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E Waste Handling Practices & Challenges: A Sustainable Approach

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ABSTRACT - Electronic waste, sometimes known as e-waste, is the term for abandoned gadgets and appliances that have outlived their usefulness. The volume of e-waste generated globally has increased significantly as a result of the quick development of technology, creating a problem for proper processing and disposal. Effective e-waste treatment procedures are required to safeguard the environment and general population from the potentially harmful materials found inside these gadgets. Lack of adequate infrastructure and laws, low public knowledge, and an increase in trash volume are some of the difficulties associated with treating e-waste. Reduced e-waste generation, the promotion of ethical disposal practices, and the implementation of rules to ensure proper collection, transportation, and disposal of e-waste are all components of a sustainable approach to e-waste handling. Governments, organizations, and the public sector must work together to address these concerns.

Keywords – E-waste, sustainable approach.

I. INTRODUCTION

Electronics, telecommunications, and information technology-related manufacturing are the world's largest and fastest-growing industries. Consumers now have a "use-and-throw" mentality, which holds that the newest products are always better than the previous ones and that the latter should be discarded right away, thanks to technological innovation. Due to the abuse of novel technology in its manufacturing, electronic equipment ages quickly and produces a lot of e-waste. Electronic waste (E-waste), often known as WEEE (Waste Electrical and Electronics), has been produced as a result of the unrestrained growth of the electronics and information technology industries over the past 10 years. Due to the growing number of electronic devices in use and the quick rate of technical advancement, electronic waste is an issue that is getting worse. E-waste contains toxic and hazardous substances, such as lead, cadmium, and mercury, which can harm human health and the environment if not managed properly.

Electronic waste, also referred to as E-waste, waste of electrical and electronic equipment (WEEE), or end-of-life (EoL) electronics, is the term used to describe electronic and electrical equipment (EEE), including all parts, consumables, and subassemblies, that are deemed to be out-of-date or unwelcome by the user. The term "electronic waste," often known as "e-waste," is used to refer generally to outdated, no longer useful, or discarded electrical and electronic equipment that is considered to have no further value to its owners [34]. The European Parliament Directive 2002/96/EC on Waste Electrical and Electronic Equipment provides a more thorough definition of e-waste (WEEE), as "electrical and electronic equipment" or "EEE" as "equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer, and measurement of such currents.

The proper collection and classification of valuable and dangerous components is the most important step in developing an effective and economical e-waste management for recycling system. The separation, collection, and disposal of wastes according to effective norms that consider sustainable criteria for their storage, collection, transportation, and disposal are lacking in most growing economies. E-waste collection is a severe problem for developing economies and concerns are raised among waste management authorities and professionals due to the lack of trash separation, safe disposal, and appropriate recycling.

1.2 E-WASTE MANAGEMENT IN INDIA

The techniques and procedures used in the collecting, handling, and disposal of electronic waste are referred to as "e-waste management" (e-waste). E-waste management aims to reduce the harm that electronic trash causes to the environment and people's health while recovering valuable resources. In order to ensure that electronic trash is disposed of properly and that it has minimal harmful effects on the environment, government, industry, and individuals must work together to implement effective e-waste management methods. E-waste collection, the separation of recyclable and non-recyclable materials, data security, and adherence to pertinent rules and regulations are some of these procedures.

In India, the highly structured informal sector has mostly been used to manage e-waste, including the collection, sorting, dismantling, and recycling processes. Recycling in the informal sector is carried out in a crude manner utilising ineffective techniques that harm the health of the employees, harm the environment, and result in the loss of precious

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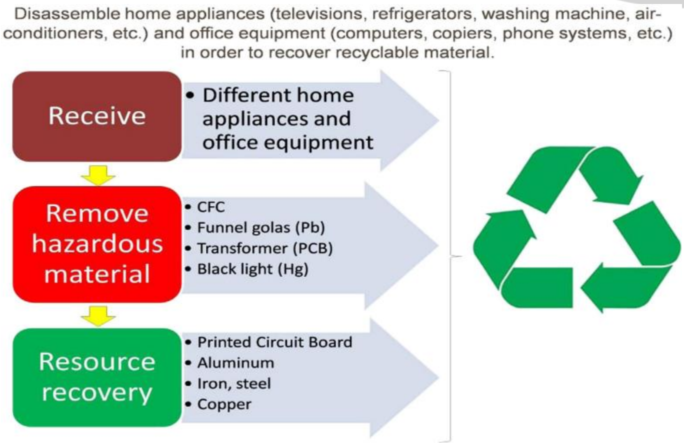
resources. India manages e-waste differently than other countries do. Because of impromptu recycling practises, e-waste disposal methods are a major challenge. There is no means for controlling the transportation of E-waste in the system, making it difficult to quantify E-waste in India.

