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Assessing India's WEEE Landscape: Challenges, Opportunities and Future Strategies

Hardik Siriah, Nikeeta Chahande, Priyadarshini Chahande

Masters' student, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, 412 96 Gothenburg, Sweden
Program manager, NewEarth B (York, Maine, USA), 141 52 Stockholm, Sweden
Professor, Department of Chemistry, Sevadal Mahila Mahavidyalaya, Nagpur, Maharashtra 440024, India

ABSTRACT: The electrical and electronic equipment (EEE) industry has been at the epicenter of the rapid advancements seen in the world of technology. This has also elevated concerns regarding management of the resultant waste electrical and electronic equipment (WEEE) commonly referred to as electronic waste (e-waste). The aim of this review is to provide a comprehensive overview of global e-waste management particularly focusing on the WEEE ecosystem in India. The article includes important aspects related to WEEE like the production levels, the categorization and composition and later shifts to comparing the statistical data trends in India vs the global level. Recent years have also seen the development of numerous innovative approaches and tools to help strategize WEEE management. The article discusses how some of these latest strategies could be applied in the context of emerging economies like India.

KEY WORDS: E-waste, E-waste management, waste electrical and electronic equipment, sustainability

I. INTRODUCTION

Electrical and electronic equipment (EEE) manufacturing has become one amongst the rapidly emerging global activities. Economic growth coupled with urbanization and globalization are the major factors responsible for the rise in consumption and manufacturing of electronic equipment [1]. With the fast-paced progress seen in this industry, their waste stream is also considered as one of the fastest growing waste streams around the world [2]. The description of Waste electrical and electronic equipment (WEEE) (commonly referred to as e-waste) is done as- those electrical and electronic appliances whose value to their owners have ceased. This includes electronic goods such as computers, television, cell phones, etc. world [2]. The Basal Convention on Action Network [3] defines e-waste as *"E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air-conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users"* [4]. There's been a continuous introduction of new products in the information and communications technology sector as well as electronic products in general which has also caused the old products to become obsolete [5],[6]. The past years have seen a rapid introduction of features like new and smart technology and design because of which old electronic equipment faces quick eradication from the market. The overall lifespans of electronic equipment have shortened owing to the advancements, marketing and customer needs [7],[8]. With advancement in lifestyles and the worldwide economic progress, an exponential rise in the e-waste generation has been seen whilst causing a rising concern about their impacts on human health and the environment [5],[9],[10]. E-waste management in the 21st century is thus regarded as one of the largest global challenges with the possibility to cause serious damage to human health and the environment [5],[11],[12].

II. GLOBAL WEEE GENERATION

WEEE represents the largest source of waste with the highest growth rate per year. The WEEE disposed of each year amounts to around 30-50 million tons, with an annual growth rate of 3-5% [13],[14]. In the year 2019, more than 54Mt

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of WEEE was accumulated on a global scale. This accounted for a global average of 7.3kg/person/year [15]. Out of the total global e-waste generated in 2019, around 83% of it was never documented which indicates that it was burnt or dumped illegally, which would have caused serious threats to health and environment. Only the remaining 17% of this e-waste in 2019 was properly collected and recycled [5],[16]. Global e-waste monitor stated that in the present year 2024 the global e-waste generation has crossed the mark of 65 billion tones [17]. The graph in **(Figure 1)** shows the amount of e-waste that was generated vs. the amount that was recycled from the year 1996 to 2023 [17, 18]. According to estimations, a volume of 75 Mt would be reached by 2030 if this trend continues [15]. While these accumulation numbers are rising, unfortunately there has been no significant rise in the WEEE recycling rates. The recycling numbers across different regions being as follows- Europe recycles around 42.5% of its waste, Asia recycles around 11.7%, America at 9.4%, Oceania at 8.8%, and Africa at 0.9% [15]. The e-waste generation numbers in 2019 across different continents are as follows- Asia (46.4% in the world), America (24.4%), Europe (22.4%), Africa (5.4%), and Oceania (1.3%). Amongst all the continents, Asia was the highest e-waste generator, however the waste generation numbers per inhabitant were the least (5.6 kg/inh) due to the large population levels of 4.4 billion. The lowest e-waste generation per inhabitant was that for Africa at 2.5 kg/inh [19]. One good approach to tackle e-waste is recycling. It is also a valuable source of many raw materials including glass, plastics and metals. Recycling e-waste is, however, a difficult task since the composition and properties of the components of e-waste are very heterogeneous [6],[20].

