TIERED INCENTIVIZATION-BASED E-WASTE MANAGEMENT STANDARDS

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ABSTRACT

Developing a standard and certification process to efficiently process e-waste is the need of the hour. This paper identifies a few but effective requirements, which need to be incorporated into the sustainability standards developed by International Electrotechnical Commission (IEC) and other national bodies such as British Standards Institution (BSI) and Bureau of Indian Standards (BIS). Customized incentivization for the identified several players in the electronics manufacturing ecosystem such as PC manufacturing ecosystem is identified and the rationale for such customized incentivization and its probable impact on an efficient e-waste processing is discussed. Further, a graded standard e-waste processing matrix is provided to encourage deeper and broader adaptation of such e-waste processes.

Keywords – *Sustainability, e-waste, standards, incentivization.*

1. INTRODUCTION

Electronic waste or e-waste has become the burning problem of recent times because of the extremely short lives of electronic components. Today the cellphones are being replaced every 23 months.[1] Laptops are becoming outdated in less than four years.[2] Electronic gadgets like smart watches, headphones, ear pods, etc., are being replaced very frequently and are expected to have a working life of not more than 6 months. Smart televisions are also becoming ubiquitous, which would become obsolete in a few years. These aspects of electronic products combined with corporate policies like planned obsolescence, technological advancements (like miniaturization), using hazardous substances to manufacture them creates not only significant e-waste that pollutes the environment, but also causes serious health risks leading to a significant drain on the economy and society.

Governments across the world, including India, have understood the impact of e-waste[3] and have framed policies to recycling e-waste[4]. Many techniques and technologies have been developed to recycle e-waste. In addition to many national and international legal regimes governing recycling e-waste, environmental standards have been developed on recycling e-waste. This paper deals with strategies and challenges in developing standards for recycling e-waste in India. It also provides a framework that could help develop an efficient standard to deal with recycling e-waste.

This paper is divided into seven parts: The first part deals with the challenge of e-waste and it's recycling; the second part deals with e-waste scenario in India; the third part deals with environmental standards and standards relating to e-waste in general and specifically in India; the fourth part prescribes strategies for developing standards relating to e-waste management in India; the fifth part concludes the paper.

2. ELECTRONIC WASTE – CHALLENGES, TECHNOLOGIES, AND ISSUES

Electronics started evolving with the discovery of electricity in the 18th century and has been responsible for innovations like the telegraph. Started with Faraday's work with electromagnetism and the invention of the vacuum tube (enabling early devices such as radios), electronics evolved into transistors, driving smaller and more efficient electronics. Integrated circuits (ICs) followed, leading to miniaturization and the emergence of computing devices (smartphones, desktop, tablets, laptop, servers etc) and the ICs are embedded on printed circuit boards (PCBs). Advancements in semiconductor technology continued, powering progress in electronics, including the Internet of Things (IoT) and artificial intelligence (AI).[5]

With advancements, the problems of electronics started emerging. Electronic components had limited life and could not be reused, creating the problem of electronic waste. Electronic devices have significant hazardous substances[6] like arsenic, lead, and cadmium, posing severe environmental and health risks if not properly disposed of[7]. Improper methods such as burning or burying e-waste release pollutants like dioxins and furans into the air and groundwater, posing further health hazards for communities[8]. Instead of recycling e-waste, many developed countries export them to developing and underdeveloped countries like China[9], India[10], Pakistan, Indonesia, many African countries[11] like Nigeria, Kenya, South Africa, and Ghana[12], etc. Despite the health risks, these facilities are deemed valuable businesses in economically distressed regions, underscoring the complex socio-economic dynamics surrounding e-waste management[13]. This is being carried out for economic reasons despite restrictions on exporting them under various international treaties and conventions.

