction to the first regulations' ineffectiveness: once in 2016 and again in 2018. These regulatory changes have created take-back objectives for manufacturers, requiring them to collect a particular percentage of the items they sold in the previous fiscal year. The take-back objectives increase from a modest 10% in 2017–2018 to 70% in 2023 and beyond.

Producers are responsible for collecting end-of-life EEE from consumers. Individual and bulk consumers are classified into two categories. Bulk consumers are defined as businesses that employ 20 or more people and have an annual revenue of more than Rs 1 crore, according to the Rules. Offices, departments, ministries, public sector enterprises (PSUs), and multinational corporations are examples of bulk or institutional customers (MNCs). Producers must also have legal agreements with recognised dismantlers and recyclers, which must be reported through their EPR plans, either individually, collectively, or through a Producer Responsibility Organisation (PRO). When applying for Extended Producer Responsibility Authorization (EPRA), an EPR plan must be presented to the CPCB. Collection stations, transportation partners, dismantling and recycling partners, website toll free numbers, details of upcoming awareness initiatives, and producer contact information are all included in the plan. Before awarding EPRA to a producer, the CPCB must approve the EPR plan. Source reduction (natural resource conservation/materials conservation), waste avoidance, design of more ecologically friendly goods, and closing of material loops to support sustainable development are the four main aims of EPR, according to the OECD. Administrative, economic, and informational mechanisms can all be used to achieve EPR. The way in which the EPR idea is adopted and applied varies from one programme to the next.

Switzerland is the world's first country to have a structured E-waste management system. The ARF technique is used in the current E-waste management system. The efficient handling of the e-waste stream by two producer responsibility organisations—The Swiss Association for Information, Communication, and Organisation Technology and Stiftung Entsorgung Schweiz—is largely responsible for the effective collection of E-waste in Switzerland.

Chapter 3

Global Practices

3.1 Global WEEE Management

In 2019, worldwide WEEE generation was estimated to be over 54 million tonnes (MT), up from 45 MT in 2016, with a global average of 7.3 kg/person/year. Over the next few years, this generation rate is predicted to expand dramatically, with total volume generated expected to reach 75 MT by 2030. Developing ways to successfully control WEEE on a worldwide basis is proving extremely difficult. Around the world, several WEEE management strategies and situations exist, with regional differences. W/EEE fluxes and movement can be complicated and interconnected, with many unaccounted for flows. Four common management scenarios, however, have been discovered and categorised.

The first scenario involves WEEE that has been legally documented and collected in compliance with existing WEEE/WEEE-related regulations. WEEE is often collected by municipal collection stations, EEE manufacturers and retailers, or through specific pick-up agreements in this case. WEEE is collected and transferred to specialised treatment facilities, where it is processed (including physical disassembly, shredding, and materials recycling) under strict criteria to guarantee that it is treated in an ecologically sound way (ESM).

The second scenario is defined by the direct disposal of WEEE in conjunction with mixed household garbage. WEEE is disposed of alongside non-segregated household garbage by consumers. Depending on the prevailing disposal procedures, the commingled garbage may be sent to a landfill or incinerated.

The third scenario includes the collecting of WEEE in an unauthorised manner. These operations may involve waste traders and dealers. Recycling of collected WEEE at specialised facilities, rehabilitation, or shipment to underdeveloped nations are some of the outcomes. Unlike the first scenario, collected WEEE in this scenario is not formally documented, making auditing and tracking creation and collected amounts difficult; this might be owing to a lack of legal requirements or a framework for WEEE management. As a result, the treatment of WEEE gathered may be harmful to the environment, or WEEE may be meant for illicit export.

The fourth scenario is more common in poorer countries and includes garbage brokers and scrappers collecting WEEE from customers informally. These operations are unregulated because of the lack of enforcement of WEEE management regulations. As a result, treatment procedures are frequently simple and primitive; usually, collectors look for metal elements in WEEE and use open burning and acid leaching to recover metals. This scenario, which includes WEEE reuse, repair, and cannibalism for components, is also common in Europe.

3.2 The Basel Convention

The Basel Convention is an International Environmental Agreement (IEA) that went into force in 1992 to regulate the trans-boundary flow of hazardous waste. It presently has 53 members. It focuses on limiting the migration of harmful waste from wealthy countries to emerging and developing countries (LDCs). WEEE's trans-boundary movement is covered by the agreement since it is known to contain trace levels of dangerous compounds. The Basel

Convention was born out of high-profile transboundary hazardous waste movements, most notably the 1988 incident involving an Italian transport of toxic garbage to Nigeria. The Convention enables hazardous waste to be transported as long as there is a bilateral or multilateral agreement on how the waste will be safely treated in the nations importing it. The Bamako Convention is an African convention that was signed in 1991 and took effect in 1998. It regulates the importation and transit of hazardous waste into and within Africa, similar to the Basel Convention.

