Heliyon 10 (2024) e28707

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

An in-depth analysis and review of management strategies for E-waste in the south Asian region: A way forward towards waste to energy conversion and sustainability

Md. Kaviul Islam [a,b,1,*], Mst. Sharifa Khatun [b,c,1], Monjur Mourshed [c]

[a] School of Science and Engineering, Canadian University of Bangladesh, Dhaka, Bangladesh
[b] Department of Mechanical Engineering, Iowa State University, Union Drive, Ames, IA, United States
[c] Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh

A R T I C L E I N F O

Keywords:
E-Waste generation
E-Waste management
South Asia region
Circular economy

A B S T R A C T

The soaring rise of electronic and electrical waste (E-waste) leads to significant challenges to the South Asian region, urging for incorporating comprehensive assessment and management strategies. The research dives into the intricacies of E-waste and examines how regulatory barriers, public ignorance, and the limited lifespan of electronic devices all contribute to the significant production of E-waste. This study emphasizes the vital need for ongoing and appropriate management practices by bringing attention to the short lifespan of electronic devices and the resulting generation of E-waste. This work also addresses the increased risks that people who live close to informal recycling sites for electronic waste face, as well as the dangerous substances that are found in them and how they harm the environment and human health. Furthermore, in order to promote circular economies and increase productivity, the study assesses management practices in both developed and developing nations, placing special emphasis on component reuse and recycling. Along with addressing the grave consequences of the illicit E-waste trade on the environment, particularly in developing nations, this review attempts to enlighten stakeholders and policymakers about the vital need for coordinated efforts to address the issues related to E-waste in the South Asian region by offering insights into E-waste assessment and management techniques.

1. Introduction

E-waste refers to discarded electrical appliances and electronic devices, which has become a significant category of waste on a global scale [1]. It encompasses previously owned electronic equipment for recovery, repurposing, recycling, refurbishing, material discarding, or abandonment [2]. In recent years, the swift advancements in technology, industrial expansion, economic progress, and shifts in living habits have led to a significant rise in the need for electronics, including smartphones, PCs, TVs, air conditioning units, hardware parts, fridges, and other electronic gadgets for use in personal, professional, and home environments [3–6]. This surge in demand has consequently led to the generation of a large volume of E-waste worldwide, as the availability of resources and prosperity contribute to higher levels of consumption [7–9]. The surge in electronic waste generation has become a notable and concerning

* Corresponding author. School of Science and Engineering, Canadian University of Bangladesh, Dhaka, Bangladesh.
E-mail address: kaviulislam@gmail.com (Md.K. Islam).

[1] These authors contributed equally to this work and co-first authors.

https://doi.org/10.1016/j.heliyon.2024.e28707
Received 31 December 2023; Received in revised form 22 March 2024; Accepted 22 March 2024
Available online 27 March 2024
2405-8440/

problem in recent years.It is estimated that the global output of electronic waste currently stands at approximately 57.4 million metric tons (MMT) per year. Among the continents, Asia leads in E-waste production, generating the highest amount of E-waste at 24.9 MMT, followed by America, Europe, Africa, and Oceania [10]. Only a minority of the world's nations, totaling 78, currently possess laws related to electronic waste. However, these laws are often not effectively enforced across various regions. In numerous developing areas, especially in Northern Africa and Southeast Asia, legislation pertaining to electronic waste is often minimal or entirely absent [11].

On the other hand, E-waste encompasses valuable materials such as iron and steel (50%), plastics (21%),other metals (13%), both hazardous and non-hazardous components, as well as and various substances including wood, glass, ceramics, and rubber (16%) [12]. Electronic devices such as printed circuit boards (PCBs), smartphones, TVs, computers, printers, washing machines, refrigerators, photocopiers, telecommunication servers, and coffee machines are making greater use of precious materials including gold (Au), platinum (Pt), silver (Ag), cadmium (Cd), palladium (Pd), copper (Cu), zinc (Zn), lead (Pb), nickel (Ni), cobalt (Co), and rare earth elements like lanthanum (La), cerium (Ce), neodymium (Nd), and yttrium (Y) [13]. Moreover, E-waste also contains heavy metals such as cadmium (Cd), nickel (Ni), mercury (Hg), lead (Pb), copper (Cu), and chromium (Cr), along with halogenated organic compounds including polychlorinated biphenyls (PCBs), chlorofluorocarbons (CFCs), polybrominated biphenyls (PBBs), and brominated flame retardants (BFRs) [13,14]. The estimated value of E-waste raw materials stands at $57 billion, yet only $10 billion of this E-waste is sustainably recycled and reclaimed, resulting in a reduction of 15 million tons of CO_2 emissions [11]. Therefore, E-waste needs to be handled with proper care to minimize the chances of releasing hazardous substances into the environment, including soil, water, and air [15]. E-waste has also possesses detrimental effects on aquatic life which causes harm to plants and animals in water bodies [16].

Metal extraction has been successfully utilized as a means of generating financial value from electronic waste in developed countries such as the United States, Japan, Taiwan, the European Union, and Canada [17]. Comprehensive management of E-waste involves distinct phases of collection, recycling, and disposal. In developed countries, authorized local government or private entities typically handle the collection of electronic waste. The majority of the waste is processed at advanced facilities equipped with well-managed infrastructure and technologies to ensure the safe and efficient extraction of valuable materials. Any remaining waste is disposed of in accordance with regulations [18]. In contrast, waste collection services in developing and underdeveloped countries are frequently inconvenient, and unregulated and poorly monitored dumping sites are common. The situation is worsening, and governance challenges further complicate the problem. Insufficient waste management institutions, rapid urbanization, and chronic underfunding make waste management a difficult undertaking in these countries and their cities [19]. On the other hand, despite of the significant market potential, the sustainability of the recycling industry is compromised due to the high labor and utility costs associated with E-waste recycling facilities [20].Therefore, most undeveloped countries and developing, gather E-waste in an unofficial, dispersed, and illegal manner by various businesses, merchants, or governmental entities. About 20% of the total E-waste generated in developing countries is recycled to extract valuable elements, using rudimentary technology without proper occupational safety precautions [21]. The leftover electronic waste frequently finds its way into landfills, leading to environmental harm by releasing harmful substances into the soil and water sources. As a result, the mix of poor waste management methods and the vast amounts of electronic waste pose considerable social, environmental, and economic issues for developing nations in the South Asian area, including India, Pakistan, Bangladesh, among others.

Based on our current understanding, the majority of existing literature primarily concentrates on examining the effects of resources, policies, and regulations on the retrieval of materials. Several articles have explored the processes involved in metal recovery, encompassing techniques such as pyrometallurgy, physical methods, and bio-hydrometallurgy [22]. However, few studies examined south Asian E-waste generation, management, and hazardous aspects. Therefore, the aim of this article is to thoroughly investigate the E-waste predicament in the South Asian region via a three phrase analysis. This study leverages secondary data gathered from diverse published materials, focusing primarily on the insights derived from existing publications.

This review paper compiles a comprehensive analysis of the E-waste generation in South Asian countries by presenting a comparative analysis on the E-waste consumption and import by those countries. The subsequent section highlights the effects of E-waste recycling on social, environmental, and economic aspects, along with the utilization of diverse assessment methods and tools. Additionally, the review includes an evaluation of the potential recovery of valuable metals through E-waste recycling and its economic implications. Moreover, this review paper sheds light on sustainable E-waste management and proposes pragmatic strategies to regulate and monitor E-waste generation and management.

2. E-WASTE generation scenerio

Electrical and electronic equipment (EEE) is prevalent in modern life and society, existing in various forms, sizes, functionalities, and compositions. EEE, along with its huge pile of wastes (WEEE), is categorized based on size, weight, functionality, and composition. According to the United Nations (UN), the global production of electronic waste (excluding PV panels) reached 53.6 MMT in 2019, equivalent to an average per capita of 7.3 kg per person. This data highlights the alarming situation we currently face, as there has been a significant (about 21%) increase in E-waste generation worldwide over the past five years [23]. From 2010 to 2020, the global E-waste generation witnessed an annual increase of 2 MMT. Starting at around 33.8 MMT in 2010, the amount of worldwide E-waste production rate has consistently risen each year and it is reported that over the course of ten years, by 2019, the quantity had surged by 58%. Yet, in the forthcoming decade, a substantial surge in E-waste generation is anticipated. Projections suggest that between 2010 and 2030, the worldwide volume of E-waste will experience an astonishing increase of about 121%, effectively more than doubling the present figures [24].

The surge in electronic waste primarily stems from electronic gadgets, reduced longevity of products, and restricted repaiability. In