The Central Government has notified these regulations considering the expanding issues with e-waste in order to exercise its authority under Sections 6, 8 and 25 of the Environmental (Protection) Act, 1986. The E-waste (Management and Handling) Rules from 2011 have been replaced by the E-waste (Management) Rules from 2016. There are 24 rules total, divided into 6 Chapters and 4 Schedules. By promoting the recycling of useable E-waste goods, this legislation hopes to reduce the amount of hazardous trash that will end up in landfills and ensure that all types of E-waste are handled in an environmentally friendly way. Each stakeholder involved in the creation of electric equipment and waste management is acknowledged and defined by the E-waste (Management) Rules 2016 (producer, manufacturer, consumer, bulk consumer, collection centres, dealers, e-retailers, refurbishes, dismantlers, and recyclers) are responsible for producing electric equipment and managing the waste produced when it reaches the end of its useful life.

Due to the high degree of variety in its composition and its poor environmental compatibility, the processing of electronic trash is particularly complicated. Manual disassembly is typically the initial phase, during which specific parts (such as casings, external wires, CRTs, PCBs, and batteries) are separated. Mechanical, chemical, and thermal processes are among the methods utilised for the treatment and recycling of electronic waste after disassembly. Various e-waste treatment technologies are shown in figure 1.

Figure 1: Environmentally Sound Treatment Technologies for E-waste



Source: Prasad & Narasimha (2020)

E-waste Rules were announced by the Ministry of Environment and Forest (MoEF) in May 2011 and went into effect on May 1, 2012. These regulations have codified the idea of EPR. According to these Rules, producers are obligated to set up take-back programmes or collections centres, either individually or collectively, to collect E-waste created when their products reach the end of their useful lives. Only establishments approved and registered with State Pollution Control Boards/Pollution Control Committee (PCCs) may recycle e-waste.

Wastes must be sold to recyclers who are registered, approved, or have environmentally friendly facilities. The rule allows for the establishment of a collection centre to collect E-waste either alone or jointly, by a registered society, a recognised agency, or by an association. The primary tool for ensuring ethical handling of e-waste is these regulations. On March 22, 2018, the Ministry of Environment, Forest and Climate Change, Government of India, New Delhi notified that the collection, storage, transportation, segregation, refurbishment, dismantling, recycling, and disposal of E-waste shall be in accordance with the guidelines published by the "Central Pollution Control Board" issued notification for rule 23 and Schedule 3(www.MoEF.com) (table 1).

Table 1: MoEF & CC Govt of India notification of Schedule 3 dated March 22, 2018

Year	E-waste Collection target (weight)
2017-18	10% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
2018-19	20% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
2019-20	30% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
2020-21	40%of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
2021-22	50% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
2022-2023	60% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan
onwards	70% of the quantity of waste generation as indicated in Extended Producer Responsibility Plan

Source: Prasad & Narasimha (2020)

II. LITERATURE REVIEW

Bhaskar and Kumar (2018) conducted a literature review on the potential link between electronic waste (e-waste) management and the achievement of sustainable development goals (SDGs). The authors emphasized the growing problem of e-waste and its negative impacts on the environment and human health, as well as the potential

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opportunities for creating value through e-waste management. The review discussed the potential linkages between e-waste management and various SDGs, including SDG 7 (affordable and clean energy), SDG 9 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 13 (climate action). The authors highlight the potential linkages between e-waste management and SDGs, as well as the potential business case for promoting e-waste management and achieving SDGs. The authors emphasize the importance of collaboration and innovation in addressing the challenges and barriers to implementation, and promoting sustainable development.

Marke et al (2019) in their paper entitled "Reducing e-waste in China's mobile electronics industry: the application of the innovative circular business models" proposed an innovative circular business model to reduce e-waste in China's mobile industry. The authors aimed to examine the feasibility and effectiveness of their proposed model by conducting a literature review of previous studies on e-waste management and circular economy. The proposed model highlights the importance of product design, product recovery, material regeneration, and value creation in achieving circularity in the mobile industry. However, its successful implementation requires overcoming various challenges, which calls for further research and collaboration between stakeholders.

Kazancoglu et al. (2020) proposed a sustainable and digital collection and classification center model to manage e-waste in emerging economies. The authors aimed to address the challenges of e-waste management in emerging economies, where there is a lack of infrastructure and awareness. They conducted a literature review to identify the current state of e-waste management practices and the potential of digital technologies in addressing these challenges. The authors propose a digital collection and classification center model based on IoT, AI, and Blockchain, which could improve efficiency, accuracy, and sustainability in e-waste management. However, its successful implementation requires addressing various challenges, which calls for further research and collaboration between stakeholders.

Khan et al. (2014) conducted a literature review to identify the challenges of waste of electric and electronic equipment (WEEE) management. The authors discussed the environmental, health, and economic implications of WEEE, and the challenges associated with its collection, transportation, treatment, and disposal. The authors discussed several strategies to improve WEEE management, including extended producer responsibility (EPR), eco-design, and the use of advanced technologies such as recycling robots and intelligent transportation systems. EPR is a policy approach that requires manufacturers to take responsibility for the collection, treatment, and disposal of their products at the end of their life cycle. They suggest that implementing EPR policies, eco-design, and the use of advanced technologies could improve the efficiency and sustainability of WEEE management.