3.3 Trans-Boundary Movement of e-waste

WEEE is transported across international borders on a worldwide basis. New and secondhand electrical and electronic items are included in the movements. UEEE is mostly shipped from developing nations in Europe, Asia, and America to less developed countries, where there has been a surge in demand for cheaper used electronics in recent years. Thousands of tonnes of WEEE are sent to underdeveloped and less developed nations, particularly in Africa and Asia, due to the difficulties in discriminating between UEEE and WEEE. Importing countries, many of which lack appropriate infrastructure for ecologically friendly WEEE handling, may find these shipments difficult.

E-waste transboundary flows have become a major source of worry for both exporting and importing countries. According to some research, the bulk of e-waste is transferred from the Northern Hemisphere to underdeveloped nations for informal disposal. Although the actual volume of e-waste movement is difficult to estimate since most of it is exported illegally or under the pretext of being meant for reuse or scrap, it is universally acknowledged that the volume is enormous, although a major portion of it travels through other means.

Transboundary e-waste transfers from developed to poor nations are a source of worry, both because they contribute to the environmental burden of the destination countries and because e-waste is likely to be managed by the informal sector.

As a result, e-waste management is carried out in an environmentally unsound way, posing substantial health and environmental dangers. However, current trends reveal that, in certain situations, e-waste shipments take a regional rather than a purely "North-South" path (e.g., from Western/Northern Europe to Eastern Europe). On the other hand, as the e-waste collection system improves in poorer countries, there is evidence that important components like Printed Circuit Boards (PCB) are being exported to the Northern Hemisphere for recycling. This is the case, for example, in Ghana and Tanzania.

And, whereas transboundary movements have traditionally been viewed as exports from the affluent to the poor, there are rising signs that previously well-regarded import nations like China are rapidly exporting e-waste to Southeast Asia, Africa, and other parts of the world. Transboundary mobility appears to be dynamic throughout time, reacting to changes in social, economic, and regulatory conditions. As a result of China's trash import prohibition, which has been in force since 2018, processing operations have shifted rapidly from China to Southeast Asian nations such as Thailand, Malaysia, and Vietnam.

International trade statistics currently does not differentiate between new and used EEE, and due to the illicit nature of the activity, illegal trade flows among nations are difficult to monitor directly. Used EEE or e-waste travels across borders at a rate of 7-20% of total e-waste created.

3.4 Comparison of E-waste Management Systems with Switzerland, Japan, and Germany

3.4.1 Effective and comprehensive legislation (L)

In India, the implementation of e-waste regulations has been a huge failure. With insufficient human, monetary, and technological capacity of pollution control boards, it has always been a big issue. As a result, a specific e-waste management institution, such as EAR in Germany, is required. India can work on the clearing house concept since the e-waste management system requires a legal and committed entity to control it. Producers, manufacturers, and importers in India should be encouraged to create specialised PROs such as SENS and SWICO in Switzerland. The vast number of producers, importers, and manufacturers (PIM) in India may require four or five PROs. Each PIM should be required to join one of the PROs. PROs will give data about their members to a clearing house, similar to the German system's clearing house (a new entity is proposed). Retailers, e-retailers, and the planned clearing house will get a list of member PIM from PROs. Retailers should only accept merchandise from PIM members. This would reduce the unaccounted EEE flow in the market and push every PIM to join PROs.

India, like Germany, must establish collection targets based on the put-on-market strategy. EPR is a notion that India has taken from Switzerland and other EU countries. In addition, the notion of DRS is included in India's new e-waste legislation, which includes collecting money from customers at the time of sale and repaying it during product disposal. Because it will be a problem in and of itself to keep the data of DRS and provide reimbursements every time a product is discarded, India should follow the simple and successful model of ARF as used in Switzerland. The ARF is a good way to raise money for recycling.

3.4.2 Collection mechanisms (CM)

In India, official sector collection is only 2% of total collection, whereas informal sector actors have a collection efficiency of over 95%. PuWaMA is required to collect e-waste in Germany. The clearing house and manufacturers provide them instructions. The German collection system, as well as the PROs system in Switzerland, must be benchmarked in India. PROs created can collaborate with municipal corporations (MC) and compensate them for improved collection efficiency. PROs should cooperate with MCs to coach and skill the informal channel players to work for them. PROs and the government should offer training and development workshops. PROs should have strong ties to other value chains, such as e-waste recyclers, retailers, and PIM members, in order to construct a seamless e-waste reverse supply chain. The proposed entity must allocate recycling objectives to recyclers. MCs must be empowered, informed, and taught to collect e-waste efficiently in India, just as they must be in PuWaMA.

