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# CLIMATE ISSUES FOR E-WASTE MANAGEMENT IN INDIA: THE UNSEEN CONSEQUENCES ON ECOSYSTEM

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**RESEARCH ARTICLE**

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**Abstract**
Due to the country's fast industrialization, urbanization, and technological innovation, India is among the world's top manufacturers of electronic garbage. E-waste management has become a serious environmental and public health concern. An organized summary of the environmental and climate-related concerns related to India's e-waste management is given in this study. Hazardous substances including lead, mercury, cadmium, BFRs etc. have been released into the environment as a result of the inappropriate disposal and uncontrolled treatment of e-waste, which has significantly contaminated land, water, and the atmosphere. These pollutants not only endanger human health but also contribute to greenhouse gas emissions, exacerbating climate change. In India, the informal sector plays a dominant role in e-waste collection and recycling, often using rudimentary methods such as open burning and acid leaching, which amplify environmental degradation. Despite regulatory frameworks like the E-Waste (Management) Rules, 2016, the country faces significant challenges in effective implementation, including inadequate infrastructure, lack of public awareness, and weak enforcement mechanisms. This review highlights key environmental and climate risks posed by current e-waste practices, analyses the policy landscape, and identifies gaps in regulatory compliance. It also emphasizes the importance of transitioning to sustainable e-waste management solutions, such as extended producer responsibility (EPR), formalized recycling systems, and public-private partnerships. The paper underscores the urgent need for a coordinated multi-stakeholder approach to mitigate environmental harm, protect public health, and curb the adverse impacts on climate, while fostering sustainable economic growth through circular economy principles.

**Keywords:** *E-waste management, Circular economy approach, Climate change, Sustainability, Climate sensitive approaches*

## Introduction

In the 21st century, the rapid growth of technology has revolutionized modern lifestyles, industries, and economies. However, one of the unintended consequences of this technological boom is the massive surge in electronic waste (e-waste), which presents a serious threat to the environment and public health. E-waste encompassing discarded electronic devices such as computers, mobile phones, and household appliances, has become one of the fastest-growing waste streams worldwide. With the rapid advancement in technology and increased consumption of electronic products, the global generation of e-waste has been escalating, reaching over 53.6 million metric tons in 2019 and projected to exceed 74.7 million metric tons by 2030 (Jayasiri et al., 2023; Nadarajan et al., 2023). The improper management of this complex waste stream poses severe threats to both ecosystems and the climate. This issue is compounded by the hazardous materials found in e-waste, including heavy metals like lead, mercury, and cadmium, and other toxic substances such as brominated flame retardants. When these materials are not properly managed, they can have far-reaching consequences for the environment, including pollution of air, soil, and water, and a significant contribution to greenhouse gas (GHG) emissions, which intensifies global climate change. The global volume of e-waste is growing at an alarming rate, with developing countries, such as India, facing significant challenges in managing this waste sustainably. India, as one of the world's largest producers and consumers of electronic goods, is grappling with the environmental and climate-related implications of its burgeoning e-waste problem. Figure 1 shows the increasing rate of e-waste in India. India generates about 3 million tons (MT) of e-waste annually and ranks third among e-waste producing countries, after China and the United States. Reports state that it might rise to 2 MT by 2025 (Chatterjee, 2011). By 2030, the developing and developed worlds are expected to trash 400–700 million and 200–300 million old computers, respectively (Garlapati, 2016).

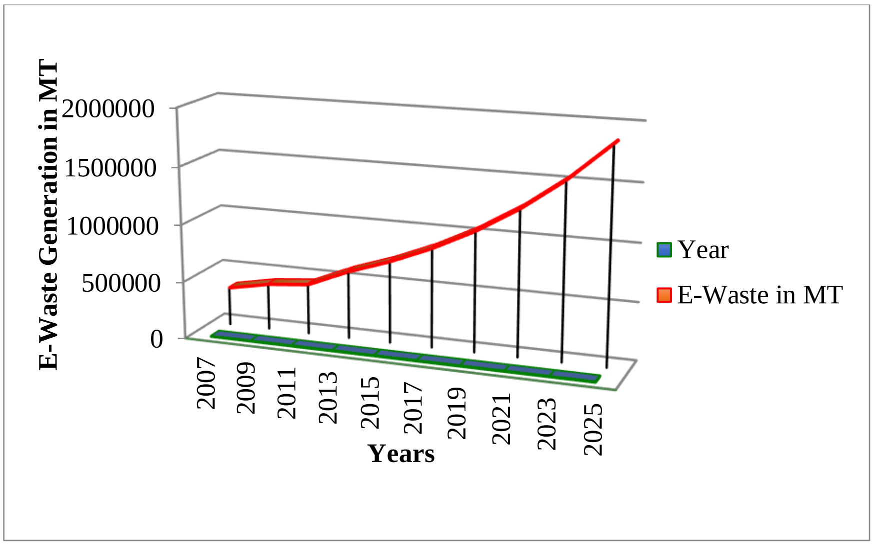


**Figure 1. Growth rate of e-waste in India** (Chatterjee, 2011)

The production of electronics is heavily reliant on the extraction of non-renewable resources like precious metals and rare earth elements. These materials are essential for producing modern technology but come at a high environmental cost. The mining and refining of these elements contribute to deforestation, habitat destruction, and significant carbon emissions. Additionally, when e-waste is not recycled, valuable materials are lost, increasing the demand for new resource extraction and perpetuating a cycle of environmental degradation. In the absence of proper e-waste management systems, much of this waste ends up in landfills or informal recycling sites, particularly in developing countries. In these settings, the lack of regulations often leads to open burning or the use of unsafe extraction techniques, both of which release toxic fumes and greenhouse gases into the atmosphere. These activities not only accelerate climate change but also degrade local environments, posing health risks to nearby communities. According to a recent BBC study, "e-waste pollution is causing serious health problems for millions of people worldwide, primarily in developing countries in Africa, Europe, US, Oceania and Asia." In the next 6–8 years, developing countries will produce twice as much e-waste as developed countries (Yu et al., 2010). The issues raised by e-waste and component materials are significant environmental concerns, as demonstrated by Table 1, which shows the worldwide production of electronic waste (the amount and per capita values) and collection rate in 2016. This table also highlights the imbalance in garbage produced, collected, and reprocessed.