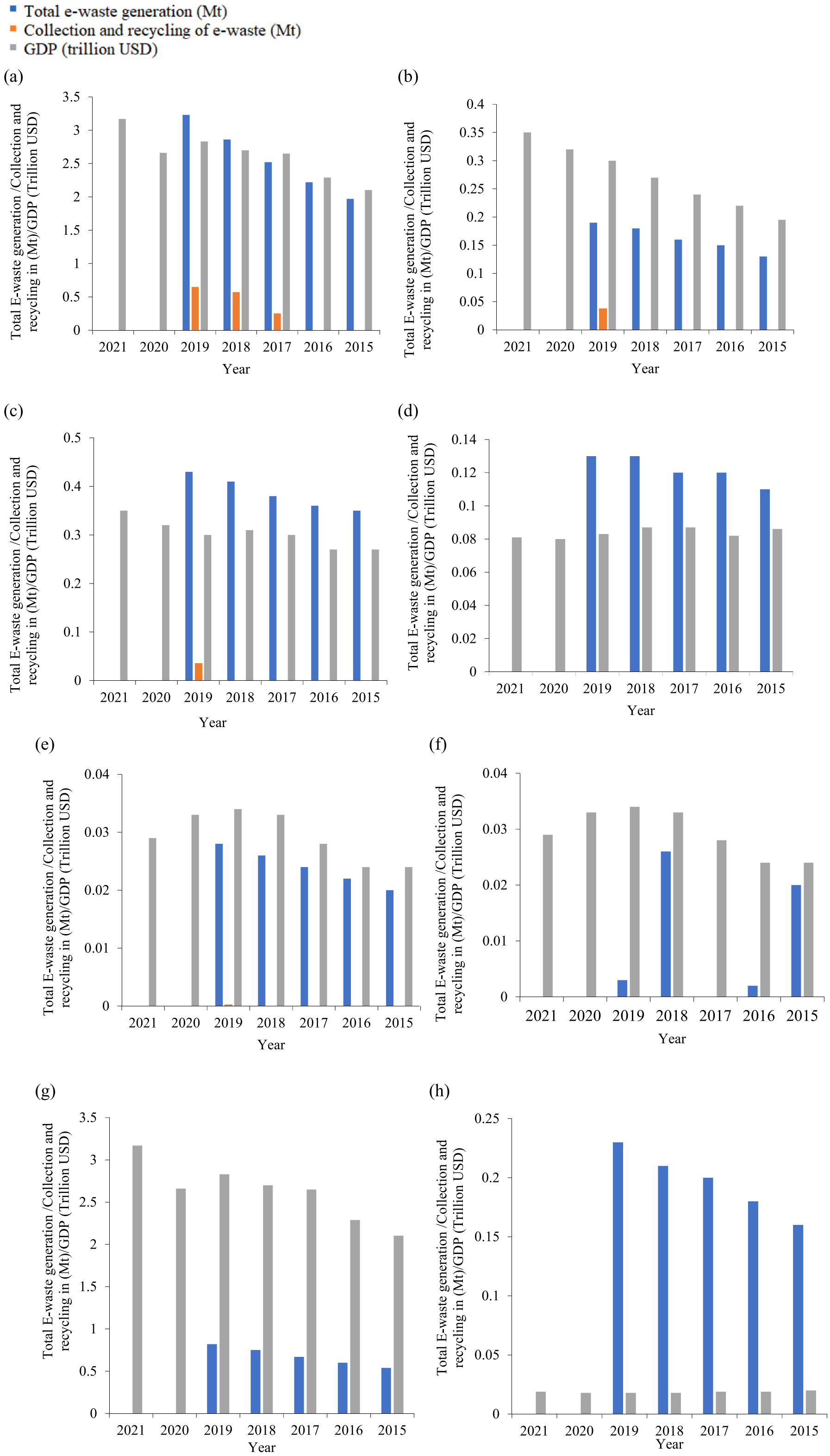

Fig. 1. E-waste generation (a) India [33–39], (b) Bangladesh [40–46], (c) Pakistan [47,48–53], (d) Sri Lanka [54–60], (e) Nepal [61–67], (f) Bhutan [68–74], (g) Myanmar [75–80], (h) Afghanistan [79–84].

2019, Asia emerged as the largest contributor to E-waste production, accounting for 24.9 MMT and Oceania being the least in terms of E-waste generation 0.7 MMT, Americas with 13.1 MMT is the second highest followed by Europe with 12 MMT. Africa generated 2.9 MMT of e -waste. Notably, China, being a technologically advanced nation, plays a significant role in Asia's dominant position in E-waste generation. According to the WEEE report on International E-waste Day held on October 10, 2021, China alone is responsible to generate about 57.4 MMT of E-waste in the same year. Moreover, developing nations in Asia, including Pakistan, India, and Bangladesh, import electronic waste for recycling purposes, thereby reinforcing Asia's dominant status as the leading continent in this regard [24,25].

In addition, standard of living is influenced by an individual's financial resources, which in turn affects their purchasing behavior when it comes to electronic devices. When people buy electronic devices solely to upgrade to the latest models, it indicates that the purchase is driven by luxury rather than necessity. This consumer behavior contributes to the increasing demand, production, and supply of goods with limited lifespans, resulting in a rise in electronic waste generation In a developing economy, electric and electronic devices are essential, and the amount of E-waste produced is closely linked to the Gross Domestic Product (GDP) of a nation [26,27]. A higher GDP (PPP) indicates increased purchasing of electronics by the population, leading to a greater volume of electronic waste being generated. For instance, the European Union (EU) has seen an annual increase of 3–5 percent in electronic waste generation, surpassing the average GDP growth rate of 2.6 percent between 2005 and 2008 [28]. The nature of E-waste is also being shaped by technological developments in the electrical appliance and electronics industries. Outdated electrical and technological equipment is being disposed of more frequently due to the increasing availability of more affordable and easily accessible electronic devices. The choice of cheaper and more accessible raw materials by manufacturers adds to the evolving composition of E-waste [29]. For instance, during the last three years, the massive Asian nation of China—which generates roughly 150,000 tons of electronic waste annually—has seen average economic growth of 8% [30]. After an extensive eight-month investigation, Mumbai, India's financial hub, was found to be the biggest producer of electronic waste, producing 19,000 tons annually [31].

Additionally, Europe produced the most E-waste in 2019, with each person producing 16.2 kg on average. This appears to be a little bit more than what Oceania produced per person (15.9 kg). On the other hand, America is third with 13 kg of E-waste produced per person, behind Asia (5.7 kg), and Africa (2.7 kg). However, Asia produces the most E-waste than the total Europe despite having the greatest per capita rate due to the region's high population density (more than 50% of the world's population). It is also reported that in 2019, several European countries (such as Germany, Italy, France, United Kingdom, and Spain) exhibited relatively higher levels of E-waste generation per capita, ranging from 20 to 25 kg per capita, compared to other nations. The development of E-waste in the United States exhibits a similar pattern. Among various Asian countries such as India, Indonesia, Turkey, and Egypt, the amount of E-waste generated per unit of GDP was notably higher and exceeding 1 metric ton per million dollars of GDP. Iran stood out with the highest value, reaching approximately 4 MT per million dollars of GDP. Fascinatingly, India recorded the lowest per capita generation of electronic waste, estimated at approximately 2 kg per person. This lower figure could potentially be attributed to India's high population density in relation to E-waste generation. Thus, greater economic prosperity in countries with higher GDPs results in more EEE being sold and, as a result, higher E-waste production. Kusch et al. highlight a non-linear correlation between GDP and the generation of E-waste, pointing to a saturation phenomenon that occurs as the focus shifts from richer economies to those with lower economic prosperity [32]. Fig. 1 presented below displays a linear trend in E-waste output annually in eight countries in South Asia and serves as an illustration of how consumption is rising as a result of rising local demand.

South Asia has emerged as a major destination for E-waste disposal, with countries like India, Pakistan, Bangladesh, and Sri Lanka being prominent in this regard. India ranks fourth and Pakistan ranks twenty-sixth among the largest E-waste producers globally [85,86]. The worldwide practice of manufacturing low-cost, short-lived electronic products has played a significant role in the escalation of waste production. In 2019, India produced 3.23 million metric tons (Mt) of E-waste, surpassing other countries in South Asia with the highest volume. However, only 20% of India's total E-waste is collected and recycled. Bangladesh, too, contributes to the generation of a considerable volume of electronic waste on an annual basis [87]; however, Bangladesh recycles 20% of total E-waste which is more than any other south Asian country, excluding India. Sri Lanka, Nepal, Bhutan, Afghanistan, and Myanmar have no fixed collection or recycling infrastructure, even though they produce a certain amount of E-waste each year. In Pakistan, domestic E-waste generation reached 1790 kilotons in 2018–2019, and it is projected to increase by 10.2% annually. Furthermore, between 2011 and 2014, Pakistan imported 95,145 tons of E-waste per year [47].In Myanmar, approximately 29,000 tons of E-waste were reported in 2014. It is estimated that globally, with a population of 66.25 million, each person generates about 0.4 kg of electronic waste annually [88]. Based on this estimate, the volume of E-waste is expected to reach 20,000 tons by 2030, using the same per capita factor of 0.4 kg/year [88]. The generation of electronic over the period from 2015 to 2021 is depicted in Fig. 1, with subfigures (a-h) for India, Bangladesh, Pakistan, Sri Lanka, Nepal, Bhutan, Myanmar, and Afghanistan respectively.

3. Consumption and import of E-waste

Asia has become the top region in the world for the generation of E-waste over the last ten years. This is especially true in South-East Asia, which is now a well-known centre for the production and assembly of electrical and electronic devices. These goods are created not only for regional demand but also to meet the growing technological demands of the area [89]. Even though the Basel Convention was established to control the transboundary movement and disposal of hazardous wastes, some E-waste scraps and used goods are exempt [90]. As a result, developed nations are still able to ship electronic waste to developing countries [91]. Therefore, the export of electronic waste from developed nations has seen a considerable upsurge, making up about 50–80% of the total E-waste generated. Nearly 90% of E-waste is divided into three categories: consumer electronics (33.7%), ICT equipment (33.9%), and large domestic appliances (42.1%) [41]. Over 70% of all E-waste comes from computers, with the remaining 30% coming from domestic sources, according to India's Electronic Waste Management. Computers are trailed by phones, telecommunications equipment, and electrical and electronic devices by 12%, 8%, and 7%, respectively [92]. Importing used and partially used goods is one of the primary reasons why the production of E-waste is rising in developing and underdeveloped nations.

In Bangladesh, 3.2 million electrical devices are consumed annually [93]. By the end of September 2022, there were 181.43 million active mobile phone subscribers whereas it is predicted that there will be 362.86 million sets in all [94]. Out of all the categories contributing to E-waste in Pakistan, cell phones are the most significant. Sales of handsets increased by 10.4% annually, while those of televisions/monitors and computers increased by roughly 5.2 and 3.8% per year (BMI 2017). The total number of mobile phone subscribers has reached 175.62 million at the end of September 2022. This growth of E-waste in Pakistan is projected to align with the rate of sales growth, as electronic devices reach the end of their useful lives.

According to Sri Lanka's Telecommunication Regulatory Authority, mobile penetration increased noticeably from 126% in 2017 to 131% in 2018 [95]. According to recent survey data from the Department of Census and Statistics of Sri Lanka, the country boasts the highest cell phone penetration rate among South Asian nations. Furthermore, the data reveals a 23.5% increase in the number of homes equipped with computers in 2017 compared to 2016 [95]. The demand for EEE, particularly mobile phones and laptops, is anticipated to rise in the coming years as a result of technological advancements that give the products more alluring features, as well as competitive costs and marketing initiatives among importers in the nation. Imported items dominate Sri Lanka's EEE market. About 95% of EEE is imported, and imports have recently surged [95]. In Nepal, the use of electronic products is steadily increasing as almost every house has multiple electronic gadgets. Nepal's imports of electronic products are on the rise, but the government lacks suitable standards and laws for their disposal once their useful life has expired [96]. Similar to Myanmar, large and small appliances (such as dishwashers, solar panels, dryers, washing machines, and electric stoves) and appliances (such as video cameras, toasters, microwaves, and electric shavers) often contribute more than 90% of the electronic trash (refrigerator, AC, etc.) by the end of their life [88]. Table 1 below displays data on local electronic goods consumption and imports across a number of south Asian nations.

According to a study, developed countries currently export approximately 23% of their electronic waste to developing nations annually [137]. This percentage is expected to rise in the future, driven by the growing demand for electronic products in the Western world. It is anticipated that two factors contribute to the increasing transfer of E-waste from developed to underdeveloped nations. Firstly, strict rules and regulations in industrialized countries like the United States which makes it challenging to dispose of electronics in landfills, considering that the potential pollution of hazardous substances and sub sequent harm to ecosystems and human health.

The lack of appropriate safety and environmental regulations in many developing countries makes it dangerous for their

Table 1
Local electronic product consumption and product imports in several south Asian countries.