Informal players in India have a collecting efficiency of 95%. As a result, the primary difficulty is to direct e-waste to a legitimate disposal method. When PROs support MCs and MCs are held accountable to PROs for e-waste collection, this will become a reality. There are a few specialised collecting locations in India (one in Mumbai, five in NCR). Despite the fact that e-waste recycling firms provide door-to-door pickup, customers are either unaware of such services or are hesitant to submit e-waste to them because of the low incentives they provide. Retailers in Switzerland (approximately 6,000 specialised e-waste collection locations) and Japan (about 380) provide collecting services. If consumers choose to deliver their recyclables directly to recyclers, they can be given recycling tickets, much like in Japan.

There is no infrastructure in place in India to assist the collection, processing, and recycling of e-waste. Switzerland and Japan, for example, built their infrastructure before implementing legislation. There is legislation in India, but there is no infrastructure to support its execution. All policyholders and tactics must pay attention to it.

3.4.3 Recycling and recovery rate (RR)

Japan has the greatest recycling rate (80%), owing to its emphasis on extracting value from materials. Its recycling systems are far more efficient than those in the United States. In India, there is a significant gap between e-waste creation and existing e-waste recycling facilities. Manufacturers in Japan are encouraged to establish recycling centres. As a result, India should look to Japan for ideas on how to improve its recycling infrastructure and resource recovery. Resource recovery is also necessary for the Make in India aim to succeed.
Landfill levies should be used to discourage the practice of filling landfills. Although India's solid waste policy opposes land filling, there is no distinct landfill regulation or charge to prevent it. To collect large fees on land filling, India could look to Japan as a model. Land filling is also quite expensive in Switzerland. As a result, India's present landfill laws must be changed to encourage resource recovery.

3.4.4 Customer involvement (CI)

Initiatives like PROs and DRS may encounter a number of obstacles until there is a better awareness or willingness among Indian customers to recycle e-waste through the official sector. Consumers in Germany, Switzerland, and Japan are aware of correct e-waste disposal methods and participate actively in e-waste management, however most customers in India are uninformed of e-waste disposal practices and their impact on health and the environment. As a result, customer involvement in e-waste management is minimal. In Germany, the PuWaMA is responsible for informing consumers of their responsibilities and informing them of the many choices available for returning and collecting e-waste in their area, as well as the environmental and human health consequences of inappropriate e-waste disposal. With the support of MCs, producers in India must also raise awareness among customers and garbage collectors about safe e-waste treatment.

3.4.5 Data availability (DA)

A key difficulty for India's e-waste management system is the lack of precise data on e-waste flows. Data on e-waste collection and recycling in EU countries is readily available. Data on the quantity of EEE sold in Germany and Switzerland, as well as the amount of e-waste collected and handled, is meticulously documented. All players, particularly the producers, submit data. By evaluating the recording systems used in Germany, Switzerland, and Japan, a full national level e-waste inventory data should be kept on a priority basis in India as well.

