
E-WASTE IMPACT ON CLIMATE CHANGE: EVALUATING THE APPROACH OF TRANSITIONING AND DEVELOPED NATIONS¹

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ABSTRACT

Electronic garbage, or e-waste, is regarded as a "ticking time bomb" in today's globalised society. The word encompasses electronic equipment that are undesirable, nonfunctional, or have reached the conclusion of their "useful life." The yearly generation of e-waste is progressively rising. E-waste poses a significant concern to all environmental strata, adversely affecting land and soil, and jeopardising the availability of potable groundwater beneath. It also contaminates air and water, since industrial businesses continue to discharge untreated garbage or employ incineration processes that emit harmful materials into the atmosphere, potentially damaging respiratory systems. In 2021, the total quantity of produced electronic garbage reached 57.4 million tonnes. Furthermore, over the years, the sum is augmenting at an approximate pace of 2 Mt annually. Experts project that the global amount of non-recycled e-waste would reach 347 metric tonnes by the end of this year. Its most detrimental effect may be its incorporation into extensive landfills, where the adjacent environment becomes tainted with toxic elements such as mercury, cadmium, and lead, resulting in various ailments. According to the World Health Organization, being exposed to electronic waste can have a number of negative effects on one's health. These include unfavourable outcomes during pregnancy, such as premature birth, changes in lung function, and respiratory difficulties. These challenges are materialising on a daily basis. Furthermore, there is a correlation between the proper collection and recycling of electronic waste and the protection and preservation of both the environment and human health. In addition, the most difficult obstacle to overcome when it comes to the management of electronic waste is international legislation, namely the dichotomy that exists between nations in the global north and those in the global south. With impoverished nations functioning as receptacles for illegal quantities of electronic trash created by wealthy countries, there is a worrying aspect of "toxic colonialism." This is a problem since it is becoming increasingly common. The objective of this research is to get an

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understanding of the existing issue and to make recommendations that are appropriate.

Introduction

Technology and humans are so linked in the 21st century that existence without them just seems impossible. Air conditioners, phones, computers, chargers, and EarPods are essential for daily life. Generative AI allows prompt-based writing and picture synthesis from basic text inputs, changing how we create. UNEP assessed 2012 e-waste² could fill 100 Empire State buildings, averaging over 6.8 kg per person alive at that time. The globe produced 53.6 million metric tonnes of E-waste in 2019, up 21% from 2014. Technology and E-waste are unavoidable. According to UNEP³, merely 17% of E-waste undergoes proper recycling. E-waste is one of the biggest and most complex waste sources, according to the ITU. E-waste production in 2019 was 53.6 million tonnes, with just 9.3 million tonnes, or 17%, collected and repurposed, according to the Global E-waste Monitor 2020.⁴ The Global E-waste Monitor 2024 shows that by 2022, the globe would generate 62 billion kilograms of e-waste, or 7.8 kg per person. Only 22.3%, or 13.8 billion kg, of e-waste was collected and recycled.⁵

E-waste is toxic, non-biodegradable, and pollutes land, air, water, and living things. Open-air burning and acid baths used to remove valuable elements from electronics release toxic pollutants into the environment. These practices may expose workers to high levels of lead, mercury, beryllium, thallium, cadmium, arsenic, brominated flame retardants (BFRs), and polychlorinated biphenyls, which may cause cancers, miscarriages, neurological impairment, and lower IQs.

The 2019 collaborative research “A New Circular Vision for Electronics- Time for a Global Reboot” suggests a circular economy-based strategy to e-waste to reduce waste and energy loss. The E-waste Coalition—ILO, ITU, UNEP, UNIDO, UNITAR, UNU, and Basel and Stockholm Convention Secretariats—is supported by the report. The study found that inadequate e-waste management depletes scarce and important raw materials including neodymium (used in motor magnets), indium (used in flat panel TVs), and cobalt. Rare earth elements are environmentally toxic, therefore informal recycling seldom yields them. Although

² Devin N. Perkis et.al, E-Waste: A Global Hazard, Volume 80 AGH. 286, 286-295 (2014).

³ UNEP, How disposable tech is feeding an e-waste crisis, (2023).

⁴ UNITAR, The Global E-Waste Monitor 2020.

⁵ UNITAR, The Global E-Waste Monitor 2024.

technology can collect 95% of cobalt from e-waste, only 30% is recovered. Laptop, smartphone, and electric car batteries employ the metal. Recycled metals are two to ten times more energy efficient than virgin metals. Gold extraction from discarded electronics generates 80% less CO₂ than ground mining.⁶

Technology, whether in artificial intelligence or electronic gadgets, is unavoidable, yet electronic waste complicates sustainable growth. 'E-waste' includes everyday home items.⁷ These include LED lights, clocks, irons, refrigerators, air conditioners, and washing machines. Small IT gear like external hard drives, routers, keyboards, and mice is combined with consumer electronics like mobile phones, headphones, remote controls, and audio devices. IT equipment including computers, laptops, tablets, printers, and hard drives is grouped with toasters, food processors, and barbecues.

E-waste contains recyclable and non-recyclable metal and plastic components; thus its environmental and public health impacts require appropriate management. Most rubbish is dumped in large landfills, often in developing nations, where it is burnt or mismanaged, harming the local people.⁸ One of the biggest injustices is that electronic trash recycling is still poor despite advances in technology and waste management. Recent research on the 'myth' of plastic recycling highlights the urgent need to address the threat of technological waste to climate change. A detailed examination is needed since a large amount is wasted in industrialised nations' backyards and these countries are becoming electronic goods makers.⁹

E-Waste Impact on Climate Change

Climate change is a human-caused disaster. Human actions, mainly the burning of fossil fuels in industry and transportation, have caused modern climate change. Volcanic activity and solar changes have historically affected world temperatures.¹⁰ AI, especially Generative AI¹¹, has a

⁶ WEO, UNEP et.al, A New Circular Vision for Electronics Time for a Global Reboot, PACE. (2019).