Suresh et al. (2018) conducted a comprehensive literature review on computer waste, focusing on the toxic elements present in e-waste, segregation techniques, and recycling methods. The authors highlighted the environmental and health hazards associated with improper handling of e-waste and emphasized the need for sustainable and efficient e-waste management strategies. The review discussed the toxic elements present in e-waste, including lead, mercury, cadmium, and brominated flame retardants. These substances can cause environmental pollution and have adverse health effects on workers involved in e-waste handling and nearby communities. The authors emphasized the need for proper segregation of e-waste to minimize the exposure of these hazardous substances. The review also discussed various segregation techniques, including manual dismantling, mechanical shredding, and automated sorting. The authors discussed the toxic elements present in e-waste, segregation techniques, and recycling methods, emphasizing the importance of proper segregation and sustainable recycling methods to minimize the environmental and health risks associated with e-waste management.

Shittu et al. (2020) conducted a comprehensive literature review on global e-waste management, focusing on e-waste trends, legislation, contemporary issues, and future challenges. The authors highlighted the increasing volume of e-waste generated globally and the need for efficient and sustainable e-waste management strategies. The authors emphasized the need for stricter and more comprehensive e-waste legislation globally to promote sustainable e-waste management practices. The authors discussed contemporary issues in e-waste management, including informal e-waste recycling, export of e-waste to developing countries, and the lack of awareness and education on e-waste management. The authors emphasized the need for sustainable e-waste management strategies that can address these issues and promote sustainable e-waste management practices globally. The authors discussed e-waste trends, legislation, contemporary issues, and future challenges, emphasizing the need for stricter e-waste legislation, sustainable e-waste management strategies, and awareness and education on e-waste management.

Williams (2016) conducted a literature review on global metal reuse and formal and informal recycling from electronic and other high-tech wastes. The author highlighted the increasing importance of metal recycling due to the scarcity of some metals and the need to reduce the environmental impacts of metal mining. The review discussed the various methods of metal recycling, including formal recycling through authorized recycling facilities and informal recycling through unregulated and often hazardous practices. The author highlighted the importance of formal

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recycling methods in ensuring safe and sustainable metal recycling practices. The review also discussed the environmental and health impacts of metal recycling, including the release of toxic substances such as lead, mercury, and cadmium. The author discussed formal and informal recycling methods, environmental and health impacts, and the importance of global collaboration and regulatory frameworks in promoting sustainable metal recycling practices.

Awasthi, Zeng, and Li (2015) conducted a critical review of environmental pollution caused by electronic waste recycling in India. The authors highlighted the growing problem of electronic waste in India due to the increasing use of electronic devices and the lack of effective management and regulation. The review discussed the various methods of electronic waste recycling in India, including formal and informal recycling methods. The authors emphasized the prevalence of informal recycling methods that are often unregulated and hazardous to the environment and human health. They highlighted the use of primitive techniques such as open burning, acid stripping, and manual dismantling, which can release toxic substances into the environment. The review also discussed the environmental and health impacts of electronic waste recycling, including soil and water pollution, air pollution, and the release of toxic substances such as lead, cadmium, and mercury. The authors emphasized the need for effective management and regulation of electronic waste recycling to minimize these impacts and protect the environment and human health. In addition, the review highlighted the importance of public awareness and education in promoting sustainable electronic waste management practices. The authors emphasized the need for public awareness campaigns to educate the public about the dangers of electronic waste and the importance of proper disposal and recycling.

Brito et al. (2020) conducted a literature review on reverse remanufacturing of electrical and electronic equipment (EEE) and its role in the circular economy. The authors highlighted the growing problem of e-waste and the need for effective management and regulation of EEE at the end-of-life stage. They emphasized the importance of reverse remanufacturing as a potential solution to this problem. The review discussed the concept of reverse remanufacturing and its potential benefits for the environment and the economy. The authors emphasized the importance of collecting and disassembling EEE products at the end-of-life stage and recovering the valuable components and materials for reuse in new products. They highlighted the potential economic benefits of reverse remanufacturing, including job creation and cost savings. The review also discussed the challenges and barriers to the implementation of reverse remanufacturing, including technical and logistical issues, lack of standardization, and the need for effective regulation and policy support. The authors emphasized the importance of collaboration among stakeholders, including manufacturers, recyclers, and policymakers, to overcome these challenges and promote the adoption of reverse remanufacturing practices. In addition, the review highlighted the potential environmental benefits of reverse remanufacturing, including reduced energy consumption and greenhouse gas emissions, and reduced demand for virgin materials. The authors emphasized the importance of life cycle thinking in promoting sustainable EEE management practices and incorporating reverse remanufacturing into the circular economy framework

Thomas and Taro (2015) conducted a literature review on the role of information and communication technologies (ICT) in promoting environmental sustainability in a changing society. The authors emphasized the growing importance of ICT in addressing global environmental challenges, such as climate change, resource depletion, and biodiversity loss. The review discussed the potential contributions of ICT in various sectors, including energy, transportation, agriculture, and urban planning. The authors highlighted the importance of smart grids, energy-efficient buildings, electric vehicles, precision agriculture, and smart cities in promoting sustainable development and reducing environmental impact. The review also discussed the challenges and barriers to the implementation of ICT for environmental sustainability, including the high cost of technology, lack of infrastructure, regulatory barriers, and social and cultural factors. The authors emphasized the importance of overcoming these challenges through collaboration among stakeholders, including governments, businesses, and civil society organizations. In addition, the review highlighted the potential role of ICT in promoting public awareness and engagement in environmental sustainability. The authors emphasized the importance of digital platforms, social media, and mobile applications in empowering individuals and communities to act on environmental issues.