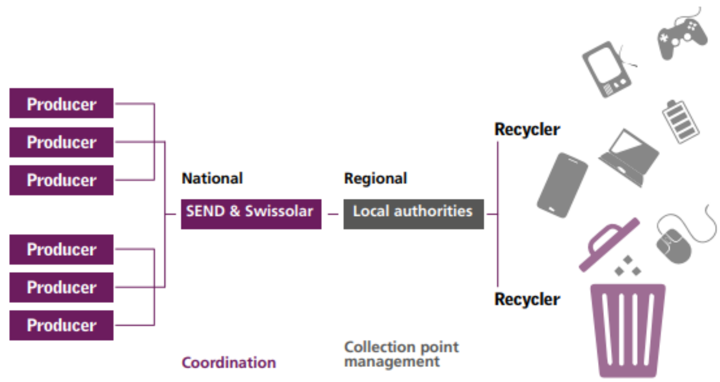

Figure 3.1: E-waste management in Switzerland

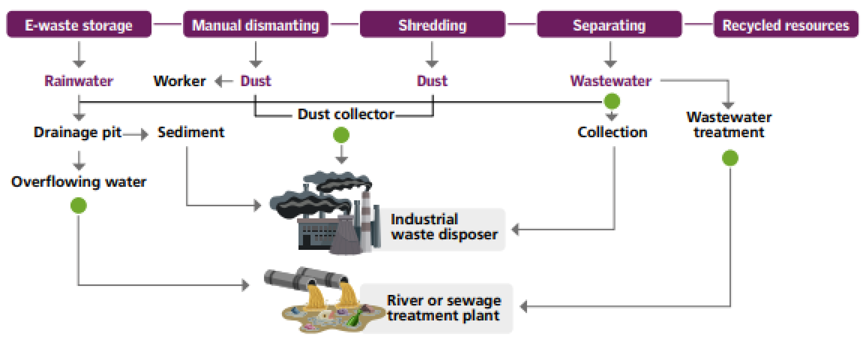

Figure 3.2: E-waste management in Japan

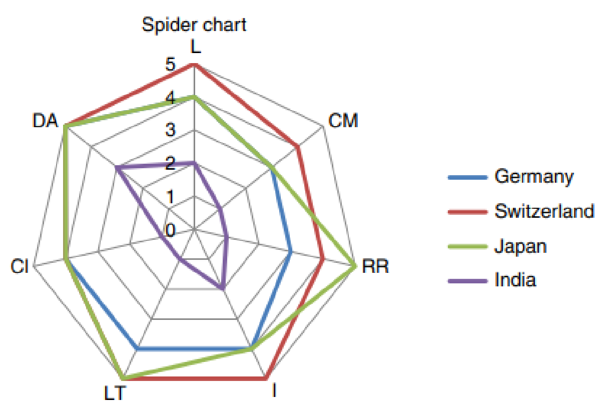

Figure 3.3: RADAR chart for comparison (LT=Landfill Taxes, I=Infrastructure)

3.5 WEEE and the Sustainable development goals (SDGs)

In 2015, the United Nations (UN) committed to an ambitious strategy for sustainable development in conjunction with Member States. By 2030, the plan aims to achieve 17 main objectives (SDGs), including eradicating poverty and creating long-term prosperity (United Nations, 2017). Waste management, among other things, is essential to achieving all 17 SDGs. Increased wealth will lead to greater living standards, which will, in turn, contribute to an increase in WEEE creation. WEEE management that is ecologically friendly helps to achieve all 17 objectives, but especially Goal 3: Good health and well-being, Goal 6: Clean water and sanitation, Goal 12: Responsible consumption and production, and Goal 13: Climate action.

Figure 3.4: Sustainable Development Goals

Chapter 4

Implications and Future Directions

4.1 Health and Environmental Implications

Infants and children have been a major focus of health impacts research due to their specific sensitivity and susceptibility to environmental toxins. Exposure to informal e-waste recycling has been linked to poor birth outcomes (stillbirth, premature birth, lower gestational age, lower birth weight and length, and lower APGAR scores), increased or decreased growth, altered neurodevelopment, poor learning and behavioural outcomes, immune system function, and lung function, according to studies. Several researches have looked at the influence of e-waste exposure on thyroid function in children, however the results have been mixed. A small number of studies have also revealed that exposure to informal e-waste management is linked to DNA damage, changes in gene expression, cardiovascular regulation alterations, premature start of blood coagulation, hearing loss, and olfactory memory.

Primary and secondary exposure to harmful metals like lead, for example, is mostly caused by open-air burning to recover precious components like gold. Fine particulate matter is produced during the combustion of e-waste, which has been related to respiratory and cardiovascular problems. While the health effects of e-waste are difficult to separate due to informal working circumstances, poverty, and inadequate sanitation, many studies conducted in Guiyu, a city in southern China, provide some insight. Guiyu is the world's largest e-waste recycling plant, and its citizens suffer from significant digestive, neurological, pulmonary, and bone disorders.

Workers in informal e-waste disassembly and recycling face a higher risk of injury due to a lack of occupational health and safety rules. Stress, headaches, shortness of breath, chest discomfort, weakness, and dizziness have all been observed by e-waste employees. DNA damage has been linked to exposure to chemicals in e-waste among people active in informal e-waste management or living in e-waste settlements. A small number of studies have found that exposure to informal e-waste recycling has negative impacts on liver function, fasting blood glucose levels, male reproductive and genital diseases, and sperm quality.

Over the last decade, there has been a significant surge in study on the health effects of e-waste recycling. Because of the limited populations studied, the range of chemical exposures evaluated, the variety of outcomes examined, and the absence of prospective long-term studies, it is difficult to determine if exposure to e-waste as a whole affects particular health effects. However, a rising body of evidence shows that there is a high danger of injury, particularly for youngsters who are still growing and developing. Lead, mercury, cadmium, chromium, PCBs, PBDEs, and PAHs are just a few of the substances found in e-waste that have been shown to have harmful effects on practically every organ system.