⁷ Anjani R.K. Gollakot et.al, Inconsistencies of e-waste management in developing nations – Facts and plausible solutions, Volume 261 JEM. (2020)

⁸ Jacklin Kwan, your old electronics are poisoning people at this toxic dump in Ghana, WIRED, November 26th 2020. <https://www.wired.com/story/ghana-ewaste-dump-electronics/>

⁹ Oliver Franklin-Wallis, 'Plastic recycling is a myth': what really happens to your rubbish?, The Guardian, August 17th 2019. <https://www.theguardian.com/environment/2019/aug/17/plastic-recycling-myth-what-really-happens-your-rubbish>

¹⁰ Dr. John Last et.al, Taking Our Breath Away, 3 (David Suzuki Foundation 1998).

¹¹ Casey Crownhart, AI will add to the e-waste problem. Here's what we can do about it. MIT Technology Review, October 28th 2024. <https://www.technologyreview.com/2024/10/28/1106316/ai-e-waste/>

significant but 'underappreciated' influence on climate change, according to one research.¹² The accelerated advancement of AI surpasses the hardware capabilities of current computers, exacerbating the E-waste problem.

Besides affecting climate change, it poses health and ecological risks, especially to aquatic animals. One research found that electronic waste treatment in developing countries like Ghana often fails, resulting in debris being dumped into the ocean. Electronic waste components release organic chemicals that harm water environments and neighbouring humans.¹³

Another Ghanaian investigation found E-waste in contaminated water and sediment. Electronic waste is largely caused by poor management, especially in developing nations. Another research in Guiyu, China, demonstrates comparable risks of electronic trash, but it also shows that industrialised nations manufacture and dispose of most of it. The analysis shows that China has a 'informal' electrical equipment business that uses cheap methods and promotes itself as a cheaper alternative to high-end brands. China has become a hub for electronics in both primary and secondary markets by manufacturing components for cell phones, PCs, game consoles, and other gadgets. Guiyu is known as the world's largest electronic graveyard due to its high output and worldwide dumping of e-waste. Electronic trash, which originates from electronic appliance manufacturing, emits greenhouse gases (GHGs) owing to poor management.¹⁴

Due to resource constraints and technological ignorance, such methods are common in underdeveloped nations. Workers in these scrap yards are often poor migrants without proper training or assistance. Workers in Ghana often incinerate wires using insulating foam from disassembled refrigerators or car tires, unprotected from highly polluted smoke and cuts and burns. Electronic trash incineration pollutes the air with zinc, iron, lead, copper, and aluminium. These activities also elevated urine and blood PAH, cadmium, and lead levels.¹⁵

E-waste's environmental effect is caused by poor management and reckless disposal. In particular, heavy metals and other components make them unsafe at open dumping sites. Lead,

¹² Anwesha Borthakur & Pardeep Singh, The journey from products to waste: a pilot study on perception and discarding of electronic waste in contemporary urban India, Volume 28 *ESPR* 24511, 24511-24520 (2021).

¹³ Jingyu Huang et.al, E-Waste Disposal Effects on the Aquatic Environment: Accra, Ghana, Volume 229 *Rev Environ Contam Toxicol* 19, 19-34 (2014).

¹⁴ Kun Wang et.al, Understanding Environmental Pollutions of Informal E-Waste Clustering in Global South via Multi-Scalar Regulatory Frameworks: A Case Study of Guiyu Town, China, Volume 17 *Int. J. Environ. Res. Public Health* 1, 1-18 (2020).

¹⁵ Damian Fischer et.al, Health Consequences for E-Waste Workers and Bystanders—A Comparative Cross-Sectional Study, Volume 17 *Int J Environ Res Public Health* 1, 1-12 (2020).

a common component of electronics, pollutes drinking water and soil, causing land erosion, agricultural decline, and health problems. Research suggests that lead exposure below 10 µg/dL might hinder cognitive development and lower IQ by 2-3 points in children. When burnt, other metals like copper release toxic vapours that damage nearby residents' respiratory function, especially workers, who are at danger of flame-retardant poisoning and respiratory diseases.¹⁶

Poor E-waste management is linked to the informal nature of the sector, especially in developing nations of the Global South¹⁷. Due to poor e-waste management legislation, the informal sector handles a large amount of these pollutants. Eliminating E-waste involves open dumping, untreated disposal, and burning. Additionally, black marketplaces in poorer nations worsen the dilemma. E-waste is often sold as 'reusable items,' taking advantage of the Basel Convention's 'repairable loophole.'¹⁸ This loophole permits the export of non-functional, defective, or untested electronics for "failure analysis, repair, or refurbishment." This avoids tight restrictions and the Prior Informed Consent (PIC) procedure, encouraging the export of harmful products, especially because disposal costs in developed nations are higher. Criminal groups use legislative flaws and coerce and bribe to dispose of E-waste in unauthorised landfills and harvest heavy metals and other materials for profit.¹⁹

The deterioration of items in open landfills, especially electronic garbage, creates greenhouse gases like methane, which exacerbate global warming. Insufficient E-waste classification and disposal worsen this situation; biohazards such leaching might develop²⁰. These contain harmful organic pollutants including ammonia nitrogen compounds, which are more complicated than residential sewage due to their volatility and heterogeneity. The leachate produced²¹ by the e-waste dump is exceedingly toxic and harmful to living organisms. POPs and PCBs, which contain over 200 chemical compounds, can be released from landfills by electronic trash. Due to their ability to travel over 1600 miles by aquatic or air currents,

¹⁶ Aimin Chen et.al, Developmental Neurotoxicants in E-waste: An Emerging Health Concern, Volume 119 EHP 431, 431-438 (2011).

