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3.3 Circular Economy Approaches in E-Waste Management

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Abstract

The management of electronic waste (e-waste) has become a pressing global concern due to the rapid proliferation of electronic devices and the associated environmental and health hazards. This paper explores the concept of circular economy as an innovative approach to address the challenges of e-waste management. By shifting from the traditional linear model of "take-make-dispose" to a circular model focused on resource recovery and reuse, stakeholders can mitigate the negative impacts of e-waste while unlocking economic opportunities. Drawing on a few innovative approaches and best practices, this paper examines various strategies and initiatives aimed at promoting circularity in e-waste management. Through collaborative efforts and policy support, the transition to a circular economy in e-waste management can contribute to sustainable development goals and foster a more resilient and resource-efficient society.

Keywords

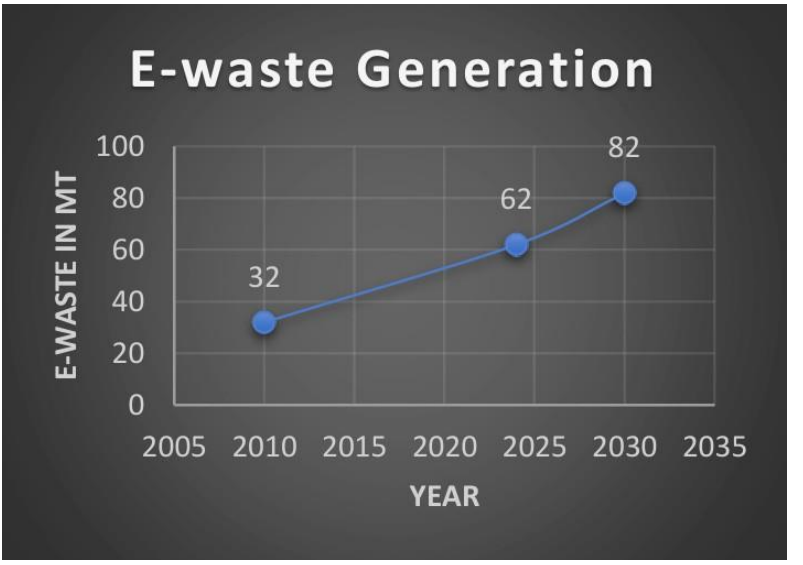
Circular Economy, Environmental Impact, Resource Efficiency, Industry 4.0, Emerging Technologies

Introduction

E-waste is a generic term used to describe all types of old, end-of-life or discarded electrical and electronic equipment, such as household appliances, office information and communications equipment etc. E-waste contains substances including mercury, cadmium and lead that can be hazardous to human health and the environment if not dealt with properly. Today, e-waste has emerged as the world's fastest growing environmental challenge. While the various components in our electronics are safe when in use, once they end up in a landfill they become biohazards. The toxins in our e-waste can seep into our soil or bodies of water and create a health hazard for people and the environment.

The world's generation of electronic waste is rising five times faster than documented e-waste recycling, the UN's fourth Global E-waste Monitor 2024 reveals [1]. In 2022 a record 62 million tonnes of E-waste were produced, up 82% from 2010 and on the track to rise another 32%, to 82 million tonnes, in 2030. Figure 1 explains the growth trend of global E-waste till 2030.

Figure 1. Growth trend of global E-waste till 2030



Source: United Nation's fourth global E-waste Monitor 2024

The proliferation of e-waste is a rapidly escalating global issue given its exponential growth coupled with poor collection and recycling of the products. Only 22% e-waste mass was documented as having been properly collected and recycled in 2022 [1] (Global E-Waste Monitor 2024). This surge is primarily attributed to the global ICT revolution, the era of industry 4.0, emerging technologies like IoT, Blockchain and hence the ever-increasing demand of electronics products.

Such staggering challenge of e-waste creates direct challenge in achieving multiple sustainable developmental goals like SDG 3(Good health and wellbeing), SDG 9 (Industry, innovation and infrastructure), SDG 11(Sustainable cities and communities), SDG 13(Climate action), SDG 15 (Life on land), SDG 12(Sustainable production and consumption) and indirectly hampers the achievement of SDG 6, SDG 7 and SDG 14. According to the UN Statistics Division Progress Chart, among the assessable targets, a mere 15 per cent are on track to be achieved by

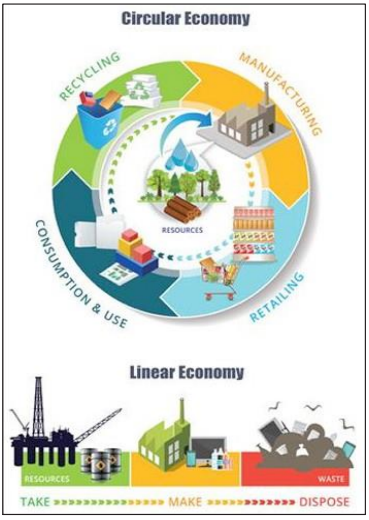
2030. Out of all SDGs nearly half, 48% of the targets show moderate or severe deviations from the desired trajectory.