E-waste is a severe problem, and without an internationally accepted definition, the associated environmental and health risks cannot be handled on a worldwide scale. There is no special rule or regulation in India that addresses the e-waste problem; nevertheless, most of the dangerous compounds contained in E-waste are covered by "The Hazardous and Waste Management Rules, 2008" under the categories of "hazardous" and "nonhazardous" waste. E-waste is regarded like municipal garbage in most Indian cities, with no specific attention paid to operations such as collection, management, disassembly, and recycling.

The majority of E-waste collection, handling, dismantling, and recycling activities are carried out by unorganised or informal sectors that lack technical and infrastructural capabilities as well as knowledge of the serious consequences of E-waste handling and disposal on the environment and human health. The environmental effect and health risk connected with E-waste are quite substantial, resulting in natural resource deterioration and pollution, as well as the development of chronic illnesses in humans. Disposing and recycling E-waste has major environmental and occupational concerns due to the dangers involved.

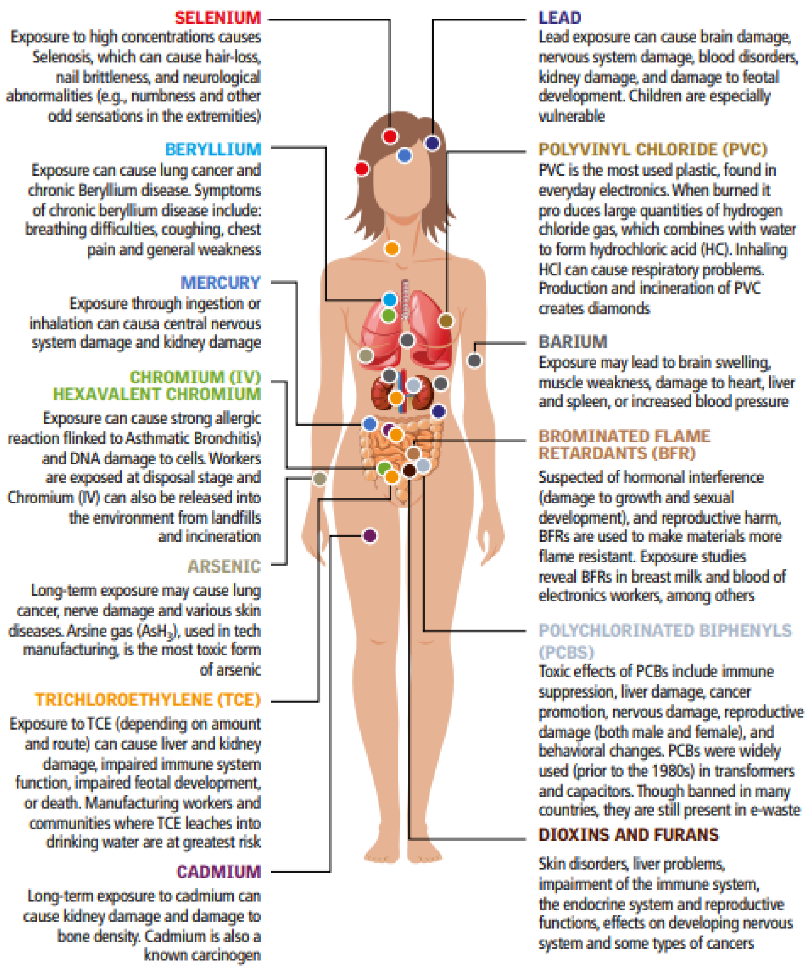

Figure 4.1: Effects of toxic substances found in e-waste

4.2 Economic Incentivisation (Circular Economy)

A global circular economy agenda can be planned by combining technical innovation for e-waste processing with financial incentives via multi-agency collaboration to improve rudimentary e-waste management in regions where waste piles up and toxic components of electronic products harm workers and the environment. Extended producer responsibility (EPR) is critical in the CE framework for closing the growing gap between the creation of e-waste and the recovery of limited resources like rare earth metals. Currently, EPR is governed by voluntary efforts mostly motivated by financial incentives. Economic incentives for resource recovery as a basis for EPR may not be sustainable, given the fast speed of technological innovation and shrinking of electronic items. Because of the necessity to handle diverse kinds of e-waste, including devices that do not include precious elements that may have justified resource recovery according to economic calculations, financing the infrastructure to assure e-waste collection can be successful with obligatory EPR.