**Table 1. Regional e-waste generation and collection rate in 2016 (Ofondu et al., 2022)**

| Region | Volume (MT) | Per capita values (Kg/capita) | The collection rate for recycling (%) |
|---|---|---|---|
| Asia | 18.2 | 4.2 | 15 |
| Europe | 12.3 | 16.6 | 35 |
| United States | 11.3 | 11.6 | 17 |
| Africa | 2.2 | 1.9 | Unavailable |
| Oceania | 0.7 | 17.3 | 6 |

Purchase et al. (2020) reported that in many cases, these countries lack the proper facilities and technologies needed to safely handle and recycle e-waste, leading to unsafe practices like open burning and the dumping of e-waste in unregulated landfills. Andeobu et al. (2021) & Van Yken et al. (2021) found that development countries such as Japan, South Korea, and Switzerland have developed advanced e-waste management systems that prioritize recycling, resource recovery, and the reduction of environmental harm. These countries have implemented stringent regulations that set targets for e-waste collection and recycling, promote eco-design, and encourage public participation in recycling programs. Eventually, technological innovation is also key to mitigating the climate impacts of e-waste. By using sustainable materials, reducing energy consumption during manufacturing, and designing products that are easy to repair and recycle, green design can significantly reduce the environmental and climate impact of electronic devices. Innovations in recycling technology are equally important. Advances in automated sorting systems, material recovery technologies, and chemical recycling processes can improve the efficiency of e-waste recycling, enabling the recovery of valuable materials with less energy. These technologies also help reduce the release of hazardous substances during recycling, protecting human health and the environment.

In termination, the mismanagement of e-waste poses a significant threat to ecosystems and contributes to climate change in multiple ways. From the greenhouse gas emissions associated with production and disposal to the pollution of soil, water, and air, the environmental and climate impacts of e-waste are vast and complex. However, by adopting sustainable e-waste management practices and transitioning to a circular economy, we can mitigate these impacts and create a more sustainable future for both the planet and its inhabitants.

## Objectives

The key objectives of this study are-

1. To assess the environmental and climate impacts of improper e-waste management.
2. To study the challenges of e-waste management.
3. To explore the climate sensitive approaches to e-waste management.

## Methodology

This study employed a qualitative research approach using a narrative literature review methodology to examine the environmental and climate issues of e-waste generations in India. As described by Cronin et al. (2008), narrative reviews are useful to provide a synthesis of different primary studies. This approach allows for a comprehensive overview of the topic, identifying trends, gaps, and areas of consensus in the literature (Baumeister & Leary, 1997). The literature search was conducted using academic databases including Scopus, Web of Science, and Google Scholar, with specific keywords such as "e-waste management," "environmental impact," "climate change," "circular economy," and "climate sensitive approaches." In line with the narrative review approach, the search was not exhaustive but intended to capture a broad range of relevant literature in this area (Grant & Booth, 2009). The review primarily focused on peer-reviewed journal articles, books, and conference proceedings published in English, to capture new developments in this emerging field. Supplementary, the data for this review paper was collected from various secondary sources. The global and regional e-waste landscape was covered based on government reports including those from the United Nations Environment Programme (UNEP) and the International Labour Organization (ILO); national agencies such as the Central Pollution Control Board (CPCB), India. Eventually, the integrative literature review was based on an iterative process of reading, identifying key themes from that data and synthesizing the information in a way as articulated by Torraco (2005). There are four key themes identified in this study: environmental effects of e-waste, climatological issues, challenges and sustainable solutions of e-waste management. Narrative synthesis sought to present a coherent, reasoned overview of existing acquaintance of the environmental and climate issues associated with e-waste management in India; clarify agreements among researchers; specify gaps in the literature that needs further investigation and suggest potential areas for future research or practice.

## Environmental and Climate Impact of Improper E-Waste Management

The World Health Organization (WHO) and the United Nations estimate that over 50 million metric tons of e-waste is generated annually (Islam et al., 2020). Despite the critical importance of sustainable disposal practices, improper management remains a widespread issue, contributing significantly to environmental degradation and climate change. This paper explores the environmental and climate impacts of improper e-waste management, emphasizing the pathways through which e-waste mismanagement accelerates environmental pollution, affects ecosystems, and contributes to global warming. E-waste contains a wide range of hazardous substances that can leach into soil and groundwater, contaminating local ecosystems. Heavy metals like lead, mercury, and cadmium are toxic to both humans and wildlife. For example, mercury from e-waste can find its way into water bodies, where it can bioaccumulate in aquatic ecosystems and enter the food chain, posing serious health risks to both animals and humans who consume contaminated fish and water. In regions where informal e-waste recycling is common, such as parts of Asia and Africa, the open burning of electronic components is a widespread practice (Lebbie et al., 2021). This burning process releases toxic fumes into the air, contributing to air pollution and respiratory problems for local populations. Furthermore, chemicals released during improper disposal contribute to the degradation of the ozone layer, further intensifying global climate issues. This not only threatens the health of marine life but also disrupts food webs and contributes to the decline of biodiversity in aquatic ecosystems. This paper assesses these impacts, examining the effects of improper e-waste management on ecosystems, human health, and the climate, while also exploring potential solutions.

### Soil contamination

One of the most immediate environmental impacts of improper e-waste disposal is soil contamination. E-waste contains a variety of hazardous materials, including heavy metals such as lead, mercury, cadmium, and arsenic, as well as persistent organic pollutants like polychlorinated biphenyls (PCBs) and brominated flame retardants (BFRs) (Robinson, 2009). When e-waste is dumped in landfills or informally burned, these toxic substances can leach into the soil. Over time, this leads to the accumulation of hazardous materials in the earth, which can disrupt plant life, reduce soil fertility, and contaminate crops grown in the affected areas (Sanghvi, 2023). In many developing countries where informal recycling practices are common, local communities and agricultural lands are directly impacted by this contamination.