III. STRATEGIES FOR SUSTAINABLE MANAGEMENT OF E-WASTE

Many Sustainable Development Goals (SDGs), starting with SDG 12 on sustainable consumption and production, are made possible by good chemical and waste management. Around 69 aims and 91 related indicators have been listed as relevant to chemicals and waste out of the 196 targets and 30 indicators included in the SDGs. The UN Environment Assembly's Towards a Pollution-Free Planet Implementation Plan intends to speed up and scale up efforts to decrease pollution as well as support nations in putting the 2030 Agenda into practise and achieving the SDGs through current MEAs and other international initiatives. According to IPBES's 2019 research, waste management under SDG Target 12.4 is anticipated to have a lot of good effects on nature and how it benefits people.

The Ministry of Environment and Forest (MoEF) is responsible for dealing with the E waste Mechanism

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handling standards, which include limitations on the use of hazardous compounds in accordance with international best practises. Several Sustainable Development Goals (SDGs) are supported by India's management of electronic waste. The objectives of various SDGs are particularly linked to the business case for managing e-waste. Some of the most crucial SDGs—like clean water and sanitation—that aim to improve water quality by reducing pollution, eliminating dumping, and minimising release of hazardous chemicals and materials to protect and restore water-related ecosystems are essential for businesses looking to safely handle e-waste. Another Sustainable Development Goal (SDG) for responsible consumption and production emphasises sustainable management and effective use of natural resources, environmentally sound management of chemicals, and control of all wastes through their life cycle. This SDG has significant environmental benefits. The sustainability of businesses is intimately tied to other components of this SDG, such as the decrease of waste generation through prevention, reduction, recycling, and reuse. Any organisation, public or private, should view the e-waste problem resolution from the perspective of achieving the goal of becoming a sustainable organisation. Thus, Integrating E-waste handling perspective with SDGs is vital for proper handling of e-waste through sound management of e-waste.

In the past two decades, sustainable E-waste management has become a significant environmental concern, particularly in developing nations like Malaysia, Indonesia, Nigeria, India, and China. By effectively implementing E-waste management rules and formalising the recycling and material recovery processes, the industrialised countries have, to a significant extent, been successful in resolving this issue. Due to the availability of inexpensive labour, the general lack of awareness among the populace, and the ineffective application of the existing rules by the monitoring agencies/institutions, the recycling of e-waste is still primarily carried out in the informal sector in developing nations like India. E-waste, or the safe management of electrical and electronic trash, is a severe problem in many nations. For developing nations, it poses a significant challenge because of substantial generation, transboundary movement, and lack of technical expertise [9]. It is estimated that the world generates around 2050 million tons of E-waste annually, most of it from Asian countries.

Even though there are more authorised recyclers and collectors across the nation, most of the e-waste still goes to the unregulated market. The "E-waste (Management) Rules 2016" were released in 2015 after certain changes were made to address some of the flaws of the E-waste (Management and Handling) Rules, 2011, and they went into effect on October 1, 2016. The E-waste recyclers now have certain additional duties as a result of the new regulations. According to the new regulations, recyclers will oversee making sure that no environmental harm is done to the environment during the storage and transportation of E-waste and that the recycling process has no negative effects on human health or the environment. Additionally, they must see to it that the fractions or materials that cannot be recycled in their plant are given to the appropriate approved recyclers. A stricter requirement was put in place for recyclers to keep a record of the entire amount of e-waste they had collected, dismantled, recycled, and sent to authorised recyclers in Form 2 and to copy that record to the CPCB or SPCB (State Pollution Control Board). Many E-waste recyclers have applied for registration with the State Pollution Control Boards or the Central Pollution Control Board as a result of the new law. As a result, there are now 178 formal recyclers and dismantlers registered with the Central Pollution Control Board (CPCB) across the nation. It can be observed from the list that Karnataka has the largest number of registered recyclers/dismantlers in the country followed by Maharashtra and Uttar Pradesh.