EPR should start with a 'superfund' mechanism in which all electronic product manufacturers contribute financially, and manufacturers should be compensated for adopting green chemistry or eco-design principles that avoid the use of hazardous materials that endanger environmental quality and human health at any point in their product's life cycle. To be effective, the EPR superfund must also include end-of-life recovery of used products and reuse of recovered materials, with manufacturers contributing funds proportionate to the number of products sold, and an independent agency designing and implementing strategies for the worldwide collection, sorting, and recycling of defunct electronic products. This CE approach may be more feasible for big, readily marked and monitored electronic devices for which technical expertise of repair or refurbishment is not commonly available among workers in developing market nations engaged in resource recovery. Preventing hazardous and unprincipled rudimentary recycling is a priority for incorporation into the proposed EPR superfund and CE framework for this category of e-waste.

The recovery of obsolete and dilapidated electronic products from consumers is a major roadblock to proper e-waste management around the world. The Baidu and Recycling Brother (Huishouge) apps, which connect consumers who want to dispose of e-waste to certified services of recycling and dismantling companies, are pioneering the rising popularity of web-based applications for e-waste collection in China. The Baidu app was launched with the United Nations Development Programme (UNDP) Asia–Pacific Innovation Fund. There is further interest in building an alliance of stakeholders including electronics manufacturers and financial institutions\sto build a comprehensive online e-waste management process. Experiences from informal recycling collectives in Chinese industrial parks might be combined with Indian microfinance economic incentives in this way. The merger might lead to the creation of self-help group (SHG) parks, which would be overseen by environmental regulatory agencies.

The Sustainable Development Goals (SDGs) 8 and 12 of the United Nations provide a valuable framework for examining the numerous facets of collaboration required to reform informal e-waste management. The SDGs encourage policies that may create employment through public-private partnerships, diversification of high-value-added and labour-intensive sectors, protection of labour rights, and promotion of safe and secure working environments for workers, including minimising environmental and human health impacts, in line with the principles of a CE. According to the United Nations Environment Programme (UNEP), the information and communication technology industry, which is predominantly supported by electronic devices, presents several potential and difficulties for long-term development.

EEE is quite difficult to design from a material standpoint. EEE contains up to 69 elements from the periodic table, including valuable metals (gold, silver, copper, platinum, palladium, ruthenium, rhodium, iridium, and osmium), essential raw materials (cobalt, palladium, indium, germanium, bismuth, and antimony), and noncritical metals (aluminium and iron). The mining of e-waste should be regarded as a key source of secondary raw materials in the circular economy paradigm. Because of challenges such as primary mining, market price volatility, material scarcity, availability, and resource access, it has become vital to enhance secondary resource mining and minimise the need for virgin materials. Countries might secure long-term material demand reductions by recycling e-waste.

Only 17.4 percent of e-waste is formally collected and recycled throughout the world. Globally, collection and recycling rates must be improved. On the other hand, the recycling industry is frequently plagued with high recycling prices and material recycling issues. For example, the recovery of some elements, such as germanium and indium, is difficult due to their widespread use in goods, and the products are not designed or manufactured with recycling principles in mind. Base metals (such as gold) used in some gadgets, such as mobile phones and PCs, on the other hand, have a rather high concentration: 280 grams per tonne of e-waste. Separating and recycling e-waste can be cost-effective, especially if done manually with fewer than 5% material losses. For items having large concentrations and quantities of precious metals, separate collection and recycling of e-waste may be commercially viable. Nonetheless, most CRMs have a poor recycling rate, which may be increased for precious metals by better e-waste collection and pre-treatment.

In 2019, the overall value of chosen raw materials contained in e-waste was estimated to be around $57 billion USD, amounting to a total of 25 million tonnes. In 2019, iron, aluminium, and copper account for the bulk of the total weight of raw waste materials discovered in e-waste. Only in an ideal situation, when all e-waste created globally is recycled and the recycling of all selected raw materials is economically viable or even conceivable with existing recycling methods, could these quantities and material values be recovered. A significant number of secondary raw materials – precious, critical, and non-critical – may be made readily accessible to re-enter the production process by improving e-waste collection and recycling practises throughout the world, minimising the ongoing extraction of new materials. In 2019, the demand for iron, aluminium, and copper for new electronics was estimated to be at 39 Mt. Even if all of the iron, copper, and aluminium from e-waste (25 Mt) were recycled, the world would still need around 14 Mt of iron, aluminium, and copper from basic resources to make new electronics (11.6 Mt, 1.4 Mt, and 0.8 Mt, respectively). This suggests that there is a significant gap between the secondary iron, aluminium, and copper found in e-waste and the need for these metals in the creation of new EEE. This is a result of the continued development of EEE sales. With the present established official collection and recycling rate of 17.4 percent, e-waste has a potential raw material worth of $10 billion USD and 4 million tonnes of secondary raw materials may be recycled. When comparing emissions from their usage as virgin raw materials to secondary raw materials, iron, aluminium, and copper recycling helped save up to 15 Mt of CO_2 equivalent emissions in 2019.