¹⁷ Erin McIntire, The International Tribunal for E-waste: Ending the Race Towards Lethal Fallout, Volume 5 SJEL 75, 75-107 (2015).

¹⁸ Nikita Shukla, How The Basel Convention has Harmed Developing Countries, Earth.Org, March 30th 2020. <https://earth.org/how-the-basel-convention-has-harmed-developing-countries/>

¹⁹ Serena Favarin, Transnational trafficking networks of end-of-life vehicles and e-waste, Volume 24 GC 215, 215-237 (2022).

²⁰ Zhao Youcai, Leachate Generation and Characteristics, in Pollution Control Technology for Leachate from Municipal Solid Waste 1-30, (Butterworth-Heinemann 2019).

²¹ E.A Omondi et.al, Phytoremediation of Polychlorobiphenyls (PCB's) in Landfill E-Waste Leachate with Water Hyacinth (E.Crassipes) Volume 4 IJSTR 147, 147-156 (2015).

persistent organic pollutants (POPs) can be detected in remote environments, even locations where they have never been used. Precipitation, percolation, surface leachate penetration, groundwater permeation, cover material leachate, free water inside trash, and organic matter decomposition are the main causes of landfill leachate.

Worryingly, e-waste generation is growing. Detailed worldwide data research highlights another issue: North-South political division. India's domestic industry was valued USD 22.68 billion in FY23, and China provided one-third of the world's electronics. However,²² these two nations are major E-waste producers worldwide; Asian markets²³ have seen a rise in output. Poor E-waste management rules have hurt these places' environment; despite domestic legislation, understanding of proper disposal and safety standards is weak. However, developed nations contribute significantly to E-waste, especially in illegal dumping sites where large amounts of illicit waste come from criminal activities linked to developed nations or the Global North. This is called 'toxic colonialism.' When examining the negative effects of E-waste production, one must also consider political division, which can be assessed by analysing international agreements on E-waste, such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, and national legislation and policies.

Failures of policy implementation- a look into International and Domestic legislations

The Basel Convention- robust framework still ineffective implementation

E-waste has increased worldwide due to technological advances, posing an environmental threat and prompting countries to regulate its handling. These restrictions aim to reduce the growing waste stream from international and regional mandates. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (BCCTMHWD), signed by 189 governments, restricts hazardous waste transfers to low- and middle-income countries. Regardless of its global setting, reducing hazardous waste flow is key. The Basel Convention is the leading international framework for transboundary electronic waste issues. The Basel Convention replaced E-waste disposal with rubbish reuse and recycling. EoL electrical and electronic equipment from wealthy nations is mostly sold to

²² Dr. Geeta Shrivastava, National Legal Regime on E-Waste Management in India, Volume 17 PJAEE 1573, 1573-1582 (2020).

²³ Alviti Kankanamalage Hasith Priyashantha et.al, E-waste scenario in South-Asia: an emerging risk to environment and public health, Volume 37 EAHT 1, 1-18 (2022).

impoverished nations as used products. Importing waste creates a business opportunity for developing nations while meeting the need for cheap secondhand electronics.²⁴

The Agreement allows parties to limit hazardous waste imports and requires them to inform other parties. Importing states must approve shipments, and an oversight body must approve or reject them. Basel Convention and various domestic E-waste management laws are based on Extended Producer Responsibility.²⁵ It holds manufacturers accountable for their goods throughout their lives, including post-consumer. Doing so helps meet environmental goals like recycling. EPR collects, sorts, and recycles trash and produces extensive data on production, goods, waste creation, and treatment. Producers fund this.

The Convention expanded the list of hazardous plastic wastes subject to Prior Informed Consent (PIC) in 2019. The Basel Convention Plastic Waste Partnership was launched in 2019 to promote environmentally sound plastic waste management at global, regional, and national levels and avoid its creation. Over 140 member firms are engaging in an Extended Producer Responsibility (EPR) forum to promote action and debate among stakeholders, harmonising with the Basel Convention. The 2019 amendment is based on the 1995 'Ban' amendment.

Ambiguous phrasing allows exporters to exploit Basel Convention loopholes to export hazardous waste to needy nations without breaking the law. Without common definitions for words like 'hazardous' and 'waste', rules are interpreted by each nation-state. This gives exporters the leeway to keep selling waste to poor nations as 'commodities.' Thus, more hazardous rubbish is dumped in poorer nations, where local labourers disassemble it, harming their health and the environment. The Convention cannot eliminate illegal transactions, the 'basis' of E-waste.²⁶

The term 'taking into consideration social, technological, and economic aspects' in the convention's Preamble allows many states to argue that their social or economic constraints prevent them from reducing hazardous waste or influence their interpretation of what is appropriate²⁷. In numerous instances, this serves as a convenient justification for nations to

²⁴ UNEP, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes.

²⁵ Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, Forum on Extended Producer Responsibility for Plastic Wastes.

²⁶ Zada Lipman, A dirty dilemma: the hazardous waste trade, Volume 23 HIR 67, 67-71 (2002).