### Water pollution

E-waste also contributes to water pollution. As toxic chemicals leach into the soil, they can infiltrate groundwater systems, rivers, lakes, and oceans. Water sources near informal e-waste recycling sites have been found to contain dangerously high levels of heavy metals and other contaminants. For instance, in areas where acid baths are used to extract precious metals from electronic components, the leftover acidic wastewater is often dumped directly into nearby water bodies. Many countries illegally ship e-waste to developing nations, where it is often discarded in unregulated dumpsites. Over time, the e-waste breaks down and releases toxic substances into the surrounding waters, affecting marine ecosystems and biodiversity (Kalamaras et al., 2021).

The leaching of mercury from e-waste is of particular concern, as mercury bioaccumulates in the food chain, ultimately affecting fish and other marine life, as well as humans who consume seafood.

**Air pollution**

Improper e-waste management can also lead to significant air pollution. Informal recycling methods, such as burning e-waste to extract valuable metals like copper and gold, release harmful toxins into the atmosphere. Open-air burning of e-waste emits dioxins, furans, and other harmful chemicals, which are known carcinogens (K. S. Gupta, 2007; Lebbie et al., 2021; Robinson, 2009). These pollutants contribute to poor air quality and have been linked to respiratory problems, cancers, and other serious health conditions in both workers involved in recycling activities and surrounding communities.

**Greenhouse gas emissions (GHGs)**

The production, use, and disposal of electronic devices involve significant energy consumption. When e-waste is incinerated, the burning process releases toxic fumes and $CO_2$, contributing to climate change. One of the primary climate-related concerns associated with e-waste is its contribution to greenhouse gas (GHG) emissions (Belkhir & Elmeligi, 2018; Fawole et al., 2023). Burning e-waste, especially plastic components and circuit boards, releases persistent organic pollutants (POPs), such as dioxins and furans, which are known to have detrimental effects on the ozone layer and contribute to global warming.

**Resource depletion**

Many electronic devices contain valuable materials like gold, copper, and rare earth metals. Improper disposal leads to the loss of these resources, requiring more mining and extraction activities, which themselves are energy-intensive and contribute to deforestation and $CO_2$ emissions (Oberle et al., 2019).

The improper management of e-waste poses significant environmental and climate risks, from soil and water contamination to air pollution and greenhouse gas emissions. These impacts not only harm ecosystems but also threaten human health and exacerbate global climate change. Addressing these challenges requires a comprehensive approach that includes stronger regulations, investment in sustainable recycling technologies, and greater public awareness.

## Challenges of E-Waste Management

The rapid growth of e-waste poses significant challenges for waste management systems worldwide. The unique characteristics of e-waste, including its hazardous components, complex material composition, and rapid product obsolescence, make effective management particularly challenging. Below are some of the major challenges in managing e-waste. Figure 2 depicts that the challenging steps of e-waste management.

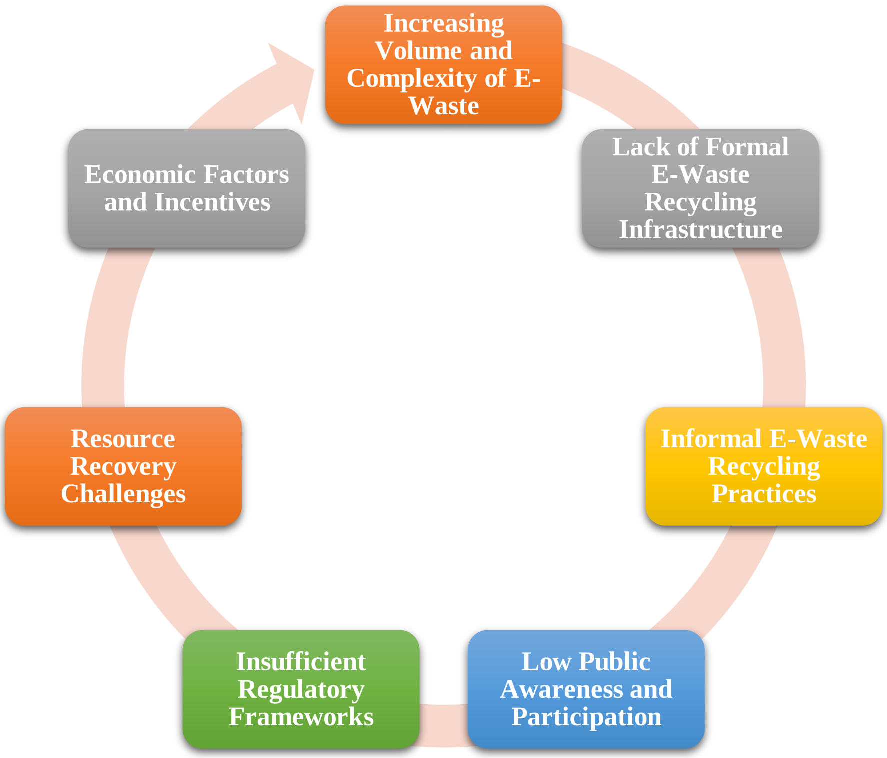


**Figure 2. Challenges of e-waste management**

**Increasing volume and complexity of e-waste**

The sheer volume of e-waste is one of the most pressing challenges. The ever-increasing demand for electronic devices – spurred by technological innovation, consumer behavior, and short product lifecycles – has led to a sharp rise in the quantity of discarded electronics. Moreover, advancements in technology mean that electronic devices are becoming increasingly complex. Modern electronics are made from a mixture of metals, plastics, and toxic substances, making recycling and safe disposal more difficult. As products become more miniaturized, they also become harder to dismantle for resource recovery. The complexity of components such as circuit boards and batteries further complicates efforts to safely extract reusable materials.

**Lack of formal e-waste recycling infrastructure**

A major hurdle in e-waste management is the inadequate formal recycling infrastructure, particularly in developing countries. Many regions lack the necessary facilities, technologies, and trained personnel to handle e-waste safely. This deficiency forces a large percentage of e-waste into informal recycling sectors, where hazardous practices are often employed. In regions without effective recycling programs, e-waste is often dumped in landfills or subjected to open burning, causing serious environmental and health risks. Only around 20% of global e-waste is formally recycled, while the rest is either dumped, incinerated, or handled informally (Bel et al. 2019; Ilankoon et al., 2018; Islam et al., 2020).