Country	Product category	Appliances	Product consumed (million)	Product Import (million)	Countries import from
Bangladesh	Electronic gadgets	Mobile phones	170.14 [97]	0.62 [98]	India, China, Hongkong [99]
		Computer	6.56 [100]	1.29	China, Singapore, Malaysia [101]
	Home appliances	Television	21.76 [102]	0.03 [103]	China, Malaysia, Vietnam [104]
		Refrigerator	2.6	–	–
		Air conditioner	0.14	–	–
India	Electronic gadgets	Mobile phones	1,180 [105]	5.6 [106]	China, Taiwan, Hongkong, South Korea, Thailand [107]
		Computer/ laptops	27.36 (2020) [108]	0.73 (2020) [109]	China, Hongkong, Malaysia, Taiwan
	Home appliances	Television	210 [110]	1.12 [111]	China, South Korea, Hongkong
		Refrigerator	98.35 [112]	0.001 [113]	Thailand, Indonesia, South Korea [114] [115]
		Washing machine	22.48	–	–
		Mixer grinder	89.92	–	–
Pakistan	Electronic gadgets	Mobile phones	175.62 [116]	24.51 [117]	USA, UK, China [118]
		Computer/ laptop	4.5 [27,119]	0.628 [120,121]	China, USA, Malaysia, Singapore [122]
	Home Appliances	Television	27.47 [123]	0.025 [124]	–
		Refrigerator	30 [125]	0.0037 [126]	China, Slovakia, Austria
		Air Conditioner	3 [127]	0.007 [128]	China, Thailand, Bahrain
Sri Lanka	Electronic gadgets	Mobile phone	29.73 [129]	–	–
		Computer/ laptops	8 [130]	–	–
	Home appliances	Television	3.8 [131]	–	–
Nepal		Mobile phones	38.3 [132]	5.63	China
Bhutan	Electronic gadgets	Mobile phones	0.73 [133]	–	–
Myanmar	Electronic gadgets	Mobile phones	68.24 [134]	–	–
Afghanistan	Electronic gadgets	Mobile phones	22.68 [135]	–	–
	Home appliances	Television	24.91 [136]	–	–

populations and ecosystems to accept these imports. Second, the labour required for formal recycling facilities to separate, disassemble, and classify electronics by material can drive up the operational costs of recycling plants in developed nations like the USA. Due to the substantially lower processing expenses for hazardous E-waste in developing nations compared to developed ones, numerous affluent countries engage in the illegal export of their E-waste to these less economically advanced regions. Furthermore, it is stated that Vietnam, India, Ghana, Pakistan, and Nigeria are the main export destinations for E-waste [138]. Fig. 2 illustrates the transportation of E-waste from developed to developing countries and the associated health risks. The Basel Action Network conducted an investigation to trace the destination of E-waste collected at recycling sites across the country. By placing tracking devices in laptops, TVs, and printers, researchers monitored the movement of these devices. Astonishingly, approximately one-third of the tracked E-waste was found to be shipped to countries such as the Dominican Republic, China, Kenya, Hong Kong, Taiwan, Pakistan, and Mexico [137,139].

A recent study conducted in India aimed to evaluate the impact of electronic waste on developing nations, specifically focusing on two Indian locations - Mandoli and Loni.These two locations are recognized for processing a substantial volume of E-waste originating from developed nations. The study revealed alarming levels of lead contamination in the soil of both areas, with the Loni sample showing approximately 150 times higher concentration compared to the control sample. Furthermore, heavy metal contamination, including mercury, was detected in the water supplies of both regions. In fact, one water sample from Mandoli contained nearly 710 times higher than the recommended level of mercury [137]. In Ghana and Nigeria, it is also very common to burn obsolete electronics in open air which releases heavy toxic fumes into the air. These activities not only harm the environment but also endanger the workers themselves, who lack safety equipment like goggles and facemasks to protect them from the hazardous pollutants. In developing countries, the informal sector of E-waste recycling utilizes basic methods for the recovery and disposal of electronic components, aiming to extract valuable metals like cobalt, lithium, platinum, silver, gold, copper, and palladium. Families and workers depend on this metal extraction for their livelihoods. The presence of high mercury levels poses risks to the neurological system, mucosal membranes, and muscles. Prolonged exposure to mercury can lead to difficulties in chewing and swallowing food [143]. To responsibly dispose of old electronics, recycling is often considered the most convenient option. However, it is crucial to ensure that these devices do not end up in developing countries as E-waste. Unfortunately, numerous recycling companies that portray themselves as sustainable and environmentally friendly choose to export their materials instead of processing them domestically in the developed countries.

4. General composition of E-waste

E-waste features a complex composition, including a variety of materials such as steel (47% by weight), plastics (21%), copper (7%), glass (5%), and others like wood and ceramics [144]. Due to the presence of various precious metals (Au, Ag, Pt, Pd, Nd) as well as hazardous metals, E-waste is frequently referred to as an urban mine [145]. An efficient and ecologically friendly recovery of these

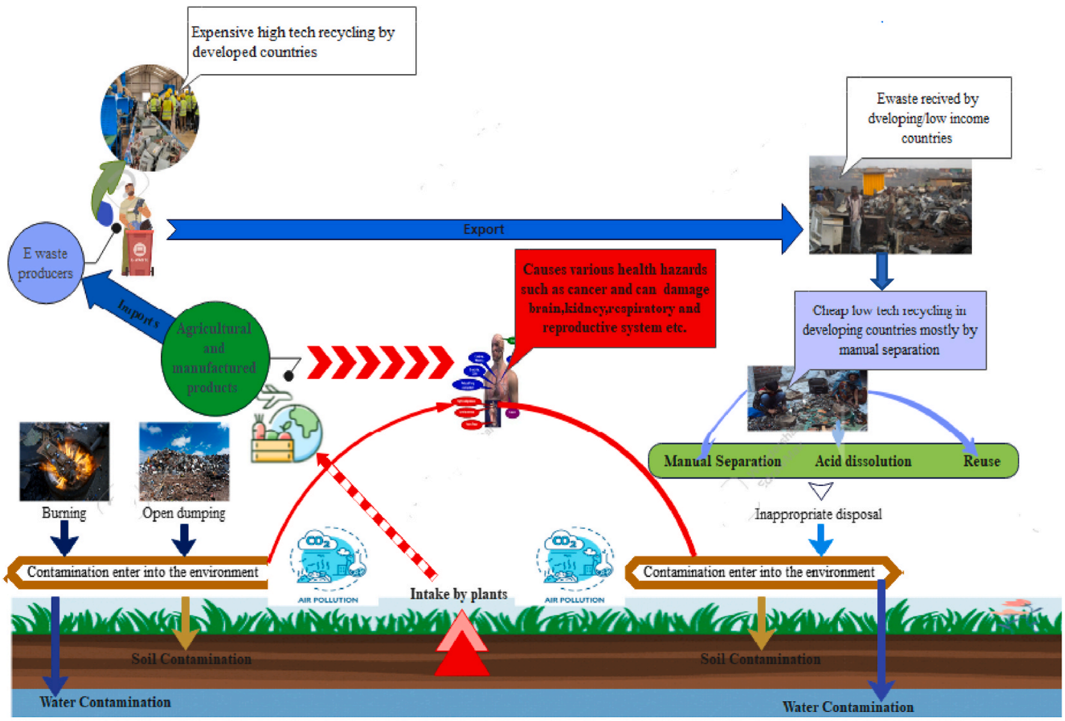

Fig. 2. E waste flow and associated health risk [137,140–142].

precious metals not only diminishes the huge pile of waste but also ensures the conversion of a useful resource [143]. In this very way, it can be identified that electronics scrap from the information technology and telecommunications industries is richer in precious metals than that from regular home equipment. For example, a mobile phone is comprised of over forty elements, including base metals like tin (Sn) and copper (Cu); special metals such as cobalt (Co), antimony (Sb), indium (In), and lithium (Li); along with precious metals like gold (Au), palladium (Pd), and silver (Ag) [146]. Fig. 3 presents an overview of the typical composition found in frequently used electronic devices like mobile phones, laptops, and televisions. Electronic appliances material composition is presented in Fig. 3, with subfigures (a-c) for mobile phone, laptop, and television, respectively.

The main hazardous substances found in electronic waste, metallic (including Pb, Ni, Hg, and As) and organic compounds (such as polychlorinated biphenyls, polybrominated diphenyl ethers), have significant health impacts. In developing nations like India, Pakistan, Bangladesh, Myanmar, a substantial portion of E-waste is not properly recycled and instead disposed of along with regular solid and liquid waste, without undergoing any treatment. This practice poses a significant health risk to workers involved in E-waste handling [150]. Unfortunately, these workers lack awareness about the potential risks and are not provided with personal protective equipment (PPE) to safeguard themselves. As a result, those most affected by E-waste exposure are the individuals who work with it, including children, women, and especially pregnant women, who often face the dangers of this hazardous environment without being fully aware of the risks involved [151].

5. Environmental and health effects of electronic waste

The management and recycling of electronic waste negatively influence the environment, affecting air, soil, and water quality, in addition to posing threats to aquatic ecosystems and human health [152–154]. If E-waste is abandoned, inadequately disposed of, or recycled without proper regulations, hazardous chemicals like mercury-gold amalgam or cyanide may leach or get washed out by