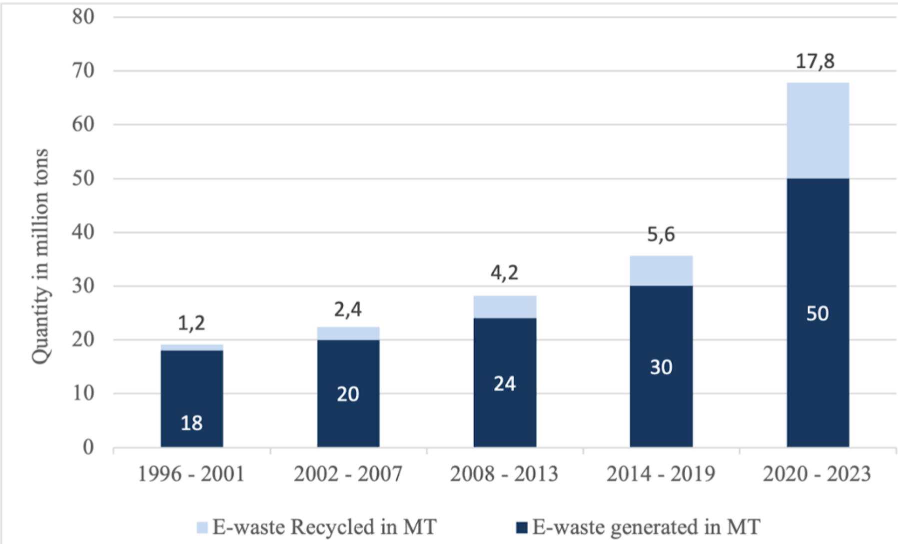

Figure 1: E-waste generation and recycled e-waste quantity from 1993-2023 [17, 18].

The WEEE is composed of precious metals like silver, gold, palladium and rare earth elements. WEEE can be regarded as a profitable method for sourcing secondary supply of precious metals. This offers a wide potential to its effective management and recycling. While WEEE contains valuable components it's management process also have the possibility to pose serious impacts on the environment [15]. This demands the need to undertake special measures when it is being discarded or recycled. The international scientific community agrees that it is essential to have an optimized system for waste management for achieving environmental, social and economic benefits [13],[14]. Handling WEEE is an essential challenge towards achieving sustainability [13],[21]. And thus, its proper management becomes important to ensure that it causes no threat to human health and the environment. An effective WEEE management strategy should include the aspects from all the processes of formal and informal recycling, collection, sorting, repairing and reusing, treatment methods wherever possible, End of Life (EOL) methods to eliminate toxic materials, recovery of valuable components along with the disposal of the toxic and non-recyclable waste in an environmentally safe way [15].

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III. CATEGORIZATION AND COMPOSITION OF THE WEEE

The composition of WEEE is extremely complex. Most of the EEE appliances are manufactured using printed circuit boards (to increase performance and functions of the equipment), also including many other different parts that are used in production. As a result of this, WEEE has become a complicated form of waste among the other types of solid wastes. Broadly, e-waste contains steel constituents 50%, copper, aluminum and other metals 13% and plastics 21%. While the amount of hazardous substances is 2.07% [2]. WEEE is also considered a bulk source of precious metals such as gold, silver, platinum and palladium. WEEE also contains the presence of critical materials such as antimony, barium, copper, cobalt, cerium, etc. The recovery of precious metal from e-waste thus provides a great business opportunity [13]. WEEE categorization is again complex as it contains lots of substances that can be classified as hazardous or non-hazardous substances. The materials that are classified as toxic or hazardous contain various heavy metals such as mercury, lead, cadmium and various organic chemical compounds [2].
The Waste Electrical and Electronic Equipment Directive (WEEE Directive) has been impactful in this regard. This Directive concerns the responsible disposal of WEEE by their manufacturers and distributors. It is the European Community Directive [22], numbered 2012/19/EU. Along with the RoHS Directive [23] 2011/65/EU, it became European Law in February 2003 [24]. The directive imposed collection, recycling and recovery targets for all the categories and types of electrical goods, with a minimum rate of 4 kilograms (9 lb) per head of population per annum recovered for recycling by 2009. The directive has also set restrictions upon European manufactures regarding the material content of new electronic equipment to be launched in the market. As per the 2019 updates in this directive, the WEEE is categorized into 10 types as stated in table (Table 1). [24, 25]