However, many individuals in poor nations like India do not have access to the new EEE because of social and economic disparities with their counterparts in affluent countries. In developing nations like India, the significant price differential between new and used EEE encourages consumers to acquire used EEE. In India, there is a significant market for used EEEs. Unscrupulous organisations in wealthy countries take advantage of a loophole in the Basel Convention to export both working and non-working electronic equipment to developing countries like India. The E-waste recycling industry has become particularly appealing for small entrepreneurs due to the large demand for used EEEs and the minimal initial investment necessary to start a collecting, disassembly, sorting, or recovery operation. Rather than raising environmental or social awareness, the major motive for E-waste recycling facility owners in India is financial profit. This is why so many urban poor people work in the E-waste recycling industry. These folks are the least aware of the negative health and environmental consequences of poor E-waste recycling. The participation of women and children in recycling activities exacerbates the challenge of E-waste management. The E-waste recycling plants in India, on the other hand, offer a lot of potential for creating jobs. Poor individuals in the nation earn money by rescuing usable equipment, components, and materials from discarded WEEE. Because E-waste collection, disassembly, sorting-segregation, and recovery are primarily done by hand in India, this industry provides major job prospects in a number of places, particularly for the urban and illiterate poor. The number of unskilled labourers employed in recycling and recovery activities in Delhi alone is believed to be at least 10,000 persons. As a result, the E-waste recycling industry creates job possibilities and a source of revenue, which must be considered and handled while developing India's E-waste management system.

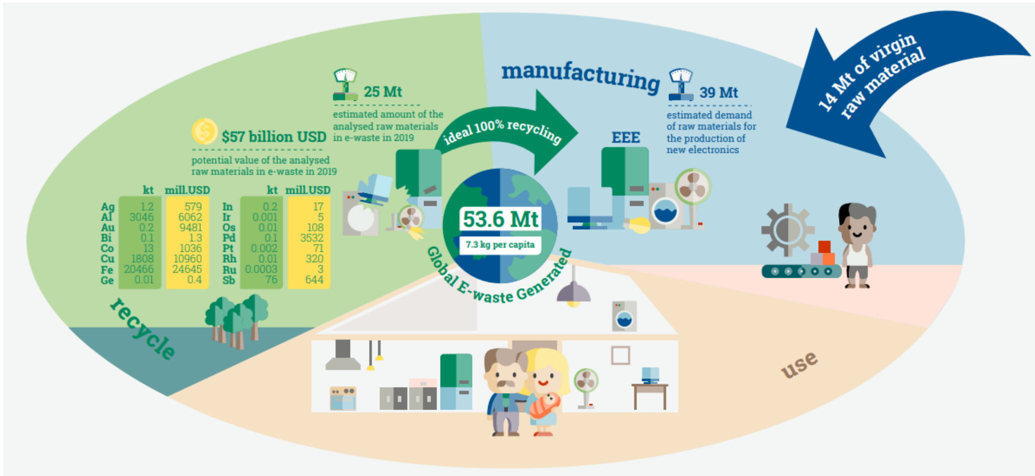

Figure 4.2: Economic implications of e-waste

4.3 Future directions

E-waste is an issue that requires expert attention. There is a need for more information on the amount of e-waste India produces each year. It's also unclear if we're bringing in e-waste as regulated rubbish or as 'used' stuff for refurbishment and re-export. Importing increases the difficulty of proper recycling and reprocessing. India has established regulations for effective collection and permitted recycling. However, the way these regulations are put into practise may be far better. Only a small percentage of the country's huge amounts of e-waste gets recycled at designated facilities. The informal sector's role in the recycling industry has to be repositioned so that it can offer cost-effective options while maintaining environmental safety and favourable working conditions.