**Informal e-waste recycling practices**

A significant portion of the world's e-waste ends up in informal recycling sectors, particularly in low-income countries. In these regions, e-waste is manually dismantled by unskilled workers using rudimentary and hazardous methods, such as open burning or the use of acid baths to extract valuable metals like copper, gold, and silver. Informal recyclers often work in unsafe conditions without protective gear, and the toxic byproducts of these methods pollute the surrounding environment (Tiwari et al., 2023). For example, the open burning of electronic components releases harmful substances such as dioxins and polycyclic aromatic hydrocarbons (PAHs), which contribute to air pollution and global warming. These informal recycling practices, while economically necessary for many communities, present both immediate health risks to workers and long-term environmental damage. Addressing the issue requires not only upgrading recycling technologies but also offering alternative livelihoods and education to those involved in informal e-waste processing.

**Low public awareness and participation**

A major barrier to effective e-waste management is the lack of public awareness and engagement in proper disposal and recycling practices. Many consumers are unaware of the environmental hazards posed by e-waste and the importance of recycling electronic devices. In regions with formal recycling infrastructure, people often discard their old electronics in regular trash rather than recycling them properly. In some cases, even when consumers are willing to recycle, the lack of convenient e-waste collection points and services makes it difficult for them to do so. Additionally, there is a lack of understanding about the value of e-waste as a resource (Sivaramanan, 2013). E-waste contains valuable metals like gold, silver, copper, and palladium, but without public participation in recycling programs, these materials are lost to landfills. Increasing public awareness through education campaigns and offering convenient recycling options are essential to improving recycling rates.

**Insufficient regulatory frameworks**

Many countries lack robust regulatory frameworks to manage e-waste effectively. In some regions, there are no clear laws governing the collection, recycling, and disposal of electronic waste, allowing informal and unsafe recycling practices to flourish. In countries with regulations, enforcement is often weak, and loopholes allow e-waste to be exported illegally to developing nations, where it is dumped or handled unsafely. International efforts, such as the Basel Convention, aim to control the transboundary movement of hazardous waste, including e-waste, but enforcement remains a challenge. Illegal shipments of e-waste from developed to developing countries continue despite international agreements, exacerbating global e-waste management issues (Ilankoon et al., 2018b).

**Resource recovery challenges**

While e-waste contains valuable materials, recovering these resources efficiently is challenging due to the complex and heterogeneous nature of electronic devices (Islam et al., 2020; Van Yken et al., 2021). The recycling process requires advanced technologies to separate and recover precious metals, plastics, and other materials without causing environmental harm. Many recycling facilities, particularly in developing countries, do not have the technology or expertise to carry out these processes effectively. Furthermore, the recovery of certain materials, such as rare earth elements, is still not economically viable due to the small quantities found in individual devices and the high cost of extraction. This limits the potential for resource recovery and leads to continued reliance on the mining of virgin materials, which has its own environmental and climate-related impacts.

**Economic factors and incentives**

E-waste management is often hindered by economic factors (Efthymiou et al., 2016; Ganguly, 2016). In many countries, the cost of properly collecting, transporting, and recycling e-waste exceeds the revenue generated from the recovered materials. This economic imbalance discourages investment in formal recycling infrastructure and creates a disincentive for consumers to participate in recycling programs. To address this, some countries have implemented Extended Producer Responsibility (EPR) programs, which require manufacturers to take responsibility for the end-of-life disposal of their products. However, these programs are not universally adopted, and their effectiveness varies depending on how they are enforced.

E-waste management presents numerous challenges, ranging from the growing volume and complexity of electronic devices to the environmental and health risks posed by improper disposal. Addressing these challenges requires a combination of technological advancements, regulatory frameworks, public awareness, and international cooperation. By improving recycling infrastructure, adopting sustainable production practices, and engaging consumers in responsible disposal, the global community can reduce the environmental and health impacts of e-waste and promote the climate sensitive approaches for sustainable future.

## Climate Sensitive Approaches to E-Waste Management

E-waste contains a mix of valuable materials and hazardous substances that if not managed properly, can result in toxic pollution, ecosystem degradation, and increased greenhouse gas emissions. As the world confronts the escalating climate crisis, it is critical to adopt climate-sensitive approaches to managing e-waste that minimize the carbon footprint of electronic products and promote sustainable resource use. These approaches focus on reducing emissions, preventing environmental damage, and fostering a circular economy to enhance long-term sustainability.

**Reducing Greenhouse Gas Emissions through Sustainable Manufacturing**

A significant portion of the climate impact from e-waste stems from the energy-intensive processes involved in the production, transportation, and disposal of electronic devices. Mining rare earth metals, refining raw materials, and manufacturing components all require substantial energy, much of which is derived from fossil fuels. To reduce the climate impact of e-waste, the electronics industry must adopt more sustainable production methods that reduce energy consumption and reliance on carbon-intensive processes. One effective strategy is improving energy efficiency during manufacturing. By adopting cleaner technologies, optimizing production processes, and using renewable energy sources, manufacturers can significantly reduce GHG emissions (Belkhir & Elmeligi, 2018; Fawole et al., 2023). Additionally, sourcing raw materials from certified, environmentally responsible suppliers can lower the carbon footprint of electronic products. Companies should prioritize materials that are less energy-intensive to mine and process, such as recycled metals, which require significantly less energy than extracting virgin resources. Eventually, designing products with a longer lifespan is another critical approach. Extended lifecycles reduce the frequency with which consumers need to replace their electronics, thereby decreasing the demand for new production and its associated emissions. This design philosophy not only benefits the climate but also encourages a shift towards more sustainable consumption patterns.

**Promoting the Circular Economy**

The circular economy is an essential framework for addressing the climate impacts of e-waste. It seeks to minimize waste by keeping products, components, and materials in use for as long as possible, reducing the need for new resource extraction and cutting down on waste generation. Figure 3 shows that the circular economy strategies to electronic production and disposal for sustainable future. In the context of e-waste, the circular economy emphasizes the reuse, repair, refurbishment, and recycling of electronic devices, all of which can help mitigate climate change (Dumée, 2022; Fawole et al., 2023; Sanghvi, 2023).