Table 1. EU directive list for different categories of electrical and electronic equipment (EEE) [24]

Sr no	Category	EEE take may fall under the category
1	Large household appliances	Large cooling appliances, Refrigerators, Freezers, Clothes dryers, Dish washing machines, Cookers, Electric stoves, Electric hot plates, Microwaves, etc.
2	Small household appliances	Vacuum cleaners, Carpet sweepers, other appliances for cleaning, Irons, Toasters, Fryers, Electric knives, Appliances for hair cutting, hair drying, tooth brushing, shaving, massage and other body care appliances, etc.
3	IT and telecommunications equipment	Centralized data processing, Mainframes, Minicomputers, Printer units, Personal computing, Copying equipment, Electrical and electronic typewriters, Pocket and desk calculators, Facsimile machine (fax), Telephones, Cellular mobile phones, etc.
4	Consumer equipment and photovoltaic panels	Radio sets, Television sets, Video cameras, Video recorders, Hi-fi recorders, Audio amplifiers, Musical instruments, Photovoltaic panels, etc.
5	Lighting equipment	Fluorescent lamps, High intensity discharge lamps, Low pressure sodium lamps, etc.
6	Electrical and electronic tools	Drills, Saws, sewing machines, Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials, Tools for nailing, screwing or removing rivets, nails, screws or similar uses.
7	Toys, leisure and sports equipment	Electric trains or car racing sets, Hand-held video game consoles, Video games, Computers for biking, diving, running, rowing, Sports equipment with electric or electronic components, Coin slot machines, etc.

8	Medical devices	Radiotherapy equipment, Cardiology equipment, Dialysis equipment, Pulmonary ventilators, nuclear medicine equipment, Laboratory equipment for in vitro diagnosis, Analyzers, Freezers, Other appliances for preventing, monitoring, detecting, treating, alleviating illness, injury.
9	Monitoring and control instruments	Smoke detector, Heating regulators, Thermostats Measuring, weighing or adjusting appliances for household or as laboratory equipment and other monitoring and control instruments used in industries.
10	Automatic dispensers	Automatic dispensers for hot drinks, automatic dispensers for hot or cold bottles or cans, automatic dispensers for solid products, automatic dispensers for money, all appliances which deliver automatically all kinds of products.

E-waste is thus a rising concern since it is composed of many types of substances that are hazardous and can damage human health and the environment [7],[26]. The common disposal methods used for e-waste disposal are landfilling and incineration. Both these methods can cause serious contaminations. The leachates from the landfills can contaminate groundwater with toxic substances whereas incineration in a combustor can pollute the atmospheric gases [7]. Typically, there are around 1000 toxic substances [5] in e-waste, however, the most common are- toxic metals like cadmium, barium, beryllium, copper, chromium, cobalt, lead, iron, lead, lithium, lanthanum, manganese, mercury, nickel, silver, molybdenum, along with persistent organic pollutants [7]. E-waste is known to impact human health in two major ways- i. contamination from the processes of recycling and disposal that causes toxic substances to enter into the food chain and further in humans. ii. occupational exposure to toxins to the workers handling these processes of recycling [7]. The presence of heavy metals in e-waste made it indifferent to the municipal biodegradable waste as they not only hamper the bio-degradation process but also harm the human health and environment [27]. People working in the e-waste treatment process are directly exposed to these metals while carrying out the recycling process and are mostly affected. The WEEE toxins can also affect aquatic life and the water system. Contaminants can enter the aquatic system through soil leaching from landfilling sites. Similarly, the disposal of acid by hydrometallurgical process into water or soil, as well as the dissolution or settling of airborne contaminants, can also result in contamination of aquatic systems [28]. Several case studies have been performed in China and Ghana that have confirmed the effects of e-waste toxicity to human health both in terms of chronic as well as acute conditions. The exposure to contaminants like heavy metals and persistent organic pollutants (POPs) released from e-waste treatment processes have the potential to cause major health risks to the on-site workers and the local inhabitants nearby especially women and children [7].