²⁷ Zelalem Bogale, Comment: E-Responsibility: E-Waste, International Law and Africa's Growing Digital Wasteland, Volume 18 U.C. DAVIS J. INT'L L. & POL'Y 225, 225-239 (2011).

evade accountability. In countries like India, despite the existence of a comprehensive framework such as the E-Waste Management Rules 2022²⁸, The informal sector generates large amounts of e-waste. Nearly 56% of such garbage is disposed of in public dumpsters without environmental or health treatment. Incinerating cable wires with their rubber insulation intact in huge dumps releases strong odours that harm neighbouring residents' respiratory health.²⁹ The government acknowledges a lack of awareness, transparency, and information on E-waste disposal, repurposing, and recycling.³⁰

The Convention can't hold governments liable for non-compliance, especially as waste-related disasters make preventive and control ineffective. The PIC technique, supposed to be its greatest strength, sometimes fails to verify if the exporting nation has enough waste management facilities in the importing country. Non-signatory states compound the problem, especially with electronic trash smuggling and trading. In 2008, the USGAO reported that the Environmental Protection Agency (EPA)'s enforcement shortcomings and limited jurisdiction allow a large volume of untreated and illegal electronic waste to flow unimpeded from its exports.³¹

The PIC has shown its ineffectiveness even without convention participation, and the US's non-membership hinders enforcement of standards linked to the problem³². The PIC protocol's complexity and implementation approaches have caused delays in a country that uses it. The EU's Waste Shipment Regulation complies with the Basel Convention, and the European E-Waste Recyclers Association (EERA) has carefully documented these concerns and implemented more efficient methods.³³ Authorities in successful implementation nations have needed many papers beyond their jurisdiction, outside Basel Convention legal requirements. Environmental agencies might impose strict (and possibly impossible) standards to avoid abuse. Since competent authorities in various nations are unwilling to bear accountability for the unlawful trafficking of hazardous and other wastes, fear of error may lead to mistrust. The Basel Convention's promises disappointed many African nations, therefore they ratified the

²⁸ E-Waste (Management) Rules, 2022. REGD. No. D. L.-33004/99.

²⁹ Toxic Link, Informal E-Waste Recycling in Delhi, (2019).

³⁰ As seen in Shailesh Singh S/o Mr. Babu Singh v. State of Uttar Pradesh, Execution Application No.4/2024. (India)

³¹ USGAO. Electronic Waste: Harmful U.S. Exports Flow Virtually Unrestricted Because of Minimal EPA Enforcement and Narrow Regulation, GAO-08-1166T (2008).

³² Alan Andrews, Beyond the Ban – Can the Basel Convention Adequately Safeguard the Interests of The World's Poor in The International Trade of Hazardous Waste?, Volume 5 LEAD 169, 169-184 (2009).

³³ StEP and Prevent, Practical Experiences with the Basel Convention: Challenges, Good Practice and Ways to Improve Transboundary Movements of E-Waste in Low- and Middle-Income countries.

Bamako Convention. These states banned E-waste imports into Africa to address regional difficulties brought up by trade tensions. Article 11 of the Basel Convention encourages regional hazardous waste agreements to achieve its goals.

A major issue is that important contributors in 'toxic colonialism,' like the US, have not signed the convention, resulting in unequal E-waste disposal duties for impoverished nations.³⁴ In 2019³⁵, the Basel Action Network (BAN) produced a paper on illegal electronic trash, including a research on EU waste 'leakage' to underdeveloped nations. Over 58% of exported garbage went to poor nations including Africa, Thailand, Pakistan, Nigeria, Ghana, and Tanzania. BAN found that WEEE (E-waste) was often recycled unsafely, exposing workers and polluting communities by crushing, burning, melting, or chemical acid stripping to extract copper, gold, steel, and aluminium. Some equipment was kept in operation, but mercury, lead, and brominated flame retardants were disposed of or burnt in neighbouring landfills. BAN is concerned that recent efforts by electronics manufacturers (Digital Europe) and the EU to create a "Repairable Loophole" in the Basel Convention will allow Europe to import defective, low-value electronic waste, undermining the Convention's fundamental purpose and threatening a circular economy. The EU wants to legalise dangerous exports, therefore its exaggerated sorrow is ludicrous. To ensure Europe's future well-being is not dependent on harming others, enforcement must be strengthened, not legalised.

A major weakness of the Convention is that it limits waste to 'substances or items that are discarded, intended for disposal, or prescribed for disposal by national legislation'. The Basel Action Network, a staunch opponent of the 'recycling loophole', claims that most waste exported to developing nations for reuse or recycling is either 'sham' recycling, where the importer discards or incinerates the materials, or 'dirty' recycling, which pollutes the environment and endangers workers.

Convention's 'prior informed consent' fails to address power imbalances between nations. Because the Convention doesn't clearly forbid the export of some hazardous waste, low-income countries may readily acquiesce despite environmental and health concerns, perceiving garbage imports as a way to boost foreign exchange profits.

³⁴ Lekha Sridhar and Parul Kumar, *The New Face of Waste Colonialism: A Review of Legal Regulations Governing the Import of Waste into India*, Volume 15 SLR 101, 101-130. (2019).

³⁵ Basel Action Network, *Holes in the Circular Economy: WEEE Leakage from Europe*, (2018).

Without a strong non-compliance mechanism with severe repercussions, the Convention's efficacy may have been hampered, and sovereignty concerns may have prevented certain nations from signing it. Before recently, it excluded plastic and certain e-waste. Fourth, the US, a major waste dealer, is not a Convention signatory. Fifth, the Convention requires the exporting countries to guarantee the importing nation has waste disposal facilities, although this is often ignored. Empirical research suggests the Convention has had little impact on international waste trade. The cost benefits of waste transfer to developing nations and the difficulties of numerous low-income countries to execute import bans made the Convention ineffectual.