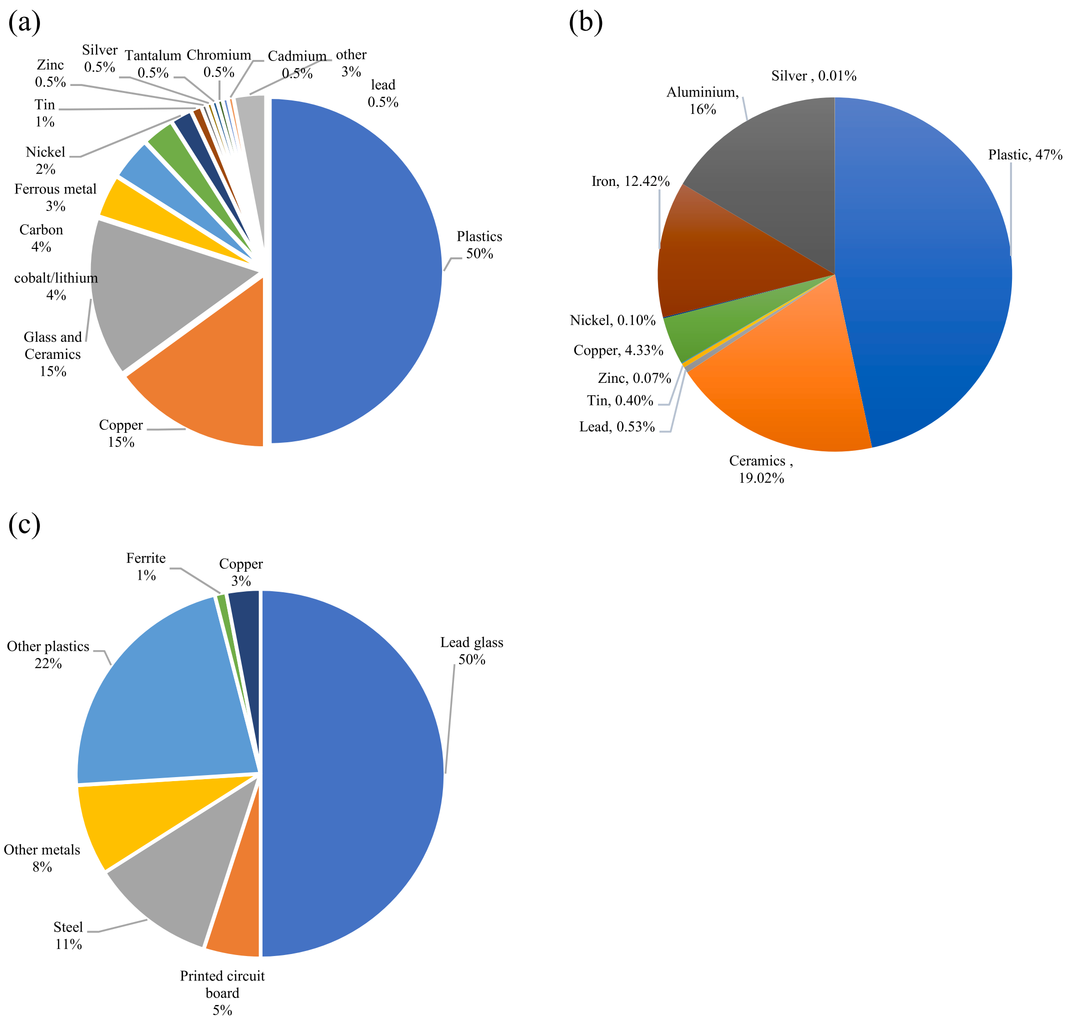

Fig. 3. Material composition of electronic appliances(a) Mobile phone [147], (b) Laptop [148], (c)Television [149].

heavy rainfall, contaminating drinking water sources such as rivers, ponds, and underground water [9,155]. Producers and recipients of E-waste take different pathways based on factors like treatment facilities, the condition of the E-waste, and convenient transportation options [18]. Improper recycling of E-waste may also pose significant health and safety risks for those involved, including E-waste collectors, handlers, and the local community residing near E-waste recycling facilities.

Individuals residing near electronic waste recycling facilities may be exposed to environmental risks, even if they are not actively participating in the recycling activities, due to the contamination of the environment, food, and water sources by the pollutants from E-waste. Inhalation, ingestion through food, and direct skin contact are the main ways that one can become exposed. According to research, people who live close to E-waste recycling facilities are more likely to be exposed to heavy metals on a daily basis and carry more weight overall. Exposure to this substance has been associated with a number of health problems, such as physical illnesses, cognitive decline, mental health disorders, and general bodily damage [156]. Prolonged exposure to harmful substances can lead to various detrimental health consequences, such as negative birth outcomes, cancer, persistent and irreversible cognitive impairment, and organ damage affecting the kidneys, liver, lungs, and thyroid [157,158]. Excessive intake of copper can lead to liver damage and cause irritation in the nose and throat, whereas long-term exposure to cadmium increases the risk of kidney damage, musculoskeletal disorders, and lung cancer. Individuals exposed to lead, chromium, cadmium, and nickel are at a lifelong risk of developing various types of cancer [159]. Beyond harming the lungs and kidneys, exposure to certain substances also impacts the reproductive and nervous systems. Mercury exposure is associated with both carcinogenic and non-carcinogenic effects, including disorders of the brain and liver. Due to the pollution emanating from informal recycling locations, residents, especially children, have a higher likelihood of developing cancer and other health issues. Exposure to E-waste during pregnancy and in the neonatal period can have negative impacts on newborns' health. This includes issues such as low birth weight, low APGAR scores, stillbirths, as well as long-term learning and behavioral difficulties [19]. In mothers from Guinea, significant exposure to perfluorooctanoic acid has been observed to impact the growth and development of infants. Newborns in Guiyu, a major electronic waste recycling hub, exhibited elevated levels of placental metallothionein, a protein indicative of exposure to dangerous metals. This condition was associated with the parental participation in electronic waste recycling activities [160]. Additionally, newborns in Guiyu exhibited higher levels of lead in their cord blood, which correlated with parental participation in the re-use process and the amount of time mothers spent in E-waste recycling facilities during pregnancy [153]. Additionally, research has indicated an increase in DNA damage among populations exposed to electronic waste, encompassing newborns, children, and adults, in comparison to groups not exposed to such conditions [161]. DNA breaks can lead to errors in DNA replication, mutations, and potentially cancer if tumor suppressor genes are affected. The specific impacts of electronic

Table 2
Status of different e waste components after utilization.

Material	Percentage contribution in total E-waste (%)	Heavy material	Toxic material	Health Hazard	Waste to energy	Waste to product	Direct dumping	Reference
Pb	0.01	✓	✓	➢ Cause to damage of brain and nervous system ➢Can affect reproductive system ➢Negative impact on cognitive growth in children, cardiovascular and renal system impairment	X	✓	X	[92,162]
Hg	0.0022	✓	✓	➢Cause long-term brain damage ➢Cause issues related to breathing and skin	X	✓	✓	[149,160,161]
Cd	0.0094	✓	✓	➢Cause to damage of kidney and bone density ➢Can cause cancer	✓	✓	✓	[149,163,164]
Cr	0.0063	✓	✓	➢Can causes bronchitis ➢Can result in a severe allergic response ➢Cause DNA damage to cells	–	✓	–	[149,165]
Ni	2	✓	✓	➢Causes allergy to the skin and to the lung results in asthma	✓	–	✓	[149]
Cu	20.12	✓	✓	➢Copper negatively affects the lungs and kidneys	✓	✓	X	[149,164]
Plastics	30.23	✓	✓	➢Dioxin is produced during the burning process, which causes reproductive and developmental issues ➢Liver problems, skin disorders, and impairment of the immune system can cause cancer	✓	✓	–	[163,164,166]
Be	–	X	✓	➢Carcinogenic can cause (lung cancer) ➢Chronic beryllium illness can be developed through inhaling fumes and dust	–	✓	–	[163,164]
Sn	4%	✓	X		✓	✓	–	

waste on human health are summarized in Table 2.

E-waste harms not only just the water but also the land and surrounding air [167]. Gallium (Ga), chromium (Cr), lead (Pb), palladium (Pd), beryllium (Be), and other toxicants contaminate our food chain through interacting with soil, water, and air [168]. E-waste is also associated with a variety of chemical pollutants, including dioxins, polyvinyl chloride, esters of benzene, polyaromatic hydrocarbons, phthalate, and others, which represent a risk to nearby soil, plant, and microbial species in addition to people [169]. Among the hazardous components discovered in E-waste those are thrown into landfills are arsenic, mercury, lead. The soil loses its fertility and ground water gets contaminated as a result and becomes useless (by preventing the growth of beneficial bacteria). Table 3 below displays the allowable concentration of heavy metals in air and soil in relation to electronic components.

Flame retardants and heavy metalscan leach out from electronic waste, penetrating the soil and leading to the contamination of groundwater and crops in the future. This soil contamination with heavy metals makes crops more vulnerable to absorbing these harmful substances, resulting in various ailments and reduced agricultural productivity. When E-waste is shredded, burned, or demolished, large particles are released and quickly settle back onto the ground which further pollutes the soil. Factors such as temperature, soil type, pH levels, and composition influence the extent of soil contamination. These contaminants may remain in the soil for prolonged durations, affecting plant life and soil-dwelling microorganisms.Ultimately, animals and wildlife reliant on the natural environment may consume affected plants, leading to internal health complications.

Lead, lithium, mercury, and barium—heavy metals that can contaminate soil and eventually reach groundwater—are found in E-waste. Heavy metals have the ability to spread to streams, rivers, ponds, and lakes after they have contaminated groundwater. Even though the communities, plants, and animals are located several kilometers away from the E-waste dumping site, they are nevertheless at serious risk due to this contamination pathway. Finding clean drinking water for communities is a challenge due to the presence of acidic and toxic substances in the water, rendering it unsafe for consumption. When freshwater and marine organisms are affected by acidification, it can have disastrous effects that disrupt biodiversity, kill off species, and destroy ecosystems. Acidification's detrimental effects can impede or even prevent the recovery of an ecosystem's water resources. Refer to Fig. 4 for a visual representation of the environmental impact of E-waste.

In contrast, the importation of electronics into economically disadvantaged countries can pose a significant risk to the health and environment of towns and villages. Various types of E-waste contain harmful substances, and hazardous processing methods like burning, crushing, and the use of acid baths can result in the release of mercury, cadmium, lead, and arsenic into the surrounding environment. Countries like the United States have acknowledged the potential dangers these substances pose to human health and ecosystems, resulting in the enactment of legislation that bans the landfill disposal of electronic devices [179]. However, many impoverished nations lack similar legislation and the capacity to restrict the influx of such imports.

6. The financial dimensions of electronic waste

Effective management of E-waste is vital and still much needed for ensuring environmental sustainability. Throughout the process of E-waste recycling, valuable items are collected and sold to individuals or entities who can enhance their value or find potential buyers. The value of E-waste is determined by factors such as its composition, processing location, and other relevant considerations.

Numerous studies have analyzed the generation of electronic waste through different economic evaluations, highlighting the importance of proper E-waste management while also considering the economic aspects of waste [8]. The global demand for precious metals such as Pt, Au, Ag, Pd and base metals including Pb, Cu, Zn, Ni, as well as rare earth minerals like La, Ce, Yt, Nb, has spiked linearly with the use of electronic items like printed circuit boards (PCBs), smartphones, computers, refrigerators, photocopiers, televisions, printers, washing machines, telecommunication servers, and coffee machines [180].In a report from London, it was noted that the total value share ranged from 85% (in printed circuit boards, or PCBs) to 93% (in mobile phones) and primarily consisted of precious metals such as Pt, Pd, Au, Ag, with less than 10% consisting of base metals like Fe, Cu, Al and others [181]. It is forecasted that in 2020, the recoverable quantities of silver (Ag), palladium (Pd), gold (Au), copper (Cu), and platinum (Pt) could reach 119 metric tons (MT), 54 MT, 21 MT, 12.5 MT, and 10 MT, respectively. The corresponding market values per kilogram for these metals are estimated to be $2020 for Ag, $66,500 for Au, $2184 for Pd, $6.45 for Cu, and $97,400 for Pt [182]. From 2021 to 2040, E-waste creation will increase by 60% per capita, increasing the total commercial value of Pt, Cu, Au, Ag, and Pd in E-waste streams from US$ 2.2 billion to US$ 14 billion. Forecasted electronic waste materials are estimated to include 165 metric tons of gold, 826 metric tons of silver, 368 metric tons of palladium, 95 thousand tons of copper, and 109 metric tons of platinum [181]. The extraction of valuable metals plays a crucial role in attaining sustainability within the management of electronic waste.