IV. WEEE SCENARIO IN INDIA

In India, the definition of e-waste is as mentioned by the E-waste (Management) Rules of 2016—issued by the Central Pollution Control Board (CPCB)- *"electrical and electronic equipment (EEE), whole or in part, discarded as waste by consumers (individual or bulk) as well as rejects from manufacturing, refurbishment and repair processes".* E-waste is identified as all the EEE items that have been used and are no longer fit for their originally intended use which are ready to be discarded [29],[30]. India being one of the fastest emerging economies of the world has caused the country to top the numbers for WEEE generation when compared to other countries [31]. There are however very few sources that have the accurate number for quantifying the e-waste generation in India [29]. India falls in the top 5 e-waste producing countries in the world. The annual e-waste production levels of India are 2 million tons [32]. As per the *Global E-waste Monitor, 2020,* 3.2 million metric tonne (mMT) of e-waste were generated in India in 2019 with metropolitan cities like Mumbai, Delhi and Bangalore leading the list [29]. [Electrical and Electronics manufacturing in India, ASSOCHAM & NEC Technologies, 2018] [33]. The generation numbers for the year 2018 were at a staggering 2.86 mMT and 2.22 mMT in 2016 [29]. [Electrical and Electronics manufacturing in India, ASSOCHAM & NEC Technologies, 2018]. The global e-waste monitor report 2020, has placed India as the world's third largest e-waste generating country right after China and the US [34]. There has been a 43% rise in India's e-waste generation between the years of 2018 and 2020. It has been

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predicted that by 2050, India could be generating more than 161 million tonne of e-waste [35]. The *Electrical and Electronics Manufacturing in India, 2018*, report by ASSOCHAM, and NEC technologies India Pvt Ltd have reported the percentage distribution by states towards the country's total e-waste generated. The chart is led by Maharashtra with a percentage contribution of 13.9%, followed by Tamil Nadu at 9.1%, Andhra Pradesh 8.7% and Uttar Pradesh at 7.1%. These numbers indicate that EEE penetration is the highest in urban and peri-urban areas in the country [35]. Out of the entire e-waste generated in the country, the maximum portion is contributed by large households (42%), followed by the Information, Technology (IT) and Communication sector (33.9%) [36]. It is also interesting to know that on a global level the Indian IT sector is one of the leading contributors to e-waste. The Indian e-waste component distribution is as follows- 37% is glass waste, 33% is constituted by metallic waste, while 30% comes from the plastic waste [29],[16]. According to the Schedule I of the E-waste (Management) Rules, 2016, in India, EEE equipment has been classified into two categories of- Information, technology and communication (ITEW) and Consumer electrical and electronics (CEEW) [29]. Interestingly, in India, around 80% of electronic items usually get stored because of the presence of confusion about dealing with them. These become part of what can be referred to as the electronic junk which lies unattended in homes, workplaces etc. Later, these get mixed with the various household wastes and then usually end up in landfills [37].

V. WEEE- THE WORLD AND INDIA

E-waste and the resultant pollution are a global problem. According to the UN data, the global e-waste generation is expected to increase by 40 million tons every year. The atrocity of e-waste is not limited to landfill pollution, but also extends to causing severe chemical leaching into the ground water tables. This is especially harmful to health since these toxins enter agricultural lands and their produce, finally making their way to humans. Asia being the largest continent of the world (4.6 billion total population), experiences a constant growth in the demand of EEE. Asian countries roughly generate 25 million metric ton of WEEE a year with China (63%) and India (14%) being the largest contributors [17]. **Figure 2** shows the percentage distribution of top e-waste generating Asian countries.