Management of E-waste is a worldwide challenge in achieving the sustainable development goals. Several conventions and policies have been introduced from time to time in order to manage E-waste. These include:

- The 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Waste and the Disposal of Hazardous Waste aims to decrease the development of hazardous waste, limit their transboundary movements, and encourage environmentally appropriate management.
- The 2004 Rotterdam Convention encourages countries that export and import electronic waste to share responsibility. It outlines how to gather and disseminate data so that countries that import e-waste can choose whether to accept it from exporting nations.
- The European Union passed the Waste Electrical and Electronic Directive in 2012 with the goal of protecting the environment and human health by preventing or decreasing the negative effects of e-waste and by establishing rules for product design and obligations at the end of the product's life. In order to reduce disposal and all activities associated with the life cycle, including treatment of E-waste, it encourages reuse, recycling, and other types of recovery of E-waste. As a result, it is the manufacturer's responsibility to collect, recycle, and dispose of electronic waste.
- The Restriction of Hazardous Substances (RoHS) Directive, adopted in 2011, limits the use of potentially harmful materials during production and encourages their environmentally responsible recovery and disposal. In the production of new electrical and electronic equipment, it bans the use of six dangerous compounds, including heavy metals like lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl, and polybrominated diphenyl ethers. The

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government is required by the Reduction of Hazardous Substances (RoHS) rules to cover the cost of sampling and testing in order to carry out the RoHS test. The manufacturer is responsible for paying the test costs if the test results do not support the RoHS specification.

IV. MAJOR CHALLENGES ON EMERGING ISSUES OF E-WASTE AND CONCLUSION

Worldwide production of waste electrical and electronic equipment (WEEE) is rising. This is the waste stream that is expanding the fastest because of rising consumer demand, deliberate and perceived obsolescence, rapid technological advancements, the creation of new electronic devices, the limited lifespan of some products, and bad design that does not consider recycling [29]. EEE manufacturing is one of the industries with the greatest rate of growth in the world, and as a result, more harmful and valuable e-waste is produced in greater quantities. While both rich and developing nations face difficulties with final disposal and recycling as a result, poorer nations are disproportionately affected because electronic gadgets are frequently disposed of in a dangerous manner there. According to estimates, only around 15% of the e-waste produced in 2014 was formally handled by national take-back programmes that resulted in the greatest quality of recycling and safe disposal, and 20% in 2016, and 17.4% in 2019. Since recycling increased by only 4 Mt while e-waste increased by roughly 2 Mt per year, recycling efforts are not keeping up with e-waste growth rates. On the other hand, 82.6% of the world's e-waste is still unknown, and its fate will vary depending on the region. Around 8% of e-waste in high-income nations is simply disposed of in routine rubbish collections before being landfilled or burned. In high-income countries, 7–20% of the e-waste produced is either illegally exported under the pretence of reuse when the device has reached the end of its useful life or refurbished electronics that are sent to low- or middle-income countries as used goods. However, most of this waste in high-income countries is probably combined with other waste streams and recycled, albeit in subpar ways [7].

Lead, mercury, cadmium, nickel, beryllium, zinc, and persistent organic pollutants like flame retardants or those present in product fluids, lubricants, and coolants are examples of hazardous components of e-waste. These damage ecosystems through formal and informal recycling as well as traditional landfilling. The risk of environmental and public health effects rises as more of these goods are disposed of in landfills, especially in many low- and middle-income nations where their management and disposal are typically unregulated. Leachates from dumping activities, particulate matter (coarse and fine particles) from dismantling activities, fly and bottom ashes from burning activities, fumes from mercury amalgamate "cooking," desoldering, and other burning activities, wastewater from dismantling and shredding facilities, and effluents from cyanide leaching and other leaching activities are some examples of typical emissions or outputs that contain toxic substances.

Due to the volume of e-waste generated and the unknown hazards to the quality of surface and groundwater, incorrect e-waste disposal is a growing concern. If the plastic parts are burned, the hazardous elements they contain release dioxins into the air, and the dangerous materials they contain leach from landfills into groundwater and streams. Burning PVC covering in order to recover copper wires pollutes the environment, endangers surrounding inhabitants, and harms owners of recycling businesses. This hazardous environmental degradation of the land, waterways, groundwaters, and air, along with the disruption of the ecosystem, endangers human health [17; 7]. There is a need to capitalize on the value of e-waste and adopt a more circular model of production for electronic products: numerous authors have pointed out the value of e-waste [7] and the concept of urban mining as a way of achieving several of the 2030 Sustainable Development Goals (SDGs) and/or a circular economy. Coupled with this is the need to turn the informal waste sector globally into something safe and sustainable [33]. Improved e-waste recycling would also aid in reducing the issue of hazardous wastes being burned outside in open disposal sites. The items are not built nor developed with recycling practises in mind, despite the potential benefits of recycling e-waste. According to a recent analysis, there are three potential future e-waste management scenarios, all of which depend heavily on how much company behaviour is aligned with a new model of circular manufacturing [25;26].

Challenges in e-waste handling include the lack of proper infrastructure and regulations in many countries, a lack of public awareness about the environmental and health impacts of e-waste, and the growing volume of e-waste generated worldwide.

To address these challenges, several steps can be taken:

- Implementation of regulations: Governments can implement regulations to ensure that e-waste is properly collected, transported, and disposed of.
- Increase public awareness: Campaigns can be conducted to educate the public about the importance of responsible e-waste handling and disposal.
- Encouraging producers to take responsibility: Producers of electronics can be encouraged to take responsibility for the end-of-life management of their products through extended producer responsibility (EPR) programs.
- Promoting responsible disposal methods: Governments and organizations can promote responsible disposal methods, such as recycling, to reduce the environmental and health impacts of e-waste.
- Developing proper infrastructure: Governments can invest in proper infrastructure, such as e-waste recycling

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facilities, to ensure that e-waste is handled in an environmentally responsible manner.