Screens, monitors, and small information and telecommunication equipment contain more than 80% Au, Ag, and PGMs. Over 40%

Table 3
Comparison of concentration of material in electronic components and their acceptable concentration in Air and Soil.

Components	Concentration (mg/kg)	Concentration in air (μg/m^3)	Acceptable concentration in air (μg/m^3)	Acceptable concentration in soil (μg/m^3)	References
Lead	14129.9	17.30×10^6	0.10–0.30	600×10^6	[170–172]
Nickel	13244.7	16.22×10^6	0.03 [173]	700×10^6	[174]
Copper	41237.3	50.51×10^6	0.2 [175]	200×10^6	[176]
Chromium	72.4	88.69×10^3	0.309	221×10^6	[175]
Cadmium	1.9	2.32×10^3	5	–	[177]
Zinc	12471.4		–	–	[177]

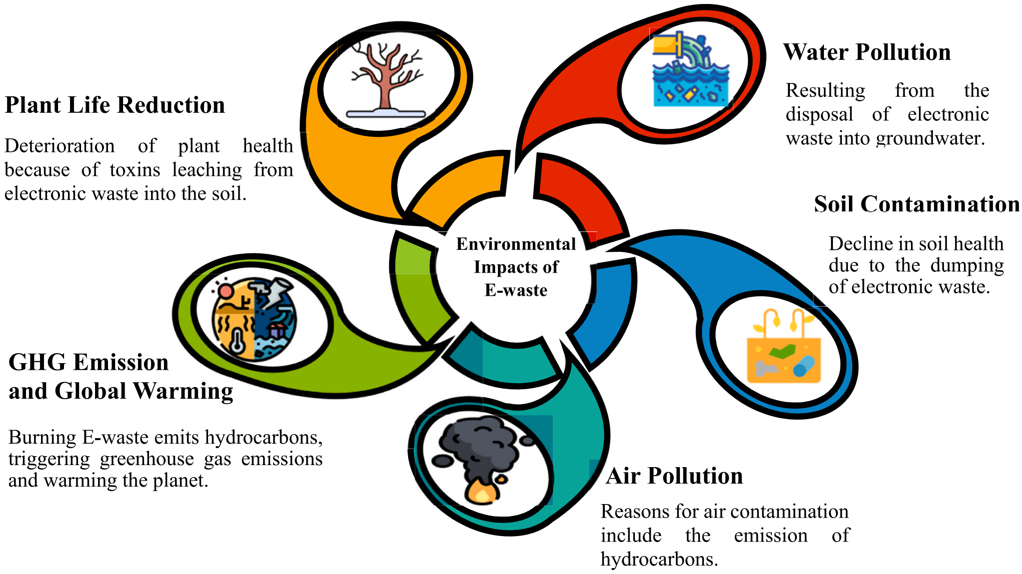

Fig. 4. Environmental impacts of e waste [47,163,178].

of E-waste valuable metals including Au, Ag, and Pd are in PCBs [16]. In Chandigarh, India, from all household appliances 6.2 kg Ag, 0.3 kg Pd and 1.2 kg Au can be recovered annually [183]. The anticipated yearly monetary losses for those precious metals were 0.042 million USD for Au, 0.0024 million USD for Ag, and 0.00448 million USD for Pd [183]. Moreover, smartphones, tablets, and notebooks contain the higher volume of precious and crucial metals [184]. Based on available literature, it is projected that the total value of recovered metals and plastics in Australia will reach up to US$8 billion by the year 2040. This underscores the enhancement of Indonesia's economic gains by extracting metals from electronic waste [181]. The success of recovery and revenue generation depends on the strategies employed. Meng et al.'s research employed super-gravity separation methods to successfully isolate Zn, Cu, Pb, and Sn from printed circuit boards (PCBs), achieving extraction rates of 80.86%, 93.23%, 94.54%, and 97.67% for each metal, respectively [185].

Each participant in the E-waste recycling chain has the potential to generate profit. For instance, a scavenger purchased a faulty electrical device from a consumer for $5 and later sold it to an aggregator for $7, making a profit of $2 in the process. At this particular instance, the consumer ended up earning more profit than the scavenger. Aggregators and classifiers, who collect materials from multiple sources including at least 10 scavengers, households, or small-scale industries, can expect their revenue to be 5–10 times higher compared to that of individual scavengers. Processors and recyclers operate outside of urban areas, servicing various industries, and often lack detailed sales records, which makes their analysis more challenging [186]. A comprehensive field investigation discovered that the average economic value of reusable electronic items or parts, based on equation (1), amounted to $2.14 per kilogram.

$$\textit{Average selling price - Average buying price} = \textit{Profit} \tag{1}$$

In case of a developing country like Bangladesh, to engage in complete E-waste recycling from 2016 to 2020, it is estimated that they could potentially save over 500 million dollars. By the year 2030, Bangladesh has the potential to generate approximately 5 billion dollars through E-waste recycling. Therefore, engaging in E-waste recycling has the potential for economic profitability. However, to achieve this, there is a need for increased awareness about recycling practices and the establishment of an effective management system. Consequently, it is crucial for the relevant authorities to enhance E-waste recycling efforts and provide modern training facilities to ensure successful implementation.

Hence, considering the gathering, categorization, and handling of materials at different points in the recycling process is vital for evaluating the economic worth of electronic waste. The recycling chain involves five key participants: the household consumer, scavenger, aggregator, classifier, and processor. The majority of E-waste contains over 60 various metals, including precious, valuable, rare base, and earth metals, which are collectively considered valuable due to their cumulative worth [187]. One promising approach to unlock this economic potential involves multiplying market prices (in $/kg) with the composition of E-waste (in grams per unit) [184]. To minimize construction and transportation costs, it is advantageous for an E-waste recycling facility to be situated near railways and roadways, ensuring a return on investment [16].

7. E-WASTE management

7.1. Formal E-waste management

Significant enhancements in material recovery and environmental protection can be achieved by integrating advanced electronic waste recycling technologies into formal E-waste management strategies. However, the initial stage in formal recycling procedures is typically involved classifying, checking, reusing, and mending recovered goods. The recyclable components are then manually or automatically retrieved after the recyclable devices have been disassembled and occasionally crushed. In addition, a large number of formal e-recycling facilities supply materials like metal, glass, and plastics to downstream parties. As an example, in India, still the informal sector handles the majority of the E-waste because of the formal sector struggles with sufficient input materials. Even though there are just a few official recyclers working in India. The formal sector's procedures are mostly restricted to separating and disassembling electronic waste up to the point of shrinking printed circuit boards (PCBs) [188]. The basic stage of formal E-waste process is presented in Fig. 5.

Sri Lanka has formal E-waste management processes under which there are eleven E-waste management facilities in operation; the majority of them are located solely in the Colombo district and pick up trash from door to door. The formal collection network has expanded during the last four years. Only seven formal sector collectors are active at the moment, though. There are currently a few non-profit organizations operating in the nation, however the money they raise is comparatively quite small. All of the gathered electronic waste is sent to licensed collectors, who carry out the process of collecting, storage, and dismantling in a more orderly manner [95]. However, there is no organized mechanism for managing E-waste in Nepal or Bangladesh. E-waste is mostly collected, disassembled, recovered, and recycled by unorganized sectors using a crude and manual process [41]. In Bangladesh, for instance, the identification of electronic waste as a carrier of hazardous substances was first incorporated within the nation's guidelines for managing medical waste [150]. Nevertheless, on June 10, 2021, amendments were made to the Bangladesh Environmental Protection Act of 1995 through the introduction of the Hazardous Waste (E-waste) Management Rules [190]. Despite this, there is no evidence of conferences, workshops, or public events addressing E-waste issues. In order to effectively enforce the E-waste Management rules, the Department of Environment and other relevant agencies need to address competing challenges.

7.1.1. Extended producer responsibility

The polluter pays principle is supported by extended producer responsibility (EPR), which shifts responsibility from consumers and local governments to producers who are much aware about the environmental effects of their products at the end of their useful lives (EoL) and have the capacity to avoid these issues from the start of product development. Through the efficient collection, treatment, and reuse or recycling, EPR primarily serves to achieve two goals: (i) design enhancements of items and their systems, and (ii) high utilization of product and material quality [191]. The flow process of EPR policy is presented in Fig. 6.

Developed countries have established robust collection and logistical systems through their national register systems. Germany was the pioneer in implementing an Extended Producer Responsibility (EPR) program, mandating that producers are responsible for collecting and minimizing packaging waste. This model was later adopted by countries like Norway, Taiwan, Sweden, and Switzerland

Fig. 5. Formal E-waste process [189].

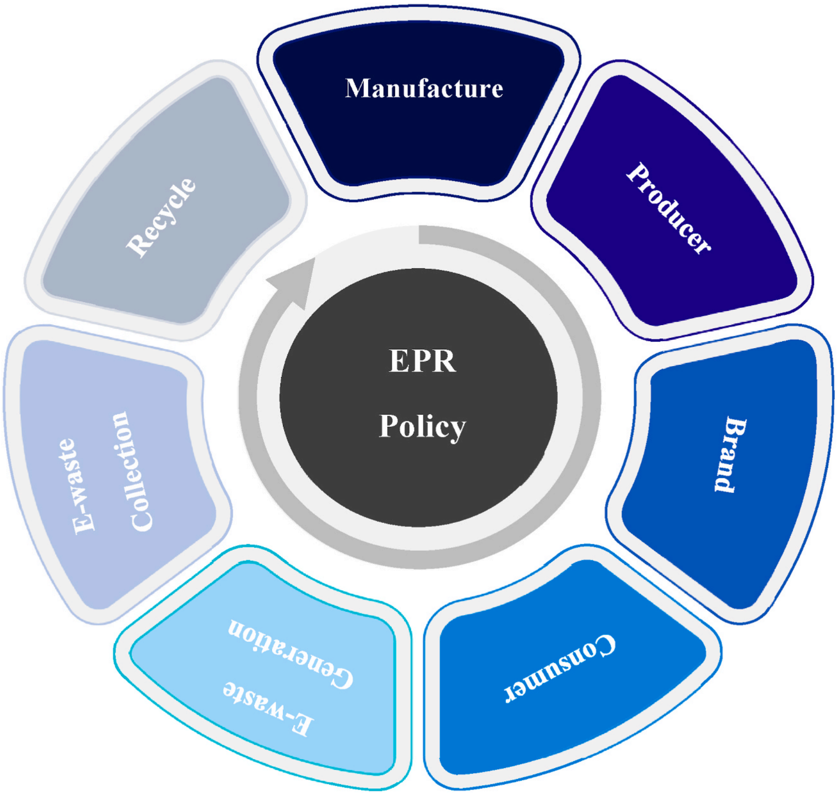

Fig. 6. Flow process of EPR policy.

for EEE manufacturers. In the European Union, legislation introduced in 2003 restricts the utilization of dangerous substances and promotes the gathering and recycling of these materials in Electrical and Electronic Equipment (EEE) and electronic waste. In contrast, China and India, lacking a national registry system to track EEE producers, have implemented the EPR system to discourage producers from generating excessive E-waste as a backup. These countries face challenges due to extensive grey markets for second-hand EEE, which weakens their position compared to industrialized nations. Although benefiting from lower labor expenses, these nations encounter significant electronic waste generation, arising from both imports and domestic manufacturing. The costs associated with transportation and the proper disposal of E-waste, coupled with expensive technology requirements, pose additional challenges, despite the presence of environmental legislation. The E-waste management sector in North America categorizes waste and recycling based on their types. This includes various market segments such as household appliances, IT, consumer electronics telecommunications, and others. Subsegments within the household category include lights, refrigerators, and more. The telecommunications and IT segment covers laptops, mobile phones, computers, printers, and related items. Consumer electronics and other divisions encompass devices like radios, CDs TVs, and music systems [192].