The International Convention to Prevent Pollution from Ships (MARPOL) convention establishes regulations for ship pollution, covering air emissions and the transportation of hazardous liquids, dangerous products, sewage, and waste. The Basel Convention on the Control of Transboundary Movements of Hazardous Waste and the Disposal of Hazardous Waste (1989) [hereinafter Basel Convention] aims to safeguard the environment and public health from hazardous waste through rules on environmental management, waste reduction, and safe disposal methods[14]. The Ozone Depletion Protocol of the Montreal Protocol (1989) restricts the production and use of ozone-depleting substances (ODS) like CFCs and HCFCs, commonly found in refrigerators and air conditioners. The Durban Declaration of 2008 calls for an African regional e-waste platform or conference to evaluate and improve e-waste management regulations, ensuring compliance and necessary revisions[15]. These treaties and conventions aim to promote sustainable design and responsible disposal practices. Efforts to implement Life Cycle Assessments (LCAs)[16] and Extended Product Responsibility (EPR)[17] signify a positive shift towards addressing environmental concerns in the electronics industry.

The Basel Convention specifically insisted on the developing countries consenting to receive such hazardous wastes.[18] Developing countries are consenting to import e-waste because by processing and recycling e-waste, certain rare metals like nickel, lead, copper, steel/iron, palladium, gallium, germanium, gold, indium, silver, zinc, fuel, etc., can be extracted[19]. For developing countries, it would mean lesser mining of those minerals, thereby saving economic resources to procure them while also saving the environment. But for the benefits to accrue, recycling and repurposing must be technologically appropriate and has to be executed in a sustainable manner.

There are various technologies that can be effectively used to recycle e-waste[20]. Some of them are managing organic and inorganic contaminants in e-waste[21], phytoremediation[22], bioremediation[23], biodegradation[24], enzymatic treatment of e-waste[25], using the plastics in e-waste as coarse aggregate in concrete for constructing roads and other infrastructure elements[26], reusing and repurposing electronic batteries[27], hydrometallurgical and aqueous recover of metals[28], mechanical processing[29], Leaching processing[30], electrometallurgical processing[31], pyrometallurgical processing[32], nanotechnology[33], and many more. This also requires specialized supply chains to collect e-waste, transport it to recycling centers, get it processed at the remanufacturing plants, ship the recycled products to customers, and then dispose the scraps efficiently without causing significant harm to the environment[34]. Most of these technologies are also patent protected[35].

While they may be experimented in lab-scale or small-scale, for a lasting solution, such activities have to be carried out in large industrial scale, in order for it to be economically viable and environmentally sustainable. Internationally, some of the industrial scale e-waste recycling plants established in Daimler Benz in Ulm Germany, NEC Group in Japan, Hellatron Recycling in Italy, Noranda Smelter in Quebec Canada, Ronnskar Smelter in Sweden, Attero Recycling in Roorkee India[36] have demonstrated that it is achievable. While these cases are worthy of replication, developing countries might be unable to adopt such best practices, due to patents and other intellectual property rights including trade secrets. Without an economically viable and efficient knowledge transfer with reasonable royalty rates to developing countries, the problem of e-waste cannot be solved. International laws and regulations, along with technology standards, especially, the ISO 14000 and 14001 series have been helping them in this process.

3. INDIA

India has a significant challenge dealing with e-waste[37]. In addition to generating significant quantities of e-waste, India faces substantial influx of e-waste from developed countries, often entering through illegal channels. Despite being signatory to the Basel Convention India struggles with inadequate enforcement and inspection mechanisms, allowing the illegal transit of e-waste. Instances of smuggling of e-waste, bypassing regulations aimed at controlling its flow, has added to the safe and sustainable disposal (or reuse) of e-waste. Addressing these challenges necessitates collaborative efforts to strengthen legislation, enhance enforcement, and promote sustainable practices in e-waste management, both domestically and internationally.