In conclusion, a sustainable approach to e-waste handling requires a combination of preventative measures, responsible disposal methods, and proper infrastructure. Addressing the challenges in e-waste handling requires a coordinated effort by governments, organizations, and the public.

V. FINDINGS IN RELATION TO SUSTAINABLE STRATEGIES FOR E-WASTE HANDLING PRACTICES

For waste management, understanding the makeup of e-waste is essential. This waste is difficult to handle because it includes dangerous substances, but it has the potential to be recycled because it contains valuable metals (gold, silver, and palladium). Due to the inclusion of both valuable and dangerous materials, e-waste treatment is difficult and unique from other waste streams. If e-waste disposal is done poorly, there are several possible negative externalities for the environment, society, and economy. As two of the most important stakeholders, manufacturers and bulk consumers, businesses have a key role in the management of e-waste. Whether they are manufacturers or significant consumers, businesses have started creating policies and procedures for adhering to Indian e-waste legislation. Various Sustainable Strategies for sound management of e-waste are as follows:

1- **Sustainable Collection of E-waste-** E-waste is collected and classified in a sustainable facility that separates it into categories for recycling, reusing, and refurbishing. E-waste recovery is essential because of the valuable metals it contains, which is important not only for safeguarding human health but also for preventing resource waste and effectively using the nation's resources. To reduce the amount of e-waste, classes on refurbishing, recycling, or reusing are also important.

2- **Proper disposal of e-waste-** It is crucial because to the health risks posed by the materials used in electronics, yet only about a third of outdated equipment are making it to the approved e-waste collectors in the nation's capital. E-waste is quickly becoming a source of environmental concern due to the extensive usage of electronic equipment and the quick replacement of older models with newer ones. Some important e-waste disposal/ processing methods are:

   a. Landfilling- burying into pits— this process is unsafe and poses the threat of chemicals leaching into soil and groundwater and contaminating them
   b. Incineration- Incineration, which entails burning primarily in the open air. If done improperly, this process could produce toxic gases.
   c. Recycling & reuse- This eco-friendly practice can help recover valuable metals, among other things.
   d. Bio-remediation -- This technique successfully uses local microorganisms to detoxify toxins; it also includes sub-processes like "Bio-sorption" and "Bio-Leaching".
   e. Phyto-remediation--Uses indigenous plants to absorb and degrade pollutants

3- **Extended Produces Responsibility (EPR)-** It has to do with the obligations that the producer or the importer have throughout the entire life cycle of the good. It encompasses the effects connected to the choice of the materials, the manufacturing process, the disposal of them at the end of their useful life, and their use. Making the manufacturer of the goods responsible for the complete life cycle of the product, notably for take-back, recycling, and final disposal of the product, is regarded as an environmental protection policy. The identification and use of EPR is a crucial component of e-waste management [6]. Numerous studies based on EPR have investigated various facets of managing e-waste. Internationally, the EPR is regarded as one of the most effective approaches to the e-waste problem. But due to the informal sector's active involvement, policymakers in poor nations are significantly concerned about the implementation of EPR, unlike in the industrialised world [18]. EPR is a legal tactic that enables producers to pay for the costs of gathering, recycling, and/or properly discarding the products that customers no longer want [16]. In European nations and in India, the EPR and Producer Responsibility Organization (PRO) initiatives have been articulately presented, but their full potential has not yet been fully realised. Since producers bear the financial burden of waste management, Extended Producer Responsibility (EPR) major's goal is to encourage them to create goods that reduce waste management expenses. EPR now comes in five different forms: financial, physical, compensation, informational responsibility, and property rights [22]. The consumer plays a unique role in the application of the EPR concept because they serve as users, customers, and holders of e-waste. Finding the factors that affect customer recycling behaviour is necessary to increase consumer engagement in e-waste collecting programmes. For the first two years of the rule's implementation, manufacturers have been given specific deadlines to manage 30% of the trash produced. By the seventh year of the rule's implementation, this objective had been gradually raised, resulting in the proper management of over 70% of the E-waste produced. The producer would not be permitted to sell items until the EPR permission was reissued as a result of the termination of the EPR authorization as a punishment for not meeting the target. Along with having a mechanism in place for managing e-waste, businesses must also lessen the number of hazardous materials they use in their products.