In India, E-waste management regulations, which cover all electronic waste, from small SIM cards to refrigerators, were enacted to give guidelines for the effective and correct handling and recycling of E-waste in that country. EPR responsibility under the E-waste (management) Rules, 2016 mandates collection targets of E-waste for producers, whether it be in weight or number [179]. The targets set are for 30% of the anticipated volume of waste to be achieved within the first two years following the regulations' enactment, 40% in the third and fourth years, 50% in the fifth and sixth years, and escalating to 70% starting from the seventh year onwards [193]. The local distributor of Lex Mark Toner cartridges in Sri Lanka uses an efficient EPR strategy by collecting used cartridges and reexporting them to the parent company in order to safeguard the brand [95].

7.1.2. *Extended consumer responsibility*

Extended consumer responsibility (ECR), take back system (TBS), and other specialized programs aid in facilitating this collection and subsequent processing system by reminding consumers that they are also responsible for the secure disposal of their items. For example, certain countries, like Japan, have implemented designated bins for collecting various types of waste, including hazardous, municipal, and recyclable materials. Conversely, some countries impose deposit fees, allowing consumers to reclaim their money upon returning their used Electrical and Electronic Equipment (EEE) products to authorized collectors or dealers. In Japan, residential users must pay a fee that contributes to covering recycling and shipping costs. This practice, known as Extended Cost Recovery (ECR), incorporates the expenses related to E-waste processing into the initial purchase price of products. Furthermore, imposing higher fees and taxes on luxury EEE items represents another strategy to mitigate environmental risks while minimally affecting market-based

Total Benefit Sharing (TBS) [194].

7.1.3. Take back system

The primary goal of EPR is to identify active TBS or design for the environment (DfE) components that will facilitate the safe disposal of E-waste. Conversely, first-world nations employ developing and underdeveloped nations like India, China, and Africa as dumping grounds in an effort to mimic donation or take-back efforts. This is because of the rigorous environmental legislation in place in these nations. Electronic equipment manufacturers in India are physically responsible for collecting electronic devices after they have reached the end of their useable lives. Takeback policies enable manufacturers to choose between creating their personal recycling and collection networks or joining a shared scheme, often called a Producer Responsibility Organization (PRO) [195]. A flowchart of the entire take-back procedure is shown in Fig. 7.

7.2. Informal E-waste management

In lower-income and developing nations, the collection and processing of electronic waste is largely handled by the informal sector, serving as an essential source of income for a vast number of individuals. Known as Tokai in Bangladesh and Kawariwala in India, or as local collectors in other countries, these entities or individuals make house calls to collect E-waste, allowing them to maintain their economic activities [196]. This not only aids in the collection of E-waste but also guarantees that consumers receive favourable pricing for their outdated EEE items. Despite facing significant health risks, E-waste workers depend on the informal economy for their livelihood. There is little material recovery from E-waste in developing and transitional nations due to inadequate government regulation and safety safeguards in the unregulated sectors processing the waste [197].

Regarding the improvement of the recycling system, one recommended method for reducing E-waste in underdeveloped nations is using the extensive gathering network of informal recyclers. Instead of dismantling this network, developing nations should leverage these businesses to transfer their E-waste to the legitimate sector. Another way to minimize the quantity of E-waste illegally exported to developing countries is for governments to invest in the resources required to provide the enforcement and monitoring required to prevent E-waste imports. The current pace at which customers are acquiring, updating, replacing, and discarding devices provides little reason to anticipate that the E-waste situation will be resolved anytime soon. There's a significant need for increased awareness about the impact of E-waste on the well-being of males, females, and young ones in underprivileged nations [139].The informal E-waste process is illustrated in Fig. 8.

In India, the informal sector is responsible for recycling 95% of electronic waste, with only 5% being processed by formal units. More than 3000 recycling units within the formal industry are operational in and around the country's major cities, handling the recycling of E-waste. Despite the existence of informal E-waste recyclers throughout India, there are major industrial clusters located in various regions such as Delhi, Dharavi near Mumbai, Tamil Nadu, the U.P., Karnataka, Gujarat, Kerala, Andhra Pradesh, Maharashtra, Rajasthan, and West Bengal [199]. However, when waste is handed over to unlicensed waste collectors, it contributes to the expansion of unregulated markets. These markets aim to extract metals from electronic devices for resale, but they may lack the necessary skills

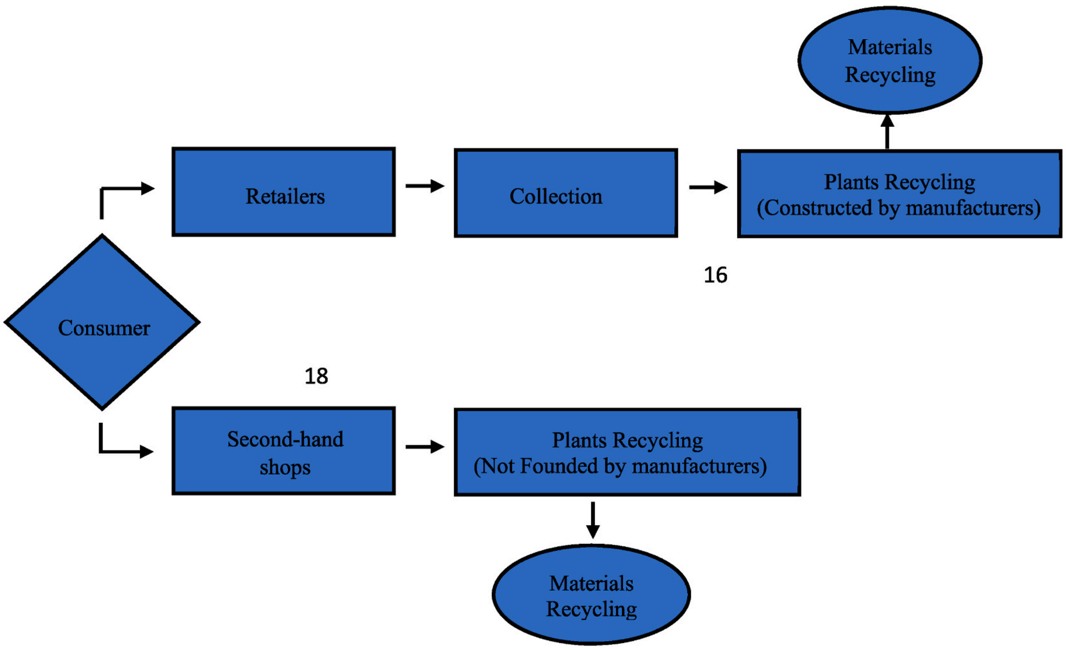

Fig. 7. Flow diagram of a TBS.

Fig. 8. Informal E-waste process [198].

and fail to adhere to essential safety regulations [200]. When it comes to the production of electronic waste in India, 70% originates from the public, governmental, and industrial sectors, with households contributing 15% and manufacturers supplying the remaining 40% [199]. Mumbai ranks first among cities, producing approximately 120,000 tons of E-waste annually, followed by Delhi and Bengaluru with outputs of 98,000 and 92,000 tons, respectively [201]. In Bangladesh, there is a lack of organized infrastructure for managing E-waste. The collection, dismantling, recovery, and recycling of electronic waste are primarily carried out by informal sectors using manual and rudimentary methods [41]. Table 4 provides details about the current regulations pertaining to E-waste management and related rules that address the management of hazardous substances in the absence of specific E-waste management guidelines.

7.2.1. Local vendors

Due to inadequate infrastructure and arrangements made by the responsible authorities, such as municipalities, to collect and treat E-waste, the informal economy is expanding. The informal sector does not follow current laws and regulations and is unfamiliar with the scientific methods needed to treat E-waste properly. The informal sector's waste collectors, also known as "Kabriwala," "Scrap dealers," "street hawkers," and "dismantlers," typically go door to door in addition to visiting nearby electronics stores to purchase old (mostly non-functional) equipment or its parts (including repairers).

In India, the management of E-waste is done informally by kawaries (ragpickers), scrap dealers, wholesalers, recyclers, and dismantlers. The entities in the non-formal sector are largely in charge of handling big operations such as collecting, sorting, disassembly, and dismantling. The door-to-door collection is mostly the responsibility of kawaries and small scrap merchants. E-waste collectors typically acquire electronic waste from consumers at a fair compensation price. Kawaries, known as one of the most efficient E-waste collectors, significantly reduce the burden on municipal organizations tasked with waste collection. E-waste is gathered in enormous quantities from government offices, IT industries, private and public sector organizations, universities, schools, and other business establishments, etc., by large scrap dealers [213,214].

To maximize financial gain, E-waste from various sources is divided into categories such as modules, glass, metals, plastics, and components. Kawaries, scrap dealers, distributors, and recyclers all perform segregation. The same parties that dismantlers work with also perform disassembly and dismantling. To metal/glass smelters and plastic re processors that transform aluminum, copper, glass, iron, and plastics, kawaries and scrap dealers provide deconstructed and glass, separated metal, and plastic pieces. Non-formal units sell scrap because they don't know the difference between smelting and reprocessing. Therefore, they play a crucial role in recycling a significant portion (more than 95% by weight) of electronic waste in an environmentally friendly manner [215].

In Pakistan, E-waste comes from the manufacture, domestic use, and import. E-waste is gathered from various sources by scrapers and sellers, who sometimes deconstruct it and sell the parts to extractors and dismantlers. Extractors and dismantlers use environmentally unsound technology to extract valuable materials, and they dispose of the debris in dumps or waterways. Occasionally, individuals involved in dismantling and scrapping activities reconstruct assorted components of outdated machinery with the intention of reselling them [216].

In Bangladesh, the informal sector in Dhaka and Chittagong is mostly responsible for recycling E-waste [217]. Buyers, brokers, and ferriwala collect electronic garbage from various repair shops. at the lowest possible cost and deliver it to local E-waste traders or scrap dealers. After useful goods came from Useable parts are recovered from these waste devices through refurbishment to bring local E-waste back into working order and sell it to various customers or mills. Unrepairable items are disassembled, scavenged for valuable metals, and disposed of in landfills [166].