According to Global E-waste Monitor 2024, poor collection of e-waste leaves US$ 62 billion worth of recoverable natural resources unaccounted for and increasing pollution risks to communities worldwide. Circular economy, thus, provides a way in mitigation of this problem of e-waste by both reducing as well as recycling it.

Understanding Circular Economy

Circular economy (CE) is an industrial system, which is an alternative to the highly extractive and resource-intensive linear economy principle of take-make-dispose. According to the World Economic Forum, transitioning to a circular economy could unlock $4.5 trillion in economic value by 2030 [2]. CE replaces the end- of-life concept with restoration and regeneration, shifts towards usage of superior design of materials, products, systems and business models for waste elimination. The Ellen MacArthur Foundation reports that circular economy principles could lead to a 28% reduction in global resource use by 2050 compared to a business-as- usual scenario [3]. CE aims to retain the value of resources, products and materials at their highest by keeping them in use as long as possible. It also incorporates innovative solutions for minimizing wastage at each life-cycle stage, and extracting the maximum value through reuse, recovery, remanufacturing and regeneration of

Figure 2: Linear vs Circular Economic Model



products and materials at the end of each service value. Figure 2 below explains the differences between the traditional linear economic model vs circular economic model [4].

Why is it Important?

This work on a circular economy is an important part of slowing climate change. We must take action to address the climate crisis, and material recovery has an important role to play. The circular economy has the immense potential to protect the environment, improve economics, and elevate social justice if it is designed in a thoughtful and inclusive manner. The European Commission estimates that transitioning to a circular economy could reduce total waste generation in the EU by 600 million metric tons by 2030 [5] and can create 7 lakh new jobs. Circular economy provides easy means to promote sustainability. However, sustainability from its foundation requires social equity. The way we extract, use, and dispose of our resources can affect already vulnerable communities disproportionately. Underserved communities across the nations have been overburdened with the negative environmental and health impacts caused by a non-circular economy. Many landfills and processing facilities are located in close proximity to low- income countries and vulnerable communities. Thus, while helping in mitigation of e-waste, CE also has an important role in promoting SDG 10 (Reduced Inequalities).

Opportunities

On the upside, e-waste contains several valuable raw materials such as gold, copper and iron. The value of raw materials in e-waste generated in 2019 was estimated at $57 billion USD [6]. One metric ton of electronic scrap from personal computers contains more gold than recovered from 17 tons of gold ore [7]. At the current collection and recycling rate (17.4%), only a raw material value of $10 billion USD could be recovered. Under the right conditions, with due health and safety precautions, e-waste recycling and refurbishment activities could also potentially create green jobs worldwide.

Through greater collaboration from local to global levels, multinationals, small- and medium-sized enterprises (SMEs), entrepreneurs, academia and civil society associations could create a ‘circular economy’ for electronics where the waste is designed out, the environmental impact could be reduced and decent work is created for millions.

The Circular Economic Approaches

Green Electronics: Electronics produced through environment-friendly processes are green electronics. They take into account the consumption of energy and production of carbon. Green electronics often feature modular designs that allow for easy upgrades and repairs. This extends the product's useful life and reduces the need for frequent replacements. According to a report by the United Nations University (UNU), extending the lifespan of smartphones by just one year could save the equivalent of 2.1 million tons of carbon dioxide emissions annually [8]. Green electronics can be integrated into circular business models where manufacturers take responsibility for the entire lifecycle of their products. This includes take-back programs, refurbishment, and responsible recycling. Products meeting specific environmental and sustainability criteria can receive eco-labels or certifications.

Innovations Inspired by Nature: Encouraging research and development in recycling technologies, materials recovery, and sustainable electronics manufacturing processes is critical. Innovation can lead to more efficient and eco-friendly methods of managing e- waste. According to a report by the International Solid Waste Association (ISWA), implementing advanced recycling technologies could increase global e-waste recycling rates from the current 17.4% to over 50%. R & D in technologies like biomining can help extract useful minerals and metals for the discarded e-waste in an ecofriendly manner [9]. Further Research in emerging fields like Biomimicry offers new solutions which can enhance the circular economy. For example, mimicking the self-repair mechanisms found in living organisms, we can incorporate self-healing polymers or coatings into electronic components to repair minor damages and prevent further degradation.

Extended Producer Responsibility (EPR): Many countries have implemented EPR programs that hold manufacturers liable for the entire lifecycle of their products, including proper disposal and recycling. Research by the International Telecommunication Union (ITU) suggests that EPR policies contribute to improved recycling efficiency by providing incentives for manufacturers to design products that are easier to recycle. It also creates a secondary resource value. The Global E-waste Monitor reports that recycling one million laptops could save the equivalent of over 1,300 tons of copper, 6.5 tons of silver, 200 kg of gold, and 40 kg of palladium.