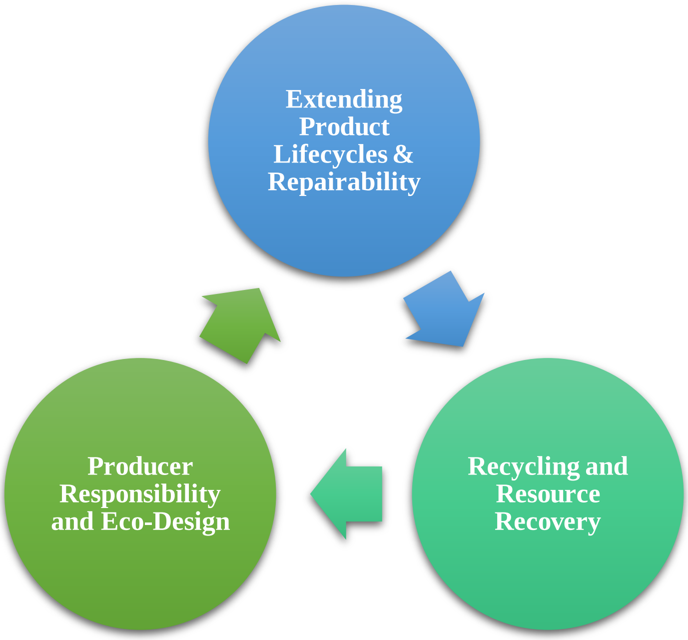


**Figure 3. Circular economy strategies to electronic production and disposal**

**Extending Product Lifecycles and Repairability**

One of the most effective ways to reduce e-waste is by extending the life of electronic devices. Manufacturers can design products with modular components that are easy to repair or upgrade, thus reducing the need for consumers to frequently replace their devices. Policies like the "Right to Repair" initiative, which advocates for consumers' ability to repair their own electronics, can help extend product lifespans and prevent devices from being prematurely discarded. By supporting repair and refurbishment markets, countries can significantly reduce e-waste and its associated climate impacts. Refurbished devices typically require fewer resources and less energy to produce than new ones and their reuse prevents the emissions that would result from manufacturing new products. This approach also reduces the demand for raw materials, minimizing the environmental impact of resource extraction.

**Improving Recycling Rates**

Recycling is a cornerstone of the circular economy and a key climate-sensitive approach to e-waste management. When e-waste is properly recycled, valuable materials such as metals (gold, silver, copper) and plastics can be recovered and reused in the production of new electronics. This reduces the need for mining and processing virgin materials, which are energy-intensive processes that contribute to GHG emissions. To improve recycling rates, governments and companies must invest in efficient recycling infrastructure and technologies that can handle the complex composition of e-waste. This includes advanced systems for separating and recovering different materials from electronic devices. Implementing Extended Producer Responsibility (EPR) policies, which hold manufacturers accountable for the end-of-life management of their products, can also incentivize companies to invest in recycling systems and design products that are easier to recycle (Ali & Shirazi, 2023; Jayasiri et al., 2023; Panchal et al., 2021).

**Producer Responsibility and Eco-Design**

Manufacturers play a crucial role in addressing e-waste and its climate impact. Extended Producer Responsibility (EPR) programs, which hold manufacturers accountable for the end-of-life management of their products, can incentivize companies to design more sustainable and recyclable products. Eco-design principles can also be applied to create products that are easier to disassemble, repair, and recycle, reducing the environmental burden associated with disposal (Fawole et al., 2023; Kiddee et al., 2013). By adopting eco-design and EPR strategies, companies can contribute to a more sustainable electronic industry and reduce the overall climate impact of e-waste.

**Reducing the Environmental Impact of E-Waste Disposal**

Improper disposal of e-waste, such as dumping it in landfills or burning it in open pits, leads to severe environmental pollution and contributes to climate change. The hazardous chemicals in e-waste, including heavy metals, flame retardants, and persistent organic pollutants (POPs), can leach into the soil and water, contaminating ecosystems. Open burning of e-waste releases toxic fumes, as well as carbon dioxide ($CO_2$) and other greenhouse gases, exacerbating global warming. To reduce the climate and environmental impacts of e-waste, countries should phase out landfilling as a method of e-waste disposal. E-waste landfills not only occupy valuable land but also release harmful substances over time, threatening both human health and the environment. Instead, governments should invest in e-waste recycling and recovery facilities that can safely process electronic waste and recover valuable materials (Murthy & Ramakrishna, 2022). In cases where landfilling is unavoidable, the use of specialized e-waste containment systems can help mitigate environmental risks. Such systems include protective linings and leachate collection systems that prevent hazardous chemicals from seeping into the surrounding environment. However, these measures should only be viewed as temporary solutions, with the ultimate goal being the elimination of e-waste landfilling altogether. To address this issue, governments need to formalize e-waste recycling sectors, providing safe working conditions and environmentally sound recycling technologies. Training and capacity-building programs can help informal recyclers transition to safer, more sustainable practices. Additionally, enforcing regulations that prohibit open burning and other hazardous recycling methods is crucial for reducing emissions and protecting the environment.

Climate-sensitive approaches to e-waste management are essential for reducing the environmental and climate impacts of the rapidly growing volume of electronic waste. By promoting sustainable production, extending product lifecycles, improving recycling rates, and minimizing improper disposal, governments, industries, and consumers can contribute to reducing greenhouse gas emissions and protecting ecosystems. Adopting a circular economy framework, advancing responsible policies such as extended producer responsibility, and fostering global cooperation are critical steps in ensuring that e-waste management is aligned with climate goals.