E-waste is collected informally in Sri Lanka. This is accomplished by scrap collectors that gather in bulk after-end-of-life EEEs from the business sector while removing E-waste stockpiles. The primary operational approach for collectors in the informal sector is door-to-door collection. As indicated in the Status Report on E-waste Management (CEA, 2016), approximately 2000 enterprises are engaged in the informal sector in Sri Lanka [95].Their collection mechanisms are economical. Metal scrap collectors dominate this

Table 4
Status of managing E-waste in different south Asian region.

Country	Having E-waste management rules?	Name of E-waste management rules/ associated hazardous substance management rule	Focusing points	Dominating waste management sectors		Having recycling and recovery institutes?
				Formal	Informal	
India	Yes	E-waste Management Rules, 2016	• Strengthened the EPR •Inquire about the equipment's constituents, components, consumables, parts, and spares, as well as a statement of RoHS (Restriction of Hazardous Substances) conformance in the product user documentation. •Since 2023, the E-waste collection goal has been set at 70% of the amount of waste generated [202].	5%	Yes [191] 95%	No
Pakistan	No [203]	Hazardous Substance Rules, 2003	•Under PEPA 1997's Hazardous Substance Rules, 2003, hazardous material imports and transportation require a license.	Not available	8.6% (Recycle) 13.8% (open dumping) 65.7% (reuse)	No
Bangladesh	Yes	The Hazardous Waste (E-waste) Management Rules, 2021	•The E-waste regulations cover a range of items including home appliances, monitoring and medical equipment, control equipment, IT and communication devices, and automated machinery. It outlines duties and accountabilities for manufacturers, collectors, assemblers, consumers, and marketers. •The regulation restricts the usage of 10 substances outlined in the EU RoHS Directive [204]	3%	97% [41]	Yes 220 [41]
Sri Lanka	No	National Environmental (Protection and Quality) Orders, No. 1 of 2008	•Inadequacy of provisions in the National Environmental Act on Electronic Waste Disposal. •According to the legislation, no one may produce, collect, transport, store, recover, recycle, or dispose of Schedule VIII waste, or build a site or facility for its disposal, unless they have a license from the Authority and follow its rules and standards [205].	Not available	Dominant [206]	Yes [207,208]
Nepal	No [209]	The Environment Protection Act, 2053 (1997)	•Nepal's Environment Protection Act 1997 does not include E-waste handling. Nepal lacks legal provisions for E-waste management [209].	Not available	Dominant [210]	Yes [211]
Bhutan	No	The Waste Prevention and Management Act, 2009	•E-waste management organizations are required under the Waste Prevention and Management Regulation 2012 to safeguard the health and safety of those who handle E-waste [212].	Not available	Dominant [210]	No [68]
Myanmar	No	Myanmar National Waste Management Strategy and Master Plan (2019–2030) [88].		Not available	Dominant [88]	Not available

sector. All 25 districts have informal sector collection. Each of the 25 districts in the nation receives informal sector collecting. This might be regarded as the nation's busiest collecting system. In general, door-to-door collecting uses tiny carts and vans. The majority of recycling in Nepal is carried out by scavengers, junk merchants, and scrap hawkers who separate the recyclable components and illegally transfer them to another country for formal recycling [210]. Myanmar boasts an active informal sector equipped with a structured system for gathering items at the end of their lifecycle, and subsequently engaging in recycling, repair, refurbishment, and salvaging of parts. The leftovers from the extraction of recyclables and reusable parts are either burned by owners, dumped in landfills, or mixed with other solid waste [88].

7.2.2. Open dumping

E-waste dumps in residential or agricultural regions are environmental "hot spots." These places transfer infections, smells, and toxic substances into rivers, ponds, and groundwater. Open waste dumping and acid leakage from abandoned lead-acid batteries may be hazardous to one's health and the environment. In addition to disposal sites, open burning of E-waste pollutes the air by generating furans, dioxins, particulate matter, heavy metals, and hydrocarbons. Most E-waste in India is not recycled because it's thrown out with domestic trash and given no special treatment. E-waste is mostly landfilled [215]. In Sri Lanka, the informal sector is expanding significantly throughout the nation, from door-to-door collecting to primitive demolition and metal recovery. This endeavor predominantly involves scrap collectors, and in certain regions, it has evolved into a community-driven operation [95].

In Pakistan, informal methods are utilized to process approximately 8.6% of E-waste, equivalent to 154.8 kilo-tons. The majority of E-waste is either directly disposed of in landfills (13.8% or 245.6 kilo-tons), redistributed for reuse through sales or donations (65.7% or 1150 kilo-tons), or retained as part of a deferred disposal strategy [47]. The country imports 95,145 tons of E-waste annually. In 2014, it was estimated that Pakistan generated around 50,000 tons of E-waste specifically from computer scrap and had an overall E-waste generation of 114,000–138,000 tons annually from 2011 to 2014 [17]. The E-waste management process in Pakistan is characterized by informal practices, which involve hazardous and unsafe recycling techniques such as burning and the use of acid baths. Consequently, the waste residue eventually finds its way into landfills, local sewers, and waterways [47,218]. In Bangladesh, just 3% of E-waste is recycled, while the rest is dumped. 97 percent of E-waste ends up in channels, rivers, landfills, sewers, lakes, ponds, and open places combined with municipal garbage [166]. In Bhutan, government-generated E-waste is deposited at the Department of National Properties (DNP) storage situated in Chamzamtog.

7.3. E-waste management models

Over the past decade, various E-waste management models have been studied These models are designed to guide the collection, recycling, and disposal operations of E-waste using appropriate technologies. Two noteworthy models in this field are Life Cycle Assessment (LCA) and Material Flow Analysis (MFA) [219]. Life Cycle Assessment (LCA) is a method utilized to assess the environmental impacts associated with each stage of the life cycle of a commercial product, process, or service [220,221]. LCA enables a thorough and effective assessment of waste management, covering handling, treatment, recycling, and disposal. It helps identify environmental impacts, critical factors, decision points, and improvement opportunities across all stages of waste management within defined system boundaries [222].

Defining system boundaries is essential when conducting Life Cycle Assessment (LCA).Typically, LCA studies on E-waste management exclude the manufacturing and use phases of electronic equipment. The focus is primarily on treatment and recycling processes [223]. The LCA methodology consists of four main steps: defining the purpose and scope, conducting an inventory analysis, assessing environmental and health impacts, and interpreting the results [224]. Over time, there has been an increasing adoption of LCA in E-waste management studies [23]. European countries tend to utilize LCA more frequently in such studies compared to emerging countries, with the exception of China. China, being a significant generator of E-waste, has led to extensive research on its management practices [14].

LCA applied to E-waste management involves three main categories. The first category entails examining the environmental impact of a particular electronic product and identifying areas of concern within the treatment process. This can involve comparing different treatment methods or assessing the life cycle of specific electronic items such as monitors, personal computers, PCBs, electronic toys, and other discarded electronic waste. Additionally, it includes evaluating metal recovery and recycling processes during treatment [225,226]. The second category focuses on optimizing the environmental impact of E-waste treatment across all products. This involves studying various strategies and approaches to minimize the environmental effects associated with electronic waste treatment [14,227–229]. The third category involves evaluating the environmental impact of the E-waste collection system. This assessment specifically examines the collection phase of E-waste management and its overall environmental implications. In E-waste management, the utilization of LCA encompasses three main categories: analyzing the environmental impact of specific products, refining treatment processes, and evaluating the environmental implications of the collection system.

Following the delineation of the scope and objectives of the LCA study, the subsequent step is inventory analysis. This phase entails tracing the movement of materials and energy throughout the system, a process referred to as life cycle inventory (LCI) [230]. The LCI includes monitoring input-output balances of waste, energy, water, and environmental pollution. To examine the inputs, outputs, and internal processes, a process flow diagram is necessary [231]. Data collection, verification, evaluation, and reporting are integral parts of the LCI process. In the context of E-waste management, the LCI analysis focuses on tracking the material and energy flows throughout the stages of collection, treatment, disposal, and transportation [232].

After the Life Cycle Inventory (LCI), the subsequent stage is the Life Cycle Impact Assessment (LCIA). LCIA involves both quantitative and qualitative evaluations of the environmental impact based on the data gathered during the inventory analysis [233]. It helps to understand the harm caused by resource consumption and emissions. The LCIA involves selecting specific environmental consequences, such as human toxicity, climate change, terrestrial acidification, among others, and categorizing them based on the LCI results. Furthermore, it computes potential impacts across various categories, taking into account emissions and resource consumption, and standardizes the impact outcomes for comparison using a reference or impact factor [234]. The LCIA quantifies the system's impacts using various methods.

In the field of E-waste LCIA, the most commonly employed impact evaluation method is the CML method, and various frameworks and impact categories are utilized for assessing inventory data. LCIA methodologies encompass both mid-point, which focuses on specific issues, and endpoint, which considers overall risks, approaches. The final step involves interpreting the results, examining their sensitivity and coherence, and drawing conclusions and recommendations based on the findings [221,223].

LCA studies on E-waste management in many underdeveloped and developing countries are scarce or nonexistent. This is mainly attributed to the absence of data and a formalized E-waste management sector, leaving a gap for further research in this area. Regional variations in environmental consequences make it necessary to study the specific context of each region, which can lead to improved policies and E-waste management practices. Despite the limited data availability, the LCA approach has been applied in developing countries such as Malaysia, China, and Pakistan, with researchers relying on assumptions to compensate for the lack of accurate data [235]. Assumptions are made, for instance, regarding the environmental impact of pre-E-waste collection processes. Transfer co-efficients and ratios for recycled product replacement are often derived from relevant literature and other sources within recycling systems [23,236]. Additionally, site-specific conditions and regional characteristics need to be taken into account. Commercial LCA software often employs European or US characterization parameters to construct the LCA model. However, it is important to consider the inherent uncertainties associated with these assumptions when interpreting the results of the analysis.

Data collection through surveys and questionnaires enables gathering information directly from the source. Subsequently, life cycle impact assessment methods can be employed to examine the environmental impact of the entire waste management system. It is crucial to evaluate the results while recognizing the uncertainties associated with data and characterization factors. The creation of an LCA model customized to the context of Bangladesh can significantly contribute to establishing a sustainable E-waste management system in the country.

Material Flow Analysis (MFA) holds considerable importance in the realms of industrial ecology, particularly in managing complex waste streams such as E-waste. It is frequently employed in research concerning E-waste management and recycling [86]. MFA is used to analyse and quantify the movement of materials, products, and substances within a specific area, allowing for the assessment of regional and national economies [13]. It encompasses all streams within a system, whether physical or financial, and provides measurements and graphical representations of these streams. The validity of the results is also evaluated as part of the MFA process [237,238].