As international regulations, particularly the Basel Convention tighten, there's mounting pressure to regulate the disposal and export of e-waste. India, like other developing countries, faces the challenge of coping with e-waste imports from the developed nations, which may soon be restricted due to unsafe disposal practices. However, India struggles with fragmented legislation and insufficient funding for electronic waste management programs, hindering effective management of the growing e-waste problem within its borders[38]

India has various laws addressing e-waste, including the Environment (Protection) Act, 1986; the Air (Prevention and Control of Pollution) Act, 1981; and the Water (Prevention and Control of Pollution) Act, 1974. The Environment Act contains penal provisions for violations, while the Air and Water Acts indirectly contribute to e-waste management. The Department of Parliamentary Standing Committee on Science & Technology, Environment & Forests has highlighted e-waste as a growing concern. Private bills like The Electronic Waste (Handling and Clearance) Bill have also been introduced. Subsequently the government of India has promulgated the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008, and the E-waste (Management and Handling) Rules, 2010. These legislative measures have revised Extended Producer Responsibility (EPR) targets for Original Equipment Manufacturers (OEMs).[39]

E-waste Rules of 2010 issued to manage electronic waste (e-waste), was revised in 2016 to focus on reducing e-waste production and enhancing recycling through Extended Producer Responsibility (EPR). Various approaches like product take-backs, regulatory measures, voluntary industrial practices, and other measures like financial instruments have been effectively used to implement these EPR in India. These updated rules prohibited unauthorized import of Waste Electrical and Electronic Equipment (WEEE) and mandated producers to collect back 30 to 70 percent of the WEEE they generated over seven years, directing it to authorized recyclers. Subsequent amendments in March 2018 further refined collection targets, gradually increasing from 10 to 70 percent over seven years. Despite 726 industries obtaining EPR authorization by 2018, only 1.5 percent of total WEEE is recycled by formal recyclers, with 75 percent kept domestically due to unclear disposal procedures, and 8 percent disposed of in landfills.[40] However, unauthorized WEEE still enters India due to weak regulation of used Electrical and Electronic Equipment (EEE), smuggling, and the burgeoning informal recycling sector, contributing to a significant increase in WEEE generation.[41]

While e-wastes are recycled to extract as much value from it[42] one has to adopt an integrated approach to e-waste management including its recycling[43].

4. E-WASTE MANAGEMENT STANDARDS – EVOLUTION AND ISSUES

Policies, legislations, regulations, and standards regarding e-waste management differ across countries, based on their stage of development. Annex – A provides a comparison of focus of policies and standards for starting, emerging, and established countries.

In today's life, standards have become a part of every person's life as we, for example, use innumerable products incorporating standards either knowingly or unknowingly. A Standard can be better understood by the following definition: "*A Standard is a prescribed set of rules, conditions, or requirements concerning the definition of terms; classification of components; specification of materials, performance, or operations; delineation of procedures; or measurement of a quantity and quality in describing materials, products, systems, services, or practices.*"[44] A Standards Setting Organization (SSO) forms and lays down a Standard. A SSO may be a trade association, Standards Development Organization (SDO), consortium, or alliance. This article focuses on SSOs aimed at developing sustainability standards, especially, focusing on e-waste management. With the increase in industrialization, standardization has become inevitable, as emphasized by the following: "*Standardization is one of the hallmarks of an industrial society*"[45]. Especially, for the increasing complexity of society and the growth of its industrial base requires the interoperability of society's products, processes, and procedures. This interoperation provides a basis for greater integration of elements in the society, which in turn causes increased social interdependency and complexity"[46].

E-waste standards have evolved significantly in recent years to provide comprehensive guidelines for the entire lifecycle of electronic waste management. The SRI project[47] and the European WEEE-CENELEC standards developed by the European Committee for Electrotechnical Standardization[48] are notable examples. These guidelines cover all aspects of e-waste management, including collectors, collection centers, logistics, preprocessors, and disposal. They detail requirements for registration, prohibited activities, management, storage, transport, handling, and worker safety. Additionally, there are specific instructions for data erasing, packaging, record keeping, transboundary movements, and transport documentation. The CENELEC standards are divided into main standards (CENELEC EN 50625) and technical specifications (CENELEC TS 50625), with more details found in sources like JRC[49]. Older documentation includes global standards (ISO, 2017) and US-specific standards (R2 and E-stewards)[50].