This might start with an inventory of e-waste to better understand the management problem. The yearly reports submitted by SPCBs, which offer an overview of the quantity of e-waste created and received by approved recyclers, must be the starting point for this. 'Imported' e-waste and e-waste that does not make it to approved recyclers continue to have data gaps. These chasms must be bridged. After the NGT directed it to submit an action plan for implementation of the E-waste Management Rules in September 2019, the CPCB built an e-waste review site. All SPCBs and PCCs have been given passwords for the review portal and told to file quarterly returns on the NGT's orders. This is a big step forward. The whole reporting procedure has been divided into four timeframes, and the site has made it simple for SPCBs and PCCs to submit reports to the CPCB on time. However, according to the CPCB's most recent update in February 2020, just 29 SPCBs and PCCs had started implementing the action plan. Furthermore, neither the SPCBs nor the PCCs, nor the CPCB, have published any of these findings into the public realm. The collection and dissemination of data on e-waste creation and recycling is critical. CPCB should order state boards to link the 'permission to establish' and 'consent to operate'—granted for the establishment of such units—to the database. To improve and assure compliance, the MoEF&CC should collaborate with the GST Council and other entities.

Second, it is critical to ensure that e-waste imports are effectively monitored and that data on licences granted and the status of imported trash recycling is available. It is critical that 'used' material, which is freely imported, be controlled and that information be supplied via HS codes so that this material can be tracked in terms of quantity, places of use, and disposal. Third, it is critical to ensure that the terms of the E-Trash (Management) Rules 2016 are strictly monitored and enforced so that EPR objectives are reached and independent information on where the collected waste is 'recycled.' Verification of e-waste flow systems offered by producers in their EPR plans is required. The verification is currently document-based, with ground verification left for subsequent phases. To guarantee policy conformance and minimise the chance of inconsistencies, ground verification should be done before an EPRA is granted. The e-waste flow pathway is not well known. There is always the risk of e-waste being transferred to the informal sector for disassembly and recycling to save money due to a lack of ground surveillance. Because e-waste is one of the most lucrative waste resources, informal labourers continue to put themselves in danger. The formal sector does not have a cost advantage over the well-established network that the informal sector has built up through time. For the e-waste business to survive, it has to integrate the formal and informal sectors. There are a number of issues here that will need to be addressed with effective stakeholder mapping.

Fourth, it is vital to ensure that the health and environmental conditions of the country's informal e-waste hubs are monitored so that those who work there are paid for any negative impacts on their health. It's also important to make sure that electronic material manufacturers are held accountable for environmental toxicity caused by incorrect handling or leaks. The truth is that improper recycling of hazardous e-waste might result in an increase in the health burden.

Companies can propose improved and incentivized recycling solutions. Recyclers must pay a 5% GST and engage in a bidding procedure to get e-waste from various stakeholders such as producers, manufacturers, and bulk consumers. They are also responsible for e-waste transportation. This makes formal recycling economically unprofitable, and it's one of the reasons why the unorganised sector sees formalisation as a danger. The Ministry of Environment, Food and Climate Change (MOEF&CC) should address this at the policy level, developing programmes to encourage and improve the formalisation of the e-waste recycling industry.

Consumer awareness of e-waste has to be improved. Citizens do not consider e-waste to be a health issue, and many are unaware of its negative environmental consequences. Practically everyone, from RWAs and NGOs to ULBs with local presence, must be entrusted with the job of raising awareness. Producers should be required to provide legal warnings in their product marketing that explicitly outline EEE disposal practises.

Chapter 5

Summary

This paper introduces the concept of e-waste, which is followed by a basic breakdown of the components of e-waste, some sources of e-waste, and continues to discuss e-waste in the global context. Coming to the management of e-waste in India, it starts with the e-waste generation rate in India, and the expected annual growth in this statistic, along with a state-wise breakdown. The legislation related to e-waste in India is then discussed along with a basic overview of the rules that have been laid down. Then the stakeholders in the process are discussed along with their respective responsibilities, followed by the treatment and processing followed for e-waste management in India, including a distinction between the formal and dominating informal sectors. The issues and challenges faced when it comes to e-waste management are then discussed before diving into the concept of Extended Producer Responsibility as a leading management mechanism to approach this problem. The next chapter dealt with global practices, looking into general WEEE management trends around the World, with a brief introduction to the Basel Convention and the main issue it addresses, transboundary movement of hazardous e-waste. This was followed by a slight peek into an e-waste management system comparison of India with Switzerland, Japan, and Germany, Switzerland having the best approach. The chapter ended with a correlation between WEEE and the Sustainable Development Goals. The final chapter dealt with the impacts of e-waste on the health and environment of all those in the vicinity of the management hotspots. This was followed by a look into the possible economic incentives that can be added to the process along with a brief look at the current global market based on the implementation of a circular economy and the chapter was ended with some possible changes that India can look to make when it comes to the management of e-waste, with a focus on the informal sector.

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