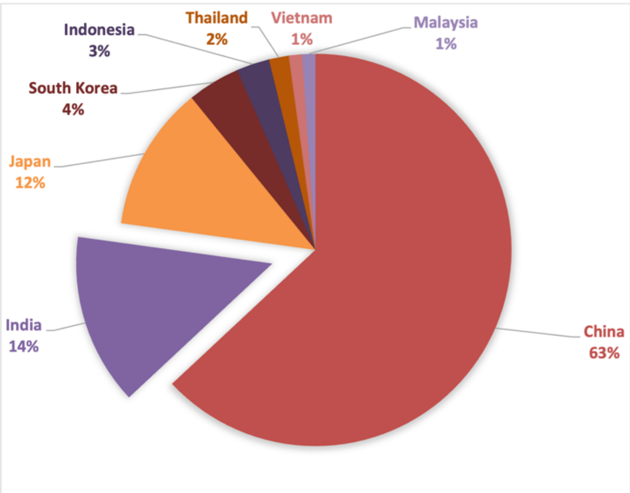

Figure 2: Percentage distribution of top e-waste generating countries in Asia [17]

With the rise in the utilization of electronic equipment all over the globe, the amount of e-waste being generated has always been on an enormous rise. For the informal sector workers in many developing nations, recycling valuable metals like gold and silver has become a good source of income. But the techniques used like burning copper cables to extract and retain the inherent copper can cause exposing adult and child workers to toxic substances. Consider an interesting scrap management situation in certain villages in India like Seelampur. In such villages, there are scrap markets where e-waste piles are separated for recycling. Copper from the wires is separated after their burning. This can contribute to major respiratory problems since plastic and Poly vinyl chloride (PVC) codes produce noxious smoke. Hence e-waste management in the developing countries needs monitoring and good levels of organization to ensure that the health of the informal sector workers is not jeopardized as well as they do not lose out on their source of income [37]. The lack of

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proper E-waste management rules and regulations has significantly impacted the ecosystem in the Asian and south Asian region. Developing countries in general, for example India and China, are gripped by the problem of e-waste accumulation that is dumped by the developed countries. Substantial quantities of used electronic items are sold to these countries in the Asia Pacific region as a result of which residue accumulation in poor areas increases. These areas are also not governed by strict environmental laws and hence, aggravating the problem. This is one of the ways by which the toxicity filled residues of the developed world makes its way into the poorer nations of the world [1].

VI. WEEE IN THE INDIAN UNORGANIZED SECTOR

The informal sector can be regarded as the backbone of e-waste recycling in India [29]. The informal sector in India recycles around 90-95% of the e-waste in the country [38],[1],[32]. Many of these have been operating for three decades now. In the informal setups, the major operations carried out are- collection, trading (including national, international and regional), component segregation, repairing, refurbishing, recovery of metals along with recycling. The destination of the recovered and recycled materials differs from and depends on buyer to buyer [29]. This unorganized sector is mainly composed of the urban slums in both metro and mini-metro cities. Here the unskilled employees carry out the recycling activities by using very primitive ways. These workers and recycling businesses are out of the governance of any health or environmental regulations. The workers involved are thus subjected to toxic working conditions where they use no protective measures or safety standards. The most dangerous threats for these workers happen to be the released gases, acids, and toxic smoke. Since many of these workers operate from their homes, they also expose their families and the people living nearby to these toxic releases. This is a usual case when working with extracting metals from circuit boards. Here, gas torches are used to heat the boards to the needed extent where the solder melts to separate the metal parts [39],[1]. Nonetheless, these workers are at risk of facing other workplace hazards like respiratory issues, physical injuries, skin diseases etc., [39]. The unscientific and primitive methods used by the informal sector have been the major point of challenge. It should however not be forgotten that the informal sector has an immensely complex and abundant outreach, which cannot be disregarded. When it comes to EEE, the informal sector immensely contributes to the key tasks of collection and segregation. What is needed now is re-evaluation and introduction of policies that will ascertain the inclusion of this sector into the mainstream business activities of e-waste management system [29]. *Rama Mohana R. Turaga, 2019 et. al.[32]* have identified some challenges that need to be addressed in the informal sectors with regards to the e-waste management system- The biggest advantage that the informal sector has is the established complex structure and the scope of flexibility. This sector is capable of accessing and collecting waste from both individual spaces and workplaces. The large network that this sector is based on is highly advantageous for maintaining streamless waste flows. However, this direct competition from the unorganized sector poses a great challenge to getting the formal sector activities functional. The invisibility of the unorganized sector is yet another challenge. It is important to provide recognition to the collection and transportation processes brought about by this sector. This is majorly challenging since it is difficult to define the waste aggregation activities as being hazardous because forward supply chains of goods having the same material composition are not regarded as being hazardous. The unlawfulness associated with this sector also needs attention. The nature of their business activities makes them capable of disappearing and then re-establishing themselves within a short time frame, all while not being noticed by the laws is a serious challenge [32].