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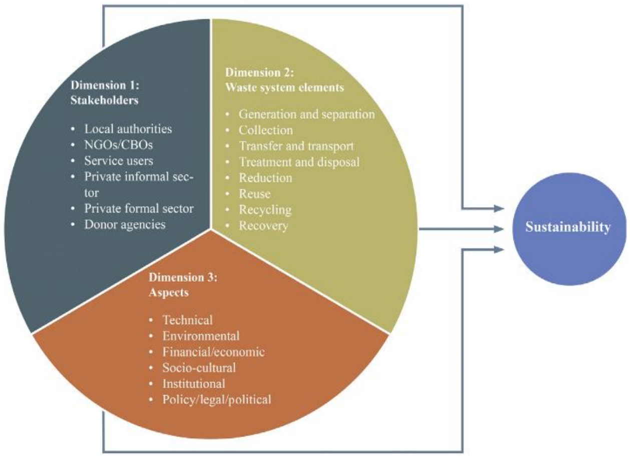
4- **ISWM (Integrated and Sustainable Waste Management) Framework-** Historically, waste management systems have been analysed using this methodology. To analyse how cities in developing nations have been addressing waste management concerns, Wilson et al., for instance, use the ISWM framework [36]. The generation, collection, and disposal stages of waste management are all considered by the ISWM framework. The interdependence of these stages with other economic subsystems, such as manufacturing, transportation, urban growth and development, and public health, is also considered [10]. Three key questions about an e-waste management system are answered by this framework: Who should be involved? What actions should be taken, and how should they be taken? [10]. These inquiries establish the framework's three dimensions: the stakeholders, the components, and the sustainability of a waste management system. Involved parties in the waste handling process include formal or informal sectors, national and local governments, non-governmental organisations (NGOs), academia, public or private companies involved in waste collection and treatment, as well as producers and consumers who generate waste [30]. The technical components, waste removal and disposal procedures (production, collection, and treatment), as well as resource-valuation procedures, make up a waste management system's constituent parts (reuse, recycling, and recovery). Finally, the sustainability aspects of a waste management system refer to elements that make waste management activities effective and sustainable, such as the political environment, legal frameworks, sociocultural contexts, environmental and health elements, as well as financial and economic elements [30]. According to ISWM framework, stakeholder is defined as any group or individual who can affect or is affected by a decision-making process. The key stakeholders and their roles were identified considering the last three stages of E-waste management proposed by UNEP: collection, pre-processing, and end-processing [31]. Next, the stakeholders were categorized according to their type, that is, the nature of the organization that each one represents. Following the ISWM framework, the third dimension comprises the factors that influence the whole waste management system and have impact in terms of efficiency and sustainability [10]. Those factors include political, legislative, and institutional frameworks, socio-cultural conditions, financial and economic factors, as well as technical and environmental aspects as shown in figure 2.

Fig. 2: ISWM framework



Source: van de Klundert, A., Anschu¨ tz, J., (2001)

5- 3-R Principle

Reduce- The technical components, waste removal and disposal procedures (production, collection, and treatment), as well as resource-valuation procedures, make up a waste management system's constituent parts (reuse, recycling, and recovery). Finally, the sustainability aspects of a waste management system refer to elements that make waste management activities effective and sustainable, such as the political environment, legal frameworks, sociocultural contexts, environmental and health elements, as well as financial and economic elements [30].

Reuse- Under this Directive, Reuse is defined as "any operation to by which products or components that are not waste are used again for the same purpose for which they were conceived" and preparing for reuse is defined as "checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing." Reuse is a significant waste reduction strategy since it increases product longevity and delays or even eliminates the need to extract virgin raw materials to produce new goods. Used items are viewed as valuable commodities that can be mended or have components retrieved for reuse in developing nations and economies in transition. The products and parts are then exchanged via markets, roadside stalls, and intermediaries. Although the techniques used to recover parts for reuse are typically viewed as improper in industrialized countries, they help to reduce poverty by generating money for a sizable number of marginalized and underpaid people in the informal sector and by facilitating higher material recovery. Reuse is hampered by the need for commodities to be gathered and directed towards this activity. The economics of reuse are greatly influenced in areas/countries with dispersed and relatively small populations by low material quantities, irregular collections, uncertain supply, vulnerability to fluctuating market pricing, and absence or inadequate technology infrastructure. Because comprehensive

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collection networks with regular and predictable supplies, higher collected volumes, and easy access to markets are easier to establish, regions and countries with larger and more concentrated populations can collect and bulk materials for reuse in a more economically viable way. The D4R idea, which stands for "design for recycling, repair, refurbishing, and reuse," can be used to create easily replicable and reusable sub-assemblies or devices that lower the risks and expenses related to disassembly. Reuse preserves units or components in their original state, unlike recycling, which necessitates the dismantling of technical components. As a result, it is feasible to recover both the materials present in the product and the value generated during design and production. Utilization of Social Enterprises Repair, renovation, and reuse of various EEE are social enterprise activities carried out by volunteer groups, nonprofits, and for-profit businesses. These organizations collect EEE, particularly white goods, to be repaired before being sold or given to underprivileged individuals both domestically and abroad. Some social enterprises run highly skilled reuse and repair operations that make use of intricate monitoring and reporting systems and assurances for environmental and health and safety compliance, standardized treatment procedures, reused products' liability, reporting, and traceability, insurance, technical know-how, training, license requirements, and after-sales service.