Waste to Art: Sustainable pieces of art can be created by transforming discarded electronic devices and other e-waste. e-waste art goes beyond its visual appeal and serves as a powerful catalyst for environmental awareness and electronic waste recycling. The damaged e-waste or the ones that have reached end of life can be converted into art centers or museums promoting tourism as well as generating green jobs. An Indian e-waste artist Mr. Haribaabu Naatesan Says:

"Science says that matter and energy are neither created nor destroyed, it can just change in form. As an artist, I change the form of the industrial scrap into art" [10]

Figure 3. Sculpture made form E-waste scrap [11]

Source: https://www.planetcustodian.com/contemporary-indian-artist-recycling-e-waste-into-art/25661/

Policy Measures

Governments across the world have been emphasizing the need to adopt the circular economy model for a safe and healthy environment, based on the learnings gained from the implementation of the policies and regulations. The European Commission's Circular Economy Action Plan includes both legislative as well as non-legislative measures. It focuses on the entire life cycle of products promoting circular economy processes, fostering sustainable consumption and ensuring that the resources used are kept in use as long as possible.

Several policy tools, ranging from information-based strategies to regulatory instruments, may be used to drive the adaptation of circular practices in the EEE sector. The measures like Extended producer responsibility, mandatory recycling targets, voluntary certification and labeling schemes to promote eco-design and

responsible consumption, right to repair, providing dedicated collection kiosk for e-waste, etc. can further boost the efforts. Along with these measures there is a need for efficient collection of e-waste. Municipal Corporation of Indore, an urban local body in India serves as a great example for this. Indore Municipal corporation collects waste in more than 5 categories from the source i.e. household itself and e-waste is one such category.

IEC and Behavioral Changes

The IEC campaign creating a massive movement to promote sustainable use of electronic devices is a crucial aspect of e waste management. At the same time behavioral changes to shift from "use and throw culture" is required to develop a circular model in true sense. Promoting the second-hand market for electronics provides a vista of opportunities for the same. Startups like Cashify, Olx are promoting such sales. The second-hand electronics product market was valued at USD 222 in 2023. It is expected to register a CAGR of 3.8 % between 2024 to 2032 [12]. Tapping this potential provides a great avenue ahead for sustainable consumption.

International Collaboration and Standards Development

At the global level, the Governments, businesses, non- governmental organizations (NGOs) and others must collaborate to create effective policies and initiatives for e-waste management. Such multi-stakeholder partnerships along with public participation can address the complex challenges associated with e-waste drive the systemic changes. Organizations like ITU have taken various proactive measures in this regard. It organizes the Green Standards Week, a global platform where policy-makers, field experts, city planners, regulators, standardization experts, civil societies and other stakeholders can come together to discuss the role of ICT in unlocking the potential of a circular economy.

Global Best Practices

1. Circular Economy Ecosystem of Japan

It focuses on collaboration of consumers, manufacturers and policy makers. The public plays a key role by source segregation of recyclables, paying recycling fees directly and holding companies accountable. Manufacturers try to incorporate more recycled materials, and make longer-lasting products

that are easier to repair and recycle. Manufacturers are also co-owners of recycling infrastructure. And because they own both manufacturing and recovery facilities, companies take proactive measures to extract maximum utility from the products with circular approaches [13].

2. WEEE Park Hong Kong, China

The Hong Kong Government in collaboration with ALBA IWS designed and built the Waste Electrical and Electronic Equipment Treatment and Recycling Facility (WEEE·PARK). The Park processes refrigerators, TVs, computers, washing machines and air conditioners into valuable secondary raw materials while controlling the management of the hazardous materials that are contained in this equipment. The Park is supposed to deliver recycling rates of over 80% and transform up to 30,000 tonnes of regulated e-waste back into raw materials each year [13].

Recommendations

The digital world is and will be undergoing rapid expansion and so is the issue of e-waste. This research paper offers a few recommendations to different stakeholders, including policymakers and industry players. The convenient and efficient collection of e-waste from consumers with source segregation forms the basis for wealth extraction and circular uses of e-waste. “Indore Model” has 5 levels of waste segregation with e-waste being one of the categories. However, making it a success requires a massive IEC and behavioral change campaign. This was done through grassroots innovations like street plays, wall paintings and creative communications through FM radio. Cultural festivals like Ganesh festival, Dusshera, Durga puja, etc. were utilized as events to spread awareness.

Along with this, adopting sustainable circular business models such as product- as-a-service, take-back schemes and remanufacturing can reduce the waste generation. Integrating circular economy principles throughout the supply chain of businesses from sourcing raw materials to product design, manufacturing, and end-of-life management is essential component of developing business processes which extracts maximum utility with minimal waste in sustainable manner. They can also act as innovation centers not only generating profits but also providing a solution for governments and CSR activities. Kolkata’s Hulladek Recycling is one such model which uses “urban mining techniques” to collect e-waste from all over India and segregates it before returning it to its natural form to be reused [14].

Conclusion

Today the management of e-waste is a global concern and with rising technological advancements like IoT, Blockchain, this concern will be aggravated. This growing e-waste crisis have an adverse impact on environmental and human health. To address the issue there is an urgent need for timely interventions, policy frameworks and innovations. The circular economy approach to e-waste provides the way out by transforming the electronics industry into a more sustainable and responsible sector. It not only lowers the environmental impact of electronic products throughout their lifecycle, from design and production to consumption and disposal, but also promotes wealth generation and resource conservation. At the same time, it also fuels our efforts for achieving the global SDGs.

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