For treatment facilities, the SRI projec[51] and CENELEC standards provide rules for depollution and monitoring, with specific instructions for different types of e-waste such as lamps, displays, cooling equipment, and PV panels. These standards include general requirements (EN 50625-1) and specific standards (EN 50625-2 series) along with templates for record-keeping. Final processing guidelines are limited but are addressed in CENELEC TS 50625-5 for end-processing of copper and precious metals. CENELEC EN 50614 outlines standards for reuse preparation, though practical documentation for promoting repairs and longer equipment life spans is scarce.

India's updated e-waste management standards, encapsulated in the E-Waste (Management) Rules, 2022, which took effect on April 1, 2023, replace the previous 2016 regulations. These new rules enhance the Extended Producer Responsibility (EPR) regime, requiring manufacturers, producers, refurbishers, and recyclers to register with the Central Pollution Control Board (CPCB). They emphasize environmentally sound recycling practices, integration of the informal sector, and provisions for environmental compensation, verification, and audits. Additionally, the rules mandate safe storage, transportation, and handling of e-waste, alongside strict guidelines for transboundary movements and data security during disposal, aiming to mitigate environmental and health impacts associated with improper e-waste disposal[52].

The Indian Standard IS 17862:2022 provides guidelines for the storage, collection, dismantling, and recycling of e-waste. This standard, developed by the Chemical Department and overseen by the Solid Waste Management technical committee (CHD 33)[53], outlines practices to manage e-waste in an environmentally sound manner. It references IS/ISO 14001:2015[54] for environmental management systems and IS/ISO 45001:2018 for occupational health and safety. These guidelines aim to ensure safe and effective e-waste management processes to minimize environmental and health impacts. The standard aims to ensure safe handling and processing of e-waste to minimize environmental and health risks.[55]

Since 2021, the International Electrotechnical Commission (IEC)[56] has been developing a global standard called IEC 63395[57] for managing electrical and electronic waste sustainably. This standard, due to be released in 2024, aims to protect the environment by establishing guidelines for handling electronic waste responsibly. IEC 63395, also known as "Environmental aspects related to electronic products," is an international standard focused on designing electronic products with the environment in mind. It encourages manufacturers to consider factors like energy efficiency, recyclability, and responsible disposal from the very beginning. By following these guidelines, companies can reduce the environmental impact of their products and possibly save costs while improving performance.

This standard emphasizes looking at electronic products' entire lifecycle, starting from the extraction of raw materials to their manufacturing, use, and disposal. It encourages practices like eco-design, extended producer responsibility, and closed-loop recycling to promote sustainability and efficient resource use.

Overall, IEC 63395 is a valuable tool for promoting eco-friendly practices in the electronics industry. It helps reduce electronic waste, conserve resources, and protect the environment. Similarly, proposed international e-waste management standards aim to address environmental and social challenges posed by electronic waste by providing clear guidelines for collection, recycling, and disposal. To ensure their success, international cooperation, flexible standards, and consideration of social and economic factors are crucial[58].

5. CHALLENGES TO ADOPTABILITY OF SUSTAINABILITY STANDARDS

5.1 Interoperability:

The increasing complexity of society and the growth of its industrial base require the interoperability of society's products, processes, and procedures. This interoperation provides a basis for greater integration of elements in the society, which in turn causes increased social interdependency and complexity"[59]. Especially, a major objective of developing a standard in telecommunications is to provide interoperability. The interoperability[60] operates as a forcing function to develop standards compliant products (SCPs) such as smart phones, laptops, desktops, server systems etc. Telecommunication services hosted on these SCPs interwork despite these SCPs developed by multiple vendors and the services provided over multiple carriers. The dependency of interoperability is becoming a core reason to develop standards (such as 5G, 6G, Wi-Fi 6, Wi-Fi 7, Bluetooth etc.) and build SCPs. However, such interoperability does not appear to be a core reason for developing sustainability standards. In the absence of interoperability acting as a forcing function to build SCPs, in sustainability standards, the processes that needs to be standardized to achieve sustainability should be based on strong incentives.