VII. WEEE IN THE INDIAN ORGANIZED SECTOR

The recycling activities by the organized sector began in the year 2009 and constitute only 10% of the total recycling process. The major challenges faced by the organized sector in India is the absence of good collection and disposal methods and relevant appropriate technologies. The already established and functioning unorganized sector also poses a competition to the implementation of the organized sector activities [40],[1]. Because there are no dedicated collection systems, often homes and workplaces tend to accumulate obsolete products. These often get resold and hence a very small percentage of them end up getting recycled [40]. The recycling methods in the formal sectors utilize environmentally safer processes. The major clients of the formal sector recyclers are multinational companies which do not want their products to enter the gray market. It is also good to note that the working of the organized and the unorganized sectors is thus different. The informal sector usually would prefer refurbishing and selling a computer. For them, selling any parts of a computer that are functional would be a better opportunity to earn money rather than selling them as metal parts[40],[1]. The formal sector also has some financial constraints when it comes to collection of e-waste from the bulk consumers. A 5 percent GST has to be paid by the formal sector operators when they procure any EEE that has reached the EOL. Whereas, while performing the activities of selling recovered resources (scrap), they are charged an 18 percent GST [29],[36].

VIII. POLICY LEVEL INITIATIVES IN INDIA

Given the harmful effect of hazardous and toxic waste to both environment and health, several countries exhorted the need for a global agreement to address the problems and challenges posed by hazardous waste. However, the initiatives at the policy level concerning e-waste management in India are quite rudimentary and need immediate attention. Following are some of the policy level initiatives in India regarding E-waste [1], [41] [42].

1. The Hazardous Wastes (Management and Handling) Amendment Rules, 2003 Under Schedule 3, E-waste is be defined as "Waste Electrical and Electronic Equipment including all components, sub-assemblies and their fractions except batteries falling under these rules". The definition provided here is similar to that of Basal Convention. E-waste is only briefly included in the rules with no detailed description [43, 44].
2. Guidelines for Environmentally Sound Management of E-waste, 2008.This guideline was a Government of India initiative and was approved by Ministry of Environment and Forest and Central Pollution Control Board. It classified E-waste according to its various components and compositions and mainly emphasizes the management and treatment practices of E-waste. The guidelines incorporate the concept as "Extended producer responsibility" [42, 43, 45].
3. The e-waste (Management and Handling) Rules, 2011. This is the very recent initiative and the only attempt in India meant solely for addressing the issues related to E-waste. According to this regulation, 'electrical and electronic equipment' means equipment which are dependent on electric currents or electro-magnetic fields to be fully functional, and 'e-waste' means waste electrical and electronic equipment, whole or in part or rejects from their manufacturing and repair process, which are intended to be discarded. These rules are meant to be applied to every producer, consumer or bulk consumer involved in manufacturing, sale purchase and processing of electrical and electronic equipment, collection centers, dismantlers and recyclers of e-waste. Responsibilities of producers, collection centers, consumers, dismantlers, recyclers etc. are defined and incorporated in these rules [46, 47].

IX. DISCUSSION OF LATEST STRATEGIES AND APPROACHES IN INDIA

According to the Central Pollution Control Board of India (CPCB), a total of 569 recycling centers are set up all over the country with a recycling capacity of 1.7 million tons per year [17]. India has created appropriate rules for ensuring the proper collection and authorized recycling. There are, however, certain loopholes that can be spotted in the implementation of these rules and hence need attention. Only a small percentage (roughly 25%) of the enormous amount of e-waste that the country generates actually ends up for recycling purposes at the authorized centers [17]. It is also the need of the hour to recognize the urgency to reposition the informal sector activities in the recycling business systems. The goal for repositioning should be to ensure cost-effective opportunities while maintaining environmental safety and adept labor conditions [29]. The report published in 2020 *"E-waste management in India: Challenges and Agenda, Centre for Science and Environment" has* recommended the following agenda- i. Inventorizing e-waste: Gaps have been identified in the data regarding the imported e-waste and the e-waste that fails to reach the authorized recyclers. It is important that these gaps are closed and attended to. It is also important that the data regarding e-waste generation and recycling is made public. ii. Strategies that can ensure proper monitoring and regulation of e-waste imports are also important. iii. Stringent monitoring of the provisions of the E-Waste (Management) Rules 2016: This will ensure that the targets related to the Extended Producer Responsibility (EPR) are effectively met. This should also involve the verification of the e-waste flow systems as proposed in the EPR plans. An absence of ground monitoring increases the chances of e-waste diversion to the informal sector. Thus, a proper integration system for the informal and the formal sectors is of prime necessity. It has been suggested that a national-level strategy could be a possible way to ensure proper benefits are provided to all of the stakeholders involved in the entire management system. iv. The report also suggests that overlooking the environment and work conditions at the country's informal hubs is necessary. The people working within them should also be entitled to good compensation for any adverse health effects. Producers of the electronic