Legislative failure of the domestic law of Global North and South nations

Many nations have built legal frameworks to manage and dispose of local and imported electronic trash since the Basel Convention. India accepted the Basel Convention on June 24, 1992, prompting the Ministry of Environment and Forests to develop local regulations. Despite these attempts, hazardous material including waste oil, PCBs, and asbestos entered the nation due to outdated import rules. As recently as 1998, no 'prior informed consent' petitions had been submitted, and many ports were unaware of the Convention until the Supreme Court ordered the Central Government to execute the Rules in 1997. The E-Waste (Management) Rules 2022 in India follow Basel Convention norms and requirements. As the policy framework has evolved, authorities have set particular norms and restrictions to reduce unlawful recycling.

The Central Pollution Control Board reports 569 recycling units with 1,790,348.27 metric tonnes of capacity.³⁶ These units are being expanded to 1,500 by 2030. To avoid illegal disposal of old electronics, the government must tighten E-commerce legislation. Electronic goods makers must also keep detailed records of its production, sale, and recycling. The government must educate the public about recycling electronic debris at specified centers.

Individuals must also understand the health and environmental risks of inappropriate trash disposal. India has a defined framework to reduce E-waste creation and promote upcycling by supporting research and development to recover valuable metals from such garbage. The

³⁶ Siddharth Ghanshyam Singh, *E-Waste Management in India Challenges and Agenda*, (eds. Arif Ayaz Parrey) (Centre for Science and Environment 2020).

country has changed its electronic waste management laws.³⁷ The CPCB has set regulations to manage and regulate E-waste creation in India.³⁸

The law punishes and penalties companies who violate E-waste restrictions. In 2011, 2016, 2018, and 2022, India revised its e-waste management legislation, which took effect in 2023. The 2016 E-waste (Management) Rules regulate E-waste disposal in the country, helping reduce and manage it. India has a comprehensive E-waste policy that gives financial aid to companies who comply. However, weak infrastructure, administration, and unequal enforcement make these policies difficult to implement. State-specific law has caused E-waste management standards to be inconsistent, stressing the need for a centralised framework to address E-waste challenges. Monitoring electronics use and disposal at the end of their lives requires a centralised system to avoid improper dumping.

In the Global South, countries like India face similar implementation, administration, inconsistency, and ineffectual legislation. These nations have an official industry for E-waste recycling, although the informal sector manages most of it. The previous section showed that illicit trading worsens E-waste dangers, harming the climate and human health. Most of the "hidden flow" of e-waste from the US is unregistered and either exported, disposed of in landfills, or incinerated. About 20% of US e-waste gets recycled, including the authorised transport to India and China.

The Chinese subcontinent's current situation requires e-waste management legislation that minimises electronic trash. By 2016, the Ministry of Ecology and Environment estimated 12 million tonnes of e-waste collected³⁹. This law requires producers and merchants to collect E-waste from customers and prohibits its illegal export to other countries. This improves county-level recycling, and China's E-waste collection, transportation, and recycling structure has reduced E-waste. The Chinese government devised the National Plan for the Prevention and Control of E-waste Pollution to reduce E-waste generation. This initiative promotes recycling and health and safety. The Act aims to reduce E-waste by 10% and increase recycling by 5%

³⁷ Richard Heeks et.al, Understanding e-Waste Management in Developing Countries: Strategies, Determinants, and Policy Implications in the Indian ICT Sector, Volume 21, ITD 653, 653-667 (2015).

³⁸ Greenpeace. Where does e-waste end up? 2009. <http://www.greenpeace.org/international/en/campaigns/toxics/electronics/the-e-waste-problem/where-does-e-waste-end-up/>.

³⁹ Yu Han et.al, Heavy metals in soil contaminated through e-waste processing activities in a recycling area: Implications for risk management, Volume 125 PSEP 189, 189-196 (2019).

yearly to improve the framework, raise awareness of E-waste infrastructure, and expand recycling facilities.⁴⁰

The 2004 Measures for the Administration of Permit for Operation of Hazardous Wastes are reviewed and changed to improve oversight and control of hazardous waste collection, storage, and disposal, including discarded circuit boards. In June 2009, the Chinese government launched the "Household Appliances Old for New Rebate Program" in four provinces and five significant cities before expanding nationwide. This program governs Chinese electronics recycling and disposal. The WEEE Management Regulation, supported by technical guidelines and directives, took effect on January 1, 2011. The July 2012 WEEE Treatment Fund Policy greatly improved China's e-waste treatment system. The "Old for New Program" and "Fund Policy" have greatly improved the official e-waste management system.⁴¹

China, the world's second-largest economy, is crucial to the low-carbon, green economy transformation. China aims to peak carbon emissions by 2030 and reach carbon neutrality by 2060 to combat climate change. To achieve these goals, the formal e-waste recycling process must be improved. E-waste recycling can aid peak carbon production and carbon neutrality. China has a harder time reaching carbon neutrality than wealthier nations due to its lower energy efficiency and higher fossil fuel use. Since China's economy is less developed than the US and EU, economic vulnerabilities are a concern.