## Discussions and Conclusion

The management of e-waste presents significant challenges to the environment, particularly in terms of its contribution to climate change and ecosystem degradation. This systematic review explores the climate issues associated with e-waste, emphasizing the complex interactions between improper disposal, resource extraction, and greenhouse gas (GHG) emissions. Nandan et al. (2023) focused that improper e-waste management through methods such as open burning and informal recycling has severe climate and ecological consequences. Open burning, for instance, is a common method used to extract valuable metals like copper from e-waste in developing countries, where informal recycling practices dominate. The burning releases not only harmful toxins but also GHGs like carbon dioxide ($CO_2$) and methane ($CH_4$), contributing to global warming. Informal recycling practices in countries with inadequate waste management infrastructure are a significant source of environmental pollution (Ghosh et al., 2022; Purchase et al., 2020; Tiwari et al., 2023). In addition to the air pollution from burning, the toxic chemicals in e-waste seep into soil and water systems, contaminating ecosystems and disrupting biodiversity. Fawole et al. (2023) & Ministry of the Environment and Climate Change (2017) alert that these environmental damages indirectly exacerbate climate change by weakening ecosystems' ability to sequester carbon, as contaminated soils and watersheds lose their capacity to support plant life and other biological processes that absorb $CO_2$. Moreover, the global production of electronic goods is energy-intensive, contributing significantly to the climate crisis. The extraction of raw materials, particularly rare earth metals, and the manufacturing of electronic components involve high levels of energy consumption, much of which is derived from non-renewable fossil fuels. This industrial activity leads to significant GHG emissions, adding to the burden of global carbon footprints. Ali & Shirazi (2023); Sanghvi (2023); Turaga et al. (2019) & Oberle et al. (2019) found that mitigate the climate impact of e-waste, adopting circular economy principles is essential. A circular economy approach emphasizes reducing waste by keeping products, components, and materials in use for as long as possible through reuse, repair, refurbishment, and recycling.

Extending the lifespan of electronic devices is a critical aspect of this approach. Unfortunately, global recycling rates for e-waste remain low, with only about 17.4% of e-waste being formally recycled, according to the Global E-Waste Monitor (Balde et al., 2017). Chibunna et al. (2012); Fawole et al. (2023); Murthy & Ramakrishna (2022) & Shahabuddin et al., 2023) found the low recycling rate is often attributed to inadequate infrastructure, lack of consumer awareness, and inefficient collection systems.

In conclusion, the climate issues surrounding e-waste management pose significant and multifaceted challenges to ecosystems and global efforts to mitigate climate change. The lifecycle of electronic devices – from resource extraction and manufacturing to usage, disposal, and recycling – contributes heavily to greenhouse gas emissions and environmental degradation. Addressing these climate issues requires a shift towards circular economy models that prioritize product lifecycle extension, repairability, recycling, and sustainable production practices. Policy interventions such as Extended Producer Responsibility (EPR) and stricter enforcement of international agreements like the Basel Convention are essential for regulating the transboundary movement of e-waste and ensuring environmentally sound disposal practices. Additionally, innovations in green design and recycling technologies can help reduce the carbon footprint of e-waste management and promote resource recovery. Achieving sustainable e-waste management will require coordinated global efforts, combining policy reforms, technological advancements, and public awareness initiatives to align e-waste practices with climate goals, ultimately contributing to a more resilient and sustainable global ecosystem. Eventually, the environmental and climate issues associated with e-waste management in India demand immediate and sustained action. As the country grapples with the consequences of rapid technological advancements and growing e-waste generation, it is imperative to adopt a holistic approach that encompasses regulatory reforms, infrastructure development, public awareness, and international collaboration. By prioritizing sustainable e-waste management, India can protect its environment, safeguard public health, and contribute meaningfully to global efforts to combat climate change. The challenges are formidable, but with concerted efforts from all stakeholders, a sustainable future is achievable, one where the benefits of technology can be harnessed without compromising environmental integrity or human health.

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## References

1. Ali, S., & Shirazi, F. (2023). The Paradigm of Circular Economy and an Effective Electronic Waste Management. *Sustainability (Switzerland), 15*(3), 1–11. https://doi.org/10.3390/su15031998
2. Andeobu, L., Wibowo, S., & Grandhi, S. (2021). A systematic review of E-waste generation and environmental management of Asia Pacific countries. *International Journal of Environmental Research and Public Health, 18*(17). https://doi.org/10.3390/ijerph18179051
3. Balde, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). The global e-waste monitor 2017. In United Nations University. https://doi.org/10.1016/j.proci.2014.05.148
4. Bandyopadhyay, A. (2008). A regulatory approach for e-waste management: A cross-national review of current practice and policy with an assessment and policy recommendation for the Indian perspective. *International Journal of Environment and Waste Management, 2*(1–2), 139–186. https://doi.org/10.1504/IJEWM.2008.016998
5. Baumeister, R. E., & Leary, M. R. (1997). Writing Narrative Literature Reviews. *Review of General Psychology, 1*(3), 311–320. DOI:10.1037//1089-2680.1.3.311
6. Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production, 177*, 448–463. https://doi.org/10.1016/j.jclepro.2017.12.239
7. Chatterjee, S. (2011). Electronic Waste and India. Ministry of Electronics and Information Technology (MeitY)
8. https://www.meity.gov.in › uploads › 2024/02
9. Chibunna, J. B., Siwar, C., Begum, R. A., & Mohamed, A. F. (2012). The Challenges of E-waste Management Among Institutions: A Case Study of UKM. *Procedia - Social and Behavioral Sciences, 59*, 644–649. https://doi.org/10.1016/j.sbspro.2012.09.325
10. Cronin, P., Ryan, F., & Coughlan, M. (2008). *Undertaking a literature review: a step-by-step approach. British Journal of Nursing (Mark Allen Publishing), 17*(1), 38–43. https://doi.org/10.12968/bjon.2008.17.1.28059
11. Dumée, L. F. (2022). Circular Materials and Circular Design—Review on Challenges Towards Sustainable Manufacturing and Recycling. *Circular Economy and Sustainability, 2*(1), 9–23. https://doi.org/10.1007/s43615-021-00085-2
12. Efthymiou, L., Mavragani, A., & Tsagarakis, K. P. (2016). Quantifying the effect of macroeconomic and social factors on illegal e-waste trade. *International Journal of Environmental Research and Public Health, 13*(8). https://doi.org/10.3390/ijerph13080789
13. Fawole, A. A., Orikpete, O. F., Ehiobu, N. N., & Ewim, D. R. E. (2023). Climate change implications of electronic waste: strategies for sustainable management. *Bulletin of the National Research Centre, 47*(1). https://doi.org/10.1186/s42269-023-01124-8
14. Ganguly, R. (2016). E-waste management in India – An overview. *International Journal of Earth Sciences and Engineering, 9*(2), 574–588. DOI:10.69968/ijisem.2025v4i156-63