Recycle- Recycling is described as "any recovery operation by which waste materials are reprocessed into goods, materials, or substances, whether for the original objectives or for additional uses" under the EU Waste Directive (2008/98/EC). It entails the reprocessing of organic material but excludes energy recovery and the reprocessing into fuel- or backfilling-purpose-specific materials. Theoretically, many metals can be recycled practically forever with little loss in their technical properties, regardless of how many times they are recovered. Metals cannot be destroyed, simply dispersed. Recycling is generally ineffectual in practice, nevertheless, because of limitations placed on product design, social behavior, recycling technologies, and the thermodynamics of separation. The need for primary production, along with all the negative effects of mining and refining, including the additional processing necessary to extract low-grade ores, is reduced by metal recycling. Additionally, secondary metal manufacturing uses 2–20 times less energy per kilogram of metal produced than primary metal production, including collection and transportation [8]. Although intentionally building systems with increased metal recycling in mind should theoretically be viable, reducing primary output will not be feasible until secondary production reaches market demand. There are three basic processes in the process of recycling electronic waste: Collection, sorting/dismantling, pre-processing, including mechanical treatment, and end processing are the first three steps (including refining and disposal) [19]. The second stage can be further broken down into two parts: a) disassembly, which involves choosing dangerous or valuable components for treatment, and b) upgrading, which involves careful processing to raise the quality of desirable materials [15]. The next step of potential strategies to lessen e-waste is material recycling and reuse. The amount of e-waste is decreased through the recovery of metals, plastic, glass, and other materials. These alternatives could save energy and prevent the release of harmful materials into the environment. Sustainability of e-waste management systems must be ensured by improving the effectiveness of collection and recycling systems (e.g., public–private-partnerships in setting up buy-back or drop-off centres) and by designing-in additional funding e.g., advance recycling fees.

6- Take Back Scheme

The vast majority (>80%) of schemes were either for-profit/commercial in nature or were carried out to support charitable organizations. Mobile phones were advertised for and collected using a variety of means, including pre-paid mail services, courier, and in-store. Since the majority of returned phones were of poor quality, they were probably meant for recycling. There is no denying the potential for such programs to divert E-o-L (End of Life) mobile phones (and other small EEE) from hoarding and landfills towards reuse and recycling.

VI. IMPLICATIONS OF THE STUDY

The study provides a wider perspective on electronic waste management in developing countries especially to IT firms and sustainability perspective which may provide some important insights on sustainable strategies by linking electronic waste management and SDGs and opens up many theoretical avenues to pursue them further. These insights need to be developed further through rigorous empirical work to gain a better understanding of the business responses to responsibilities mandated by legislations on management of e-waste and other waste streams that mandate a role for businesses. The implications of e-waste handling practices by IT firms can be significant, both in terms of environmental sustainability and social responsibility. Some major implications include:

Environmental impact: IT firms generate a significant amount of e-waste, including obsolete computers, servers, and other electronic devices. Proper e-waste handling practices, such as refurbishment, recycling, and disposal, can help minimize the environmental impact of this waste. By adopting sustainable e-waste handling practices, IT firms can reduce their carbon footprint, conserve natural resources, and minimize the release of hazardous materials into the environment. E-waste contains hazardous materials such as lead, mercury, and cadmium, which can have harmful effects on the environment if not disposed of properly. Integrating e-waste handling practices with sustainability can help reduce the environmental impact of e-waste by promoting proper disposal and recycling.

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Regulatory compliance: E-waste handling is subject to local and international regulations. By adopting sustainable e-waste handling practices, IT firms can comply with these regulations and avoid fines and other legal consequences.

Reputation: IT firms that adopt sustainable e-waste handling practices can enhance their reputation as responsible corporate citizens. This can improve their relationship with customers, investors, and other stakeholders, and help attract new business opportunities.

Cost savings: Sustainable e-waste handling practices, such as refurbishment and recycling, can help IT firms save money by reducing the need to purchase new equipment. In addition, proper disposal of e-waste can avoid the cost of potential environmental damage and legal consequences.

Social responsibility: E-waste disposal is often outsourced to developing countries, where workers are exposed to hazardous materials without proper safety measures. By adopting sustainable e-waste handling practices, IT firms can fulfill their social responsibility by ensuring that their e-waste is disposed of properly and the workers involved are protected.

Resource conservation: E-waste contains valuable resources such as gold, silver, copper, and palladium, which can be recovered through recycling. Integrating e-waste handling practices with sustainability can help conserve natural resources by promoting the recovery of these materials.

Economic benefits: Recycling e-waste can generate economic benefits such as job creation and revenue generation. Integrating e-waste handling practices with sustainability can help create a more circular economy, where materials are reused and recycled, creating a more sustainable and prosperous future.

Social impact: E-waste is often exported to developing countries where it is processed under unsafe and unregulated conditions, leading to health risks for workers and the local community. Integrating e-waste handling practices with sustainability can help promote social justice by ensuring that e-waste is disposed of properly, and the workers involved are protected.

Overall, the implications of e-waste handling practices by IT firms can be significant in terms of environmental sustainability, regulatory compliance, reputation, cost savings, and social responsibility. Integrating e-waste handling practices with sustainability can have significant positive implications for the environment, society, and the economy.

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