China lacks advanced low- and zero-carbon technologies, requiring a tripartite method to decarbonise: carbon peak, carbon slowdown, and carbon neutrality ("three stages, four steps"). Industrial ecology increasingly views eco-industrial parks (EIPs) as a systematic way to promote the circular economy, sustainable growth, and resource efficiency. It might be used to improve e-waste management in developing and wealthy nations. Two important Extended Producer Responsibility (EPR) models have been deployed in China's e-waste recycling business, despite its low adoption in developing nations. In conclusion, China must work hard to meet its carbon emission goals. China has a legal framework for e-waste management, but major difficulties must be solved to provide viable solutions. China bans e-waste imports, but

⁴⁰ Tingting Tian et.al, Managing e-waste from a closed-loop lifecycle perspective: China's challenges and fund policy redesign, Volume 29 *ESPR* 47713, 47713-47724 (2022).

⁴¹ Ying Zhou et.al, Legacy and alternative flame retardants in indoor dust from e-waste industrial parks and adjacent residential houses in South China: Variations, sources, and health implications, Volume 845 *STE* (2022).

loopholes allow it to produce a lot of it. Government initiatives and recycling efforts have failed, raising the question of whether foreign companies can solve China's e-waste problem.⁴²

China's significant e-waste imports, despite transboundary rules, exacerbates the situation. Shipments from the US, Europe, and sophisticated Asian countries like Japan and South Korea continue to meet the demand for used electronics, prompting the US to pass its law last month. Exporters avoid the import ban by mixing electronic waste with genuine trash or importing through Hong Kong.

Guiyu, Guangdong, illustrates the effects of e-waste increase in China. As the world's largest e-waste dumping site, the town's residents have digestive, neurological, and skeletal difficulties, with 80% of children having respiratory ailments. Environmental hazards result from electronic garbage breakdown. Incinerating e-waste, a common recycling procedure in China, can release hydrocarbons, brominated dioxins, and other harmful particles according to wind patterns.⁴³

In developing Asia, informal sectors manage over 95% of E-waste. These informal sectors, called "shadow economies," pumped money directly into the official economy, fuelling the country. Most E-waste recycling included small businesses, which are prevalent. Identifying and regulating this type of enterprise in underdeveloped Asian nations is tough.⁴⁴

They exploit impoverished and marginalised people who survive by collecting electrical garbage. About 2% of Asians survive on garbage scavenging. The informal group's primitive E-waste recycling practices endanger their health and environment. They never handle garbage with sophisticated tools or PPE. Everyone dismantles with bare hands and hammers, screw drivers, etc. Directly reusable components and secondary raw materials were processed in formal sectors. Young and elderly of all genders, urbanites and rural migrants, do the work. Children often participated in informal E-waste recycling. For metal recovery, they employ powerful acids without protection. Also, they labour in inadequately ventilated confined spaces sans masks. Formal and informal trash recycling occupations differ per country and have

⁴² Xin Zhao et.al, Challenges toward carbon neutrality in China: Strategies and countermeasures, Volume 176 RCR (2022).

⁴³ Bitong Li et.al, Challenges of E-Waste Dismantling in China, Volume 12 Toxics 1, 1-15 (2024).

⁴⁴ Streicher-Porte et.al, Informal electronic waste recycling: A sector review with special focus on China. Waste Management, Volume 31 MA 731, 731–742 (2011).

unique names. Small E-waste recycling enterprises are usually hidden from governmental inspection since they border the informal sector and are not included in official statistics.

In one case, US legislation's inability to stop the unrestricted movement of illegal waste contributes to the problem faced by the developing nature. Despite the 2008 UNGOA report, this problem still persists. In the US, there is no federal law that focuses exclusively on e-waste. Since there is no federal e-waste legislation, states can establish or not make their own.⁴⁵ Many issues arise from the lack of a federal norm. Most clearly, some states would allow e-waste exports to Guiyu, attracting recycling enterprises and causing a race to the bottom.⁴⁶

The US Department of Justice (DOJ) found Executive Recycling, Inc.'s chairwoman and members guilty of e-waste trafficking in 2015, among other environmental violations. Around 160 cargos totalling 100,000 CRTs of rubbish were exported and dumped in developing nations like China, Africa, Malaysia, etc.⁴⁷ Without a government E-waste management regulation, AI and other service companies like Google routinely produce carbon-free. Recent reports show that Google's AI-driven process has increased carbon emissions by 50%.⁴⁸

The EU Regulation of 2006 merged the old “amber” and “red” lists of largely hazardous wastes into one list with a uniform notification system to streamline trash transfers within, out of, and into the EU. The waste producer, holder, or other person who intends to ship must submit a written notification with standard forms, additional information, a contract, and a financial guarantee to the competent authority of dispatch, which sends the documents to the destination and transit authorities. The notifier must wait for formal approval from those authorities before shipping. The revised law restricted "tacit consent" to exports to other OECD nations and to the scenario where the competent transit authority does not respond within 30 days. Written consent and disposal or recovery completion was harmonised to 30 days and 1 year,

⁴⁵ Wharton Staff, How U.S. Laws Do (and Don't) Support E-Recycling and Reuse, Knowledge at Wharton. April 6 2016. <https://knowledge.wharton.upenn.edu/article/how-u-s-laws-do-and-dont-support-e-recycling-and-reuse/>

⁴⁶ Christian Cutillo, A Toxic Reciprocity: Examining the E-Waste Stream from the United States to China, HLP (2011).