15. Garam, B., Carolien, B., Nick, E., Vanessa, G., Ruediger, K., Athanasios, M., Iyngararasan, M. J. P. (2019). A New Circular Vision for Electronics: Time for a Global Reboot. *World Economic Forum, January*, 1–24. www.weforum.org
16. Garlapati, V. K. (2016). E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. *Renewable and Sustainable Energy Reviews*, *54*, 874–881. https://doi.org/10.1016/j.rser.2015.10.106
17. Ghosh, B. K., Mekhilef, S., Ahmad, S., & Ghosh, S. K. (2022). A Review on Global Emissions by E-Products Based Waste: Technical Management for Reduced Effects and Achieving Sustainable Development Goals. *Sustainability (Switzerland), 14*(7). https://doi.org/10.3390/su14074036
18. Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, *26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x
19. Gupta, B. M., Dhawan, S. M., Kumar, A., & Visakhi, P. (2018). E-Waste research: A scientometric assessment of global publications output during 2007–16. *International Journal of Information Dissemination and Technology*, *8*(1), 31. https://doi.org/10.5958/2249-5576.2018.00007.9
20. Gupta, D. (2022). A Study of Indian Electronic Industry in Domestic and Global Context. *Gyankosh: An Interdisciplinary Journal*, *5*(December), 51–60. https://www.investindia.gov.in/siru/electronic-systems-design-and-manufacturing-india-120-bn-market-opportunity.
21. Gupta, K. S. (2007). E-waste Management: Teaching how to Reduce, Reuse and Recycle for Sustainable Development- Need of Some Educational strategies. *Journal of Edication and Practice, 2*(3), 74–87. ISSN 2222-288X (Online)
22. Gupta, M. (2008). Guidelines for Environmentally Sound Management of E-Waste. Ministry of Environment & Forests Central Pollution Control Board, Delhi. https://cpcb.nic.in/displaypdf.php?id=UHJvamVjdHMvRS1XYXN0ZS9mdWxsLXRleHQucGRm
23. Herat, S., & Agamuthu, P. (2012). E-waste: A problem or an opportunity? Review of issues, challenges and solutions in Asian countries. *WasteManagement and Research, 30*(11), 1113–1129. https://doi.org/10.1177/0734242X12453378
24. Hossain, M. S., Al-Hamadani, S. M. Z. F., & Rahman, M. T. (2015). E-waste: A Challenge for Sustainable Development. *Journal of Health and Pollution*, *5*(9), 3–11. https://doi.org/10.5696/2156-9614-5-9.3
25. Ilankoon, I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., & Petersen, J. (2018a). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, *82*, 258–275. https://doi.org/10.1016/j.wasman.2018.10.018
26. Ilankoon, I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., & Petersen, J. (2018b). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, *82*, 258–275. https://doi.org/10.1016/j.wasman.2018.10.018
27. Islam, A., Ahmed, T., Awual, M. R., Rahman, A., Sultana, M., Aziz, A. A., Monir, M. U., Teo, S. H., & Hasan, M. (2020). Advances in sustainable approaches to recover metals from e-waste-A review. *Journal of Cleaner Production, 244,* 118815. https://doi.org/10.1016/j.jclepro.2019.118815
28. Jayasiri, G., Herat, S., & Kaparaju, P. (2023). Management of Small WEEE: Future Directions for Australia. *Sustainability (Switzerland), 15*(18), 1–22. https://doi.org/10.3390/su151813543
29. Kalamaras, G., Kloukinioti, M., Antonopoulou, M., Ntaikou, I., Vlastos, D., Eleftherianos, A., & Dailianis, S. (2021). The potential risk of electronic waste disposal into aquatic media: The case of personal computer motherboards. *Toxics*, *9*(7). https://doi.org/10.3390/toxics9070166
30. Khanderia, S. (2018). The Information Technology Agreement and the 'Make-in-India' Initiative: Weighing the Better Alternative for India. *Foreign Trade Review, 53*(2), 98–115. https://doi.org/10.1177/0015732517734749
31. Khetriwal, D. S. (2019). E-waste management in India. *Waste Electrical and Electronic Equipment (WEEE) Handbook,* 541–571. https://doi.org/10.1016/B978-0-08-102158-3.00020-3
32. Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic waste management approaches: An overview. *Waste Management, 33*(5), 1237 1250. https://doi.org/10.1016/j.wasman.2013.01.006
33. Lebbie, T. S., Moyebi, O. D., Asante, K. A., Fobil, J., Brune-Drisse, M. N., Suk, W. A., Sly, P. D., Gorman, J., & Carpenter, D. O. (2021). E watse in Africa: A serious threat to the health of children. *International Journal of Environmental Research and Public Health, 18*(16). https://doi.org/10.3390/ijerph18168488
34. Ministry of the Environment and Climate Change. (2017). Strategy for a Waste-Free Onatrio Building the Circular Economy. Queen's Printer, February, 43. https://files.ontario.ca/finalstrategywastefreeont_eng_aoda1_final-s.pdf
35. Mohamad, N. S., Thoo, A. C., & Huam, H. T. (2022). The Determinants of Consumers' E-Waste Recycling Behavior through the Lens of Extended Theory of Planned Behavior. *Sustainability (Switzerland), 14*(15), 1–27. https://doi.org/10.3390/su14159031
36. Murthy, V., & Ramakrishna, S. (2022). A Review on Global E-Waste Management: Urban Mining towards a Sustainable Future and Circular Economy. *Sustainability (Switzerland), 14*(2). https://doi.org/10.3390/su14020647
37. Nadarajan, P., Vafaei-Zadeh, A., Hanifah, H., & Thurasamay, R. (2023). Sustaining the environment through e-waste recycling: an extended valence theory perspective. Aslib Journal of Information Management. https://doi.org/10.1108/AJIM-10-2022-0475
38. Nandan, A., Suresh, A. C., Saole, P., Jeevanasai, S. A., Chandrasekaran, R., Meili, L., Wan Azelee, N. I., & Selvasembian, R. (2023). An Integrated Approach for Electronic Waste Management—Overview of Sources of Generation, Toxicological Effects, Assessment, Governance, and Mitigation Approaches. *Sustainability (Switzerland), 15*(24). https://doi.org/10.3390/su152416946
39. Ofondu, A., Iroegbu, C., & Ray, S. S. (2022). Lignin and Keratin-Based Materials in Transient Devices and Disposables: Recent Advances Toward Materials and Environmental Sustainability. ACS Publications. https://doi.org/10.1021/acsomega.1c07372
40. Osibanjo, O., & Nnorom, I. C. (2007). The challenge of electronic waste (e-waste) management in developing countries. *Waste Management and Research, 25*(6), 489–501. https://doi.org/10.1177/0734242X07082028
41. Panchal, R., Singh, A., & Diwan, H. (2021). Economic potential of recycling e-waste in India and its impact on import of materials. *Resources Policy, 74*(July), 102264. https://doi.org/10.1016/j.resourpol.2021.102264
42. Purchase, D., Abbasi, G., Bisschop, L., Chatterjee, D., Ekberg, C., Ermolin, M., Fedotov, P., Garelick, H., Isimekhai, K., Kandile, N. G., Lundström, M., Matharu, A., Miller, B. W., Pineda, A., Popoola, O. E., Retegan, T., Ruedel, H., Serpe, A., Sheva, Y., … Wong, M. H. (2020). Global occurrence, chemical properties, and ecological impacts of e-wastes (IUPAC Technical Report). *Pure and Applied Chemistry, 92*(11), 1733–1767. https://doi.org/10.1515/pac-2019-0502