materials should also be held responsible for any environmental toxicity or leakages caused due to the improper handling. v. The informal sector perceives the formal sector as a threat. The formal sector also functions in ways that make it extremely economically unproductive. The major reason for this is the need for recyclers to be part of bidding processes to acquire e-waste from stakeholders. These could be major issues that should be tackled wisely. vi. Lastly, the report also suggested that it is important to raise awareness among consumers. Citizens should be educated about the health hazards of e-waste, so they understand the environmental implications of the EEE [29].
Lakshmi S. *et. al* 2017 [37] in their article have also discussed how at industrial levels, it becomes important that the management of e-waste is overlooked right from the stage of its production. This can also be achieved through techniques like minimization of waste and sustainable product design. Here an important part could be achieved in the process of inventory management in industries. This is the step which usually involves the controlling of materials needed for the further manufacturing processes. This can be a good stage to control and limit the use of toxic/hazardous materials utilized in the processes. There can be two ways to approach the inventory management stage- one is by reducing the amounts of toxic substances used and the other is by controlling the act to stock and store excess raw materials in the stock. Both these steps can ensure that the waste generated gets significantly reduced.
In recent years, researchers have discussed many new tools and techniques that could be used to achieve circular economic and sustainable WEEE management. One such significant tool for tackling WEEE is the Material Flow Analysis (MFA). This analytical tool can address the complicated material structure of the WEEE process. MFA has been recognized as a sound decision support tool especially in resource and waste management. A typical WEEE MFA includes four primary steps- i. identifying the key MFA areas of concern ii. determining the relevant indicator elements, system limits and matter process iii. mass flow of matter and indicator compounds and lastly iv. identifying the weak areas of the entire MFA system [15]. In their article Madhav A. RR. S. *et. al.* [33], have proposed yet another innovative Artificial Intelligence (AI) tool for enhancing the e-waste collection processes. The authors discussed an E-Waste robotic system for the purpose of identifying and collecting household electronic wastes. The authors have proposed a mobile robot system that can identify common electronic waste based on the concepts of transfer learning. This system can also serve as an attachment to the existing municipal garbage trucks and can perform segregation of the materials using its arm- based lift and storage mechanism. The solution offered by the authors is intended to eliminate unskilled manual labor from the harmful processes of collection and classification of household e-waste and is a first of its kind attempt. The model uses a combination of techniques in deep learning and autonomous robotics to perform separation of e-wastes from the general solid waste stream [33]. There are also a number of studies that have identified the enablers necessary for implementing sustainable WEEE management. In their article Kuman DG. A. *et. al.* [48] have identified 23 essential enablers for the implementation of sustainable WEEE management in the context of emerging economies like India. The main goal of the article was to understand the various enablers for accessing the multiple stakeholder perspectives so as to reduce the number of uncertainties pertaining to WEEE implementation. The study identified that 'community involvement' is one of the most important enablers in context to India. This includes building awareness around the topics of waste recycling and disposal, reusing products and elimination of toxic substances [48].

X. CONCLUSION

Although significant research in WEEE management has been done, it still bears the scope for better strategization. This could be achieved through policy implementation, technological advancements and raising social awareness amongst the masses. In the context of India, it is vital to comprehend how the situation compares with the global level. More emphasis needs to be given to appropriate data collection, adapting new technology tools and aggregating the organized and unorganized sector majorly with prime focus on the labor health and safety.

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