5.2 Uniformity:

The e-waste policies of the national governments are not uniform and are non-standard and there is a need to standardize these processes and allow some level of customization to be built on the standard processes. At the international level, there have been some attempts to create cooperation between the countries and the Basel convention is one such example to control transboundary movements of hazardous wastes and their disposal, which has formed the basis of anti-dumping laws in certain countries.

Some attempt to build uniformity in the e-waste management at a regional level is attempted by European Union (EU) by setting WEEE rules and regulations. Further, in an ongoing effort, International Electrotechnical Commission (IEC) is working to develop a sustainability standard (IEC 63395 ED1) and the British Standards Institute (BSI) has been working on developing the sustainability standard IEC 63395 and the scope of such a standard is discussed and BSI is in an advanced stage in the process of finalizing such a standard.

5.3 Absence of Customized Incentivization:

However, in an e-waste management eco-system, there are several players (e.g., component manufacturers, system integrations, OEMs, sales channels, refurbishers, recyclers, smelters etc.) and the nature of operation and motivation for each of these players may be different at least, slightly. Thus, it is necessary to tailor a customized incentivization plan for the players in the electronics industry. A standard built to provide customized incentivization may ensure that the standards would be adopted widely.

5.4 Absence of Flexible Categorization:

Further, the processes prescribed in the different policies do not appear to provide flexibility to consider tradeoffs. Providing categories with different attributes may encourage wider adaptation of e-waste policies. Such flexible categorization would create necessary incentives to recyclers that would in turn help clean-up the e-waste being generated.

6. DESIRABLE APPROACH TO STANDARDS AND POLICIES.

In view of the above challenges, the authors wish to propose that the proposed standard for managing e-waste should recommend either a tiered-standard based on incentivization for the adopters. While there are many such tiered-standards, the one adopted by the LEED building ratings in the USA or the GRIHA ratings in India both of which has adopted a rating system for certifying green buildings[61]. While the GRIHA ratings introduce multi-tiered rating system for building, it does not link incentives with the ratings acquired by the building. The incentives are provided by the Government of India, where the 4-starred or a 5-starred building would be eligible for reduction in interest rates and could also become eligible for certain government incentives and subsidies. Such separation would not act as a strong motivator to implementers to move towards a higher tier of achievement.

To address this issue, the authors wish to propose a tiered incentivization-based e-waste management standard. Under this, the authors recommend that not only should the standard have multiple tiers for adoption, but also by linking incentives with such tiers, the adopters and implementers would be motivated to adopt a higher tier, thereby working towards solving a major problem faced by our society. For instance, the tiers could be divided into three categories like Platinum standard, gold standard, and silver standard with a corresponding level of incentive associated with each category. Annex - B provides a summary of the proposed implementation matrix.

Such an approach would enable wider and deeper adaptation of the standard, as it would enable stakeholders across the entire spectrum of the value-chain to be able to comply with the standard, thereby leading to efficient management of e-waste. Further, the evolutionary nature of the standards offers a technology continuum and is desirable for interoperability[62]. The authors could not, to the best of their abilities, find a similar framework that contains multi-tiered incentivization-based standard for managing e-waste and they feel that such a tiered-approach would also incentivize such participants to aspire for the next higher standard, thereby improving the compliance among the players, and also enhance the reputation of the country implementing the standard.

While implementing such staggered incentive-based standard for managing e-waste, India could also link category-based incentives for setting up the facility, rebates in custom duties, tax-breaks, and also subsidies to encourage participants to aim for higher tiers of processing e-waste.

7. CONCLUSION

Managing e-waste has become a priority for a sustainable environment. Despite numerous legislations and policies, both internationally and in India, effective and efficient management of e-waste has not been achieved. Factors like varied kinds of electronic products, numerous technologies for recycling and reusing electronic components, intellectual property rights, technology transfer policies, and domestic policies on these matters influence the efficiency in managing e-waste. Standards developed by standard setting agencies, both internationally and in India, can alleviate these problems to an extent. The authors propose a tiered-incentive based technology standard system that would help solve many of the problems in managing e-waste, thereby leading not only efficiency, but also higher aspiration among the players in the value-chain of managing e-waste, thereby moving towards an optimal e-waste management system that would ensure sustainable environment for future generations.