⁴⁷ Press Release, Executive Recycling Company and Executives Sentenced for Fraud and International Environmental Crimes. U.S. Attorney's Office, District of Colorado. April 13th 2013. <https://www.justice.gov/usao-co/pr/executive-recycling-company-and-executives-sentenced-fraud-and-international>

⁴⁸ Dan Milmo, Google's emissions climb nearly 50% in five years due to AI energy demand, The Guardian. July 2nd 2024, <https://www.theguardian.com/technology/article/2024/jul/02/google-ai-emissions>

respectively.⁴⁹

While Member States must cooperate bilaterally or multilaterally to prevent and identify unlawful shipments. They also need to select permanent staff members accountable for collaboration and physical shipping check focus areas. This duty supports IMPEL, the voluntary EU Network for the Implementation and Enforcement of Environmental Law, which brings together inspectors and enforcement bodies from most Member States and whose “TFS cluster” handles trans-frontier trash exports. EU has an excellent implementation structure that holds member states accountable for violating current rules, yet it still dumps pollution into poorer nations.

Another difficulty in our waste management dispute between the Global North and South is that 'recycling,' as it is now defined, is not viable or does not exist in the same way we understand it⁵⁰. Even though they knew it was unlikely, companies actively promoted recycling garbage, particularly plastic, for a long time. Corporate 'deception' was revealed in a 2024 Centre for Climate Integrity study.⁵¹ The worst part is that most garbage goes unrecycled, and the 'green' and 'safe' process releases tonnes of dangerous gases and carbon emissions, worsening climate change. Previous industry officials said the goal was to bypass laws and ensure a steady demand for fossil fuel-derived plastics.

Plastic is a major component of electrical trash, hence this issue is important. The informal sector responsible for its disposal and administration is insecure, thus recycling electronic trash should be done with prudence. Recent research results and recycling process inefficiencies raise doubt on the practicality of such procedures for electronic garbage. NPR revealed a substantial conflict of interest between governments in the plastic and garbage sectors, which calls into question accountability structures. This inhibits their capacity to adopt effective waste reduction initiatives or enforce responsibilities, especially because the fossil fuel sector invests heavily in U.N. talks.⁵²

⁴⁹ Thomas Ormond, The EU Waste Shipment Regulation and the need for better enforcement, ELNI 18, 18-43 (2010).

⁵⁰ Dharna Noor, 'They lied': plastics producers deceived public about recycling, report reveals, The Guardian, February 15th 2024. <https://www.theguardian.com/us-news/2024/feb/15/recycling-plastics-producers-report>

⁵¹ Davis Allen et.al, The Fraud of Plastic Recycling, Centre for Climate Integrity, February 2024. <https://climateintegrity.org/uploads/media/Fraud-of-Plastic-Recycling-2024.pdf>

⁵² Michael Copley, Reduce, reuse, redirect outrage: How plastic-makers used recycling as a fig leaf, NPR, February 15 2024. <https://www.npr.org/2024/02/15/1231690415/plastic-recycling-waste-oil-fossil-fuels-climate-change>

Technology- the solution to our problem

According to our observations, E-waste issues go beyond policy inefficiency and poor enforcement, worsened by political conflict between rich and poor nations. Another crucial feature requires our attention technology. The rapid growth of technology worldwide increases electronic trash. This is inevitable. In the graphic, we can see the main international electronic waste producers.

China and India are major manufacturers of electronic trash, but their per capita production is lower than Western nations'. Our study shows that both hemispheres create electronic trash, making this issue essential. Much of this Northern garbage gets wasted in underdeveloped nations. These countries struggle with inadequate waste management systems and the inflow of imported electronic garbage, which makes matters worse. Illicit trading persists notwithstanding the Basel Convention.

In 2008, the US Government Accountability Office found that 43 businesses exported e-waste containers, with 80% going to Hong Kong, China. Hazardous electronic trash includes circuit boards, CRT glass, and lead-acid batteries. The Basel Convention regulates hazardous waste control and disposal across borders, governing their transboundary flows. Electronic trash transboundary migration has been reduced, yet the goal remains unattainable.⁵³ Illegal smuggling and dumping undermine attempts to solve this critical issue.⁵⁴ Investigations⁵⁵ carried out by the European Union and the United Nations⁵⁶ reveal a troubling reality: African nations, especially West Africa, are increasingly receiving wealthy nations' technological garbage. Poor legislative frameworks and laws prevent low- and middle-income African states from appropriately appraising foreign e-waste imports. Even while many African states have accepted international waste transportation agreements, weak legislation and enforcement have allowed illicit e-waste recycling and importation to continue.

After learning about the myth of pristine 'recycling,' E-waste must be handled with care. To ensure a strong accountability structure, stricter policy implementation is needed. E-waste

⁵³ Carole Gibbs, Transnational white-collar crime and risk, Volume 9 CPP 543, 543-560 (2010).

⁵⁴ Josh Lepawsky, the changing geography of global trade in electronic discards: time to rethink the e-waste problem, Volume 181 TGJ 147, 147-159 (2015).

⁵⁵ I.M.S.K. Ilankoon, E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery, Volume 82 WM 258, 258-275 (2018).

⁵⁶ Mathias Schlupe, Where are WEEE in Africa?, 2012 Electronics Goes Green 2012+ IEEE. (2012).

recycling and processing in the EU is regulated by the government. Independent non-profits coordinate, organise, and oversee these procedures. There are around 500 electronic waste treatment and disposal companies. China has a comprehensive producer responsibility framework for electrical and electronic waste management. A comprehensive environmental management system customised to the nation's electronic waste circumstances supports this goal. The disposal of discarded electrical appliances fund allows electrical and electronic firms to contribute. This fund subsidises garbage recycling and processing.⁵⁷

The European Commission⁵⁸ has recently announced right-to-repair guidelines for consumer electronic products, while the UK has implemented analogous regulations mandating manufacturers to supply repair manuals and make spare parts accessible for a limited range of electronic goods, including washing machines, washer-dryers, refrigerators, dishwashers, and electronic displays. The United States is likewise poised to enact a comparable regulation on the maintenance of agricultural machinery. Nonetheless, for electronic devices, particularly smartphones, tablets, and laptops, a right-to-repair regulation remains a topic of public discourse in several nations, including Australia.