43. Robinson, B. H. (2009). E-waste: An assessment of global production and environmental impacts. *Science of the Total Environment, 408*(2), 183–191. https://doi.org/10.1016/j.scitotenv.2009.09.044
44. Sanghvi, H. (2023). Electronic Waste Taking Over the Globe: An Overview of the Law in Malaysia, India, China and the United Kingdom. *Asian Journal of Law and Policy, 3*(3), 1–14. https://doi.org/https://doi.org/10.33093/ajlp.2023.8
45. Shahabuddin, M., Uddin, M. N., Chowdhury, J. I., Ahmed, S. F., Uddin, M. N., Mofijur, M., & Uddin, M. A. (2023). A review of the recent development, challenges, and opportunities of electronic waste (e-waste). *International Journal of Environmental Science and Technology, 20*(4), 4513–4520. https://doi.org/10.1007/s13762-022-04274-w
46. Shi-Ming Huang, S.-M. H., & Shi-Ming Huang, Y.-Y. L. (2023). Machine Learning Improves Environmental Sustainability: A Teaching Case of Prediction about Scrapping Inventory. *International Journal of Computer Auditing, 5*(1), 004–031. https://doi.org/10.53106/256299802023120501002
47. Sivaramanan, S. (2013). E-Waste Management, Disposal and Its Impacts on the Environment. *Universal Journal of Environmental Research and Technology Www.Environmentaljournal.Org,3*(5), 531–537. http://www.environmentaljournal.org/3-5/ujert-3-5-1.pdf
48. Terazono, A., Murakami, S., Abe, N., Inanc, B., Moriguchi, Y., Sakai, S. I., Kojima, M., Yoshida, A., Li, J., Yang, J., Wong, M. H., Jain, A., Kim, I. S., Peralta, G. L., Lin, C. C., Mungcharoen, T., & Williams, E. (2006). Current status and research on E-waste issues in Asia. *Journal of Material Cycles and Waste Management, 8*(1), 1–12. https://doi.org/10.1007/s10163-005-0147-0
49. Tiwari, D., Mehra, G., & Dhawan, N. G. (2023). Systemic Economic Viability of Informal Sectors: E-Waste Management. *Nature Environment and Pollution Technology, 22*(3), 1431–1445. https://doi.org/10.46488/NEPT.2023.v22i03.029
50. Torraco, R. J. (2005). Writing Integrative Literature Reviews: Guidelines and Examples. *Human Resource Development Review, 4*(3), 356 367. https://doi.org/10.1177/1534484305278283
51. Turaga, R. M. R., Bhaskar, K., Sinha, S., Hinchliffe, D., Hemkhaus, M., Arora, R., Chatterjee, S., Khetriwal, D. S., Radulovic, V., Singhal, P., & Sharma, H. (2019). E-Waste Management in India: Issues and Strategies. *Vikalpa, 44*(3), 127–162. https://doi.org/10.1177/0256090919880655
52. Van Yken, J., Boxall, N. J., Cheng, K. Y., Nikoloski, A. N., Moheimani, N. R., & Kaksonen, A. H. (2021). E-waste recycling and resource recovery: A review on technologies, barriers and enablers with a focus on oceania. *Metals, 11*(8). https://doi.org/10.3390/met11081313
53. Wath, S. B., Dutt, P. S., & Chakrabarti, T. (2011). E-waste scenario in India, its management and implications. *Environmental Monitoring and Assessment, 172*(1–4), 249–262. https://doi.org/10.1007/s10661-010-1331-9
54. Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Böni, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review, 25*(5 SPEC. ISS.), 436–458. https://doi.org/10.1016/j.eiar.2005.04.001
55. Xavier, L. H., Ottoni, M., & Lepawsky, J. (2021). Circular economy and e-waste management in the Americas: Brazilian and Canadian frameworks. *Journal of Cleaner Production, 297*. https://doi.org/10.1016/j.jclepro.2021.126570
56. Yu, J., Williams, E., Ju, M., & Yang, Y. (2010). Forecasting global generation of obsolete personal computers. *Environmental Science and Technology, 44*(9), 3232–3237. https://doi.org/10.1021/es903350q