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TIERED INCENTIVIZATION-BASED E-WASTE MANAGEMENT STANDARDS

Annex – A (Policy, Legislation, and Standards for managing e-waste for different countries)

	Starting Countries	Emerging Countries	Established Countries
Policy and Legislation - Focus, scope, and intention	Deciding on when and how to develop policies for developing the habit of managing it	Deciding on when and how to revise the policies and standards for developing compliance with laws, regulations, policies and standards	Deciding on how to successfully implement it for nurturing stakeholders to become responsible for policies and standards and to develop cooperation
Stakeholders	* Government - Policy nudging, creation, and enforcement * Producer Responsibility Organizations - Adjust rules & outcomes * Producers - Extended Producers' Responsibility, Responsible for own (share of) products * Recyclers (typically NGOs) - Extensive knowledge and control on collection and treatment	* Government - Policy review & revision, inspection & enforcement, and developing standards * Producer Responsibility Organizations - work with government towards revising policies and developing standards * Producers - financial & product design responsibilities towards EPR * Municipalities, retailers, recyclers & consumer - Maximize collection of e-waste	* Government - Optimizing policy review & revision, inspection & enforcement, and standards * Producer Responsibility Organizations - Optimize policies, standards, monitoring & enforcement * Producers - financial & product design responsibilities towards EPR * Municipalities, retailers, recyclers & consumer - Maximize collection of e-waste and real-time monitoring
Key issues involved	* Lack of format treatment facilities * Strong informal sector * Substantial quality of illegal imports of e-waste and used products * Absence of organizational structures at producers, recyclers, and government entities * Drafting policies suitable for these conditions	* Formalizing and professionalizing the informal sector * Developing economies of scale and connections to international markets for recyclables * Enacting and revising legislations that focus on effective monitoring, reporting, and control * Setting various standards and implementation guidelines * Improving control and restricting imports	* Optimize and broaden the coverage of policies and standards by changing economic incentives, reviewing proportionality and efficiency of requirements, fine-tuning the scope, and real-time monitoring of collection and recycling performance * Build flexibility in the policy and standards ecosystem
Key focus of policies	* Who should primarily be in charge (producers, recyclers, informal sector, or the government) * Who can contribute to what stage of recylcing, repair, reusing, and disposing * What products to be covered by the policies and what to be excluded * What key interventions and initial implementation rules are essential * How to finance the policy implementation * How to manage conflict of interest between parties * Implementing Extended Producer Responsibility (EPR) effectively * Striking a balance between starting principles like "Polluter pays principle" vs. EPR and "collective" vs. "individual" responsibility * Setting initial collection and processing targets	* Creating a more stable policy that is not subject to constant change * Create rules and standards suitable to technical sophistication, skills, market prices, changing quantities, and composition of e-waste * Set collection and treatment targets linked with incentives for effective policy implementation * Complement policies with a series of implementation rules, standards, and agreements focusing on more collection, better treatment, higher reuse levels, more transparency in reporting, enhanced toxic control, technical development of the industry, less local and toxic emissions, safety of workers * Developing standards and their technical specifications for holistically managing e-waste in different product categories, considering the socio-economic and political conditions in the country * Align stakeholder responsibilities	* Developing circular economy-based policies that nurture innonvative business models to optimize e-waste management * Removal from scope or creating exemptions in case of contractual arrangements * Reducing & removal of administrative burden on the govt., to nudge towards more professionalization of collection & treatment practices * Improve quality of collection volumes, treatment, and reporting * Cooperation with international bodies and compliance organizations to further optimize e-waste management

Annex – B (Implementation Matrix)

CATEGORY	EFFICIENCY of PROCESSING e-Waste	FLEXIBILITY to CUSTOMIZE	INCENTIVE /CREDITS
Platinum	HIGH	LOW	HIGH
Gold	Medium	Medium	Medium
Silver	Moderate	HIGH	LOW