EU and UK right-to-repair rules were adopted in March and July 2021. The UK passed rules replicating the right-to-repair requirements agreed upon by the UK and EU before Brexit in accordance with EU regulations. The UK's new efficiency standard for washing machines and refrigerators, along with right-to-repair rules, is expected to save customers £75 (USD 103) annually on energy costs and reduce 1.5 million metric tonnes of electrical waste. EU legislation may immediately lower energy prices by 20 billion euros per year starting in 2030 and cut CO2 emissions by 50 million metric tonnes. These new guidelines aim to extend product lifespans by up to 10 years and reduce energy consumption, reducing greenhouse gases and e-waste in a circular economy.

As technology improves, especially artificial intelligence, society changes drastically⁵⁹. This development affects our culture, customs, and attitudes, complicating waste management and climate change. The effects go beyond technological trash to environmental waste and

⁵⁷ European Commission: Brussels, A new circular economy action plan for a cleaner and more competitive Europe (2020).

⁵⁸ Narendra Singh and Oladele A. Ogunseitan, Disentangling the worldwide web of e-waste and climate change co-benefits, Volume 1 CE (2022).

⁵⁹ Jim Euchner, Is the Evolution of Technology Inevitable?, Volume 64 RTM 11, 11-13 (2021).

wastewater discharge.⁶⁰

Suggestions

Digitalisation strengthens global frameworks like Extended Producer Responsibility (EPR) and advances policy-relevant R&D. Voluntary e-commerce codes of practice, a unified framework for Extended Producer Responsibility, considerations for the digital circular economy, and policy implications for online retailers across jurisdictions may reduce free-riding in digital marketplaces. In conclusion, laws on the “right to repair” and what defines refurbished goods would remove barriers to repair and refurbishing. This endeavour will reduce hazards, increase customer acceptance, and improve online sales of these goods and their components.

Securing customers' right to fix their purchases might extend their lifespan by a decade and reduce energy usage and greenhouse gas emissions. This may reduce concerns about the rapid accumulation of electronic trash, a result of excessive use. Electronic product green design is a major effort to reduce e-waste from the start. Sustainability throughout the product life cycle is key. Electronic product design requires modular, integrated, and intelligent technology and high-powered, lightweight, and ecologically friendly materials. Non-hazardous materials, energy efficiency, environmental sustainability, and recyclability must be prioritised in electronic device designs to ensure dependability and longevity. Design ideas, materials, and construction methods form the basis of environmentally responsible electrical device design.

Design principles must include product environmental features including disassembly, recyclability, maintainability, and reusability. These factors simplify end-of-life electronic product recycling. Recycling and using sustainable resources are expected to be popular. To improve recycling, harmful and hazardous products will be banned and reduced. The development of electronic product recycling construction methods can reduce the discharge of heavy metals and organic chemicals during disassembly. Additionally, it reduces the use of acidic, alkaline, and corrosive substances.

E-waste recycling demands a strong and effective design system. Governments should build an appropriate recycling framework for their economic development, urbanisation, and geography. To support electronic device recycling throughout their life cycle, governments

⁶⁰ Mark Fisher and John Severini, *Making AI Inevitable: Historical Perspective and the Problems of Predicting Long-Term Technological Change*, OIAIS (2025).

must strengthen rules and regulations using an extended producer responsibility approach. The recycling framework must incorporate environmental implications, risk avoidance, and expanded producer responsibility into the regulatory structure. Extended producer responsibility is a proven method for controlling transboundary e-waste. Complete life cycle assessment reduces environmental impacts in solid waste recycling. The biggest challenge in e-waste recycling is collecting. Financial incentives from the government may increase recycling enterprises and attract foreign investment, which can quickly improve formal e-waste recycling. This answers the main e-waste recycling question.

We also suggest recycling e-waste to recover zinc, copper, iron, and aluminium. A systematic framework permits skilful classification of e-waste into burning, treatment, and recycling and metal resource extraction categories. Copper removal methods include membrane filtration, electro dialysis, electrocoagulation, physical adhesion, chemical precipitation, co-precipitation, ion-exchange, nanofiltration, and adsorption. Due to the many flaws in international accords like the Basel Convention, two remedies have been offered. African governments have either adopted the Bamako Convention to defend against international E-waste imports or may need to update it to handle new issues. Success depends on meticulous policy maintenance, good management, and convention members' sense of duty.

Conclusion

E-waste is expanding due to the increasing number of complex electronic equipment approaching their end of life. Production, consumption, and recycling globally transport hazardous and valuable items. Basel Convention-inspired international rules attempt to ban transboundary e-waste transportation. Implementation is difficult, and a precise assessment of the present status and trends is still lacking. Worldwide efforts have been made to track e-waste's past, present, and future. Quantities, routes, and spatial distribution have been prioritised, but a global perspective is lacking. Current e-waste management systems struggle with computing demands that limit scalability and efficiency. Most nations face an increasing e-waste problem. Sustainable e-waste management is essential. E-waste has several negative repercussions. It endangers human and environmental health. Collaboration is needed to address e-waste. To avoid problems, government and individuals must act. The paper proposes a framework to handle existing issues such. Bio-metallurgy is cheaper, more efficient, and more ecologically benign than hydrometallurgy and pyrometallurgy for extracting base and

precious metals from e-waste. To recover energy and precious materials from e-waste, we need sustainable and integrated solutions.