When applied to E-waste, MFA is used to map and quantify the usage, emissions, and recycling effectiveness of electronic waste [237]. The MFA process begins with defining the problem, establishing the system boundary, identifying the substances and processes involved, and then calculating and balancing the flow of mass and concentration within the system. MFA studies have been conducted at national, regional, and local levels, and both static and dynamic models have been utilized [239]. The static model focuses on material and product flow over the course of a one-year lifespan, while the dynamic model considers materials and products with variable lifetimes exceeding one year and predicts their flow within the system [240].

MFA research encompasses various electronic devices such as cell phones, desktop, refrigerators, televisions, vacuum cleaners, microwave ovens, washing machines, and more. The recovery of valuable metals like gold, palladium, and silver is the primary concern [239] While most MFA studies at the national level have been conducted in industrialized countries, a few studies have been carried out in developing countries such as India, Vietnam, China, Indonesia, Brazil, and others. China, in particular, has conducted numerous MFA studies due to the growing issue of E-waste, and India has also undertaken MFA research [86]. It is crucial for developing countries to engage in MFA research to inform policy decisions and improve their E-waste management systems based on the insights gained from the MFA model [238,239,241,242]. Due to its reliance on data, MFA investigations have proven to be more successful in underdeveloped countries. However, MFA does not assess the environmental effects of E-waste specifically [243]. For instance, a study conducted in Delhi utilized material flow analysis to measure E-waste [244]. A comparable approach can be adopted in Bangladesh as it endeavors to quantify E-waste and establish a trade value chain. Additionally, outcomes from the Material Flow Analysis (MFA) model can provide valuable insights into the economic aspects of the E-waste management system. Conducting an MFA investigation in Bangladesh will illuminate the transactions and flows of E-waste, empowering the government to regulate and formalize E-waste management in alignment with the study's findings.

Managing E-waste presents a substantial sustainability challenge for developing nations. To foster a sustainable and environmentally sound future, forthcoming research efforts should prioritize the improvement of E-waste collection, disposal, and recycling technologies [245]. One possible solution lies in the integration of both new and existing technologies [246]. Hence, there is an urgent need for comprehensive research methods to address these issues effectively It is crucial to establish well-documented E-waste recycling policies and methods, with support from national television and print media to ensure successful implementation [247]. Government regulations should facilitate the establishment of integrated E-waste management facilities, requiring the approval of relevant authorities. Furthermore, continuous monitoring, control, and data archiving programs are essential to oversee process variables, safety protocols, effluents, pollutants, as well as the inflow and outflow of materials and waste [248].

8. Treatment of E-waste

8.1. Reuse and refurbishing

Redistributing used items to new owners is another technique to cut down the volume of E-waste generation. If the used electronics are still in workable condition, donation centers, community centers, domestic violence shelters for women, homeless youth programs, local refugee organizations, or a number of other organizations may be in need of them for the clients they serve. Local or online businesses offer cash in exchange for the used electronic gadgets that they would refurbish and resell [249]. The primary distinction between recycling and refurbishing lies in their processes. Recycling entails the extraction and repurposing of resources, while refurbishing involves the reuse of functional components in manufacturing new goods. Even good recycling procedures produce waste; therefore, refurbishment is better for the environment. Due to the fact that many materials cannot be recycled indefinitely, a great deal of E-waste eventually becomes utterly useless to recyclers. On the other side, refurbishing is viable because practically endlessly reusable operational components may be reincorporated into new items.

An advantage of refurbishing E-waste is that obsolete components may be replaced without compromising the quality of freshly manufactured gadgets. When purchasing a new electronic product made from refurbished E-waste, consumers who are passionate about technology will not detect any change in quality. In order for refurbishment to be efficient, recyclers need to retrieve devices, while manufacturers must incorporate second-generation items into the production of new electronics [250].

Moreover, the initial manufacturing of a computer consumes approximately 75% of fossil fuels and energy. However, by extending the lifespan of a computer through reclamation, refurbishment, and reuse, a relief on the environmental impact caused during its initial production can be considered. The refurbishment process also contributes to the reduction of waste in landfills and addresses the environmental consequences resulting from poor management practices within the E-waste recycling industry. Additionally, refurbished computers serve as products that can help to bridge the digital divide, both domestically and globally, while also assisting in reducing unemployment rates [251].

8.2. Recycle

The most crucial factor in reducing E-waste is recycling. Waste from electronics recycling provides a number of benefits including decreasing the pollution of the air and water that results from manufacturing new items from raw materials, preserving natural resources, lowering GHG emissions, and creating jobs, among others [252]. E-waste is typically disposed of at landfills and incinerators from where hazardous greenhouse gases like methane and carbon monoxide are produced as a result of the breakdown and decomposition of this garbage. It has a significant impact on global warming. The harmful chemicals that are released into the groundwater by rubbish piles in landfills eventually make their way to surrounding freshwater bodies and wells. These dangerous toxicants can build up in water bodies, harming aquatic ecosystems and the surrounding population who depend on the water body for survival. Recycling electronic waste keeps these harmful substances from entering inland waterways, keeping the water clean and safe to use [253]. E-waste recycling enables the recovery of valuable elements from outdated or obsolete EEEs.

The used electrical equipment is transported by specialized garbage removal firms from the recycling facility to a processing facility, where it is shredded into little bits. After being crushed, powerful magnets extract ferrous metals like steel, while electrical currents are used to collect non-metallic metals. Various techniques, such as the use of infrared light or density separation, are used to

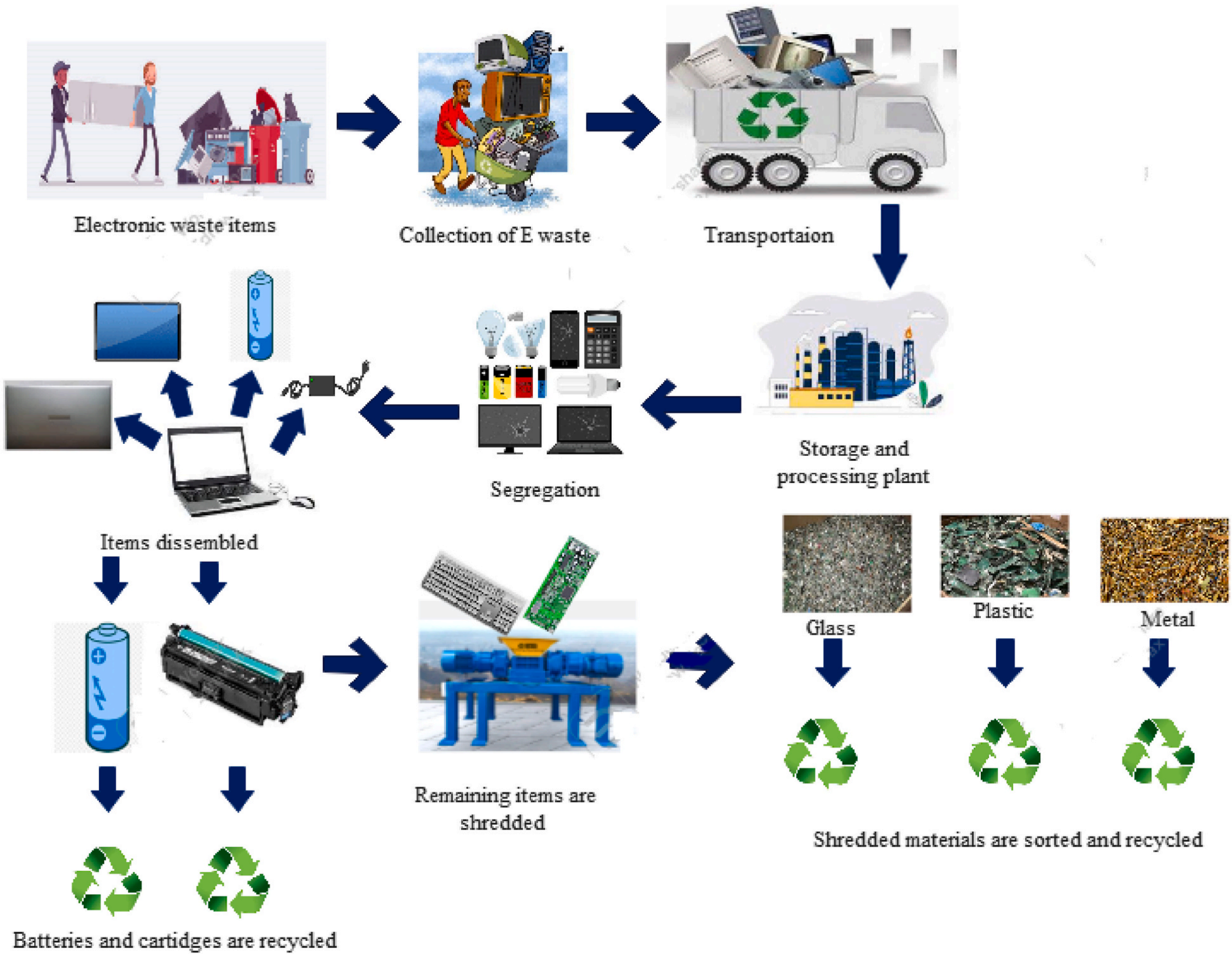

Fig. 9. A simplified diagram of E-waste recycling process [259–262].

classify plastic components into different groups. Plastic is used to make a variety of products, including plastic fence posts, plastic trays, insulators, equipment holds, and plastic sleepers and vineyard stakes [254].

The efficacy of E-waste management hinges significantly on recycling. A proficient recycling process has the capacity to markedly diminish environmental pollutants while conserving natural resources and energy. The local government must support it and educate the public. Reusing electrical waste circuit boards is the hardest. The circuit boards printed on contain valuable metals such as silver, tin, gold, platinum, among others. Conventional methods utilizing common metals like aluminium, copper, iron, etc., rely on mechanical separation and shredding, which prove to be ineffective [255]. Another method for managing electronic waste involves melting circuit boards and employing open-pit acid leaching to separate burnt cable sheets, facilitating the extraction of precious metals for copper wire recovery. Electronics reuse or disposal reduces greenhouse gas emissions, health issues, and unemployment. Cryogenic dissociation, another approach for reusing printed circuit boards, is presently being studied. Downcycling involves the transformation and recycling of materials into lower-grade products, which may not be as environmentally friendly or socially responsible as their original counterparts.Due to the presence of mercury, cadmium, and lead, numerous countries opt to repurpose large coin cells and buttons containing 2–9V batteries [255].

Reusing materials from obsolete gadgets is the best way to reduce E-waste. Metal may be recycled from most electrical gadgets. Eliminating and reusing potential reuse preserves natural resources and prevents water/air pollution from hazardous E-waste disposal. Plastic makes up about 21% of the weight of E-waste. The durable ABS plastic used in hover mowers is frequently used in products, including pipes, cases, musical instruments, and car bumpers. It is possible to recycle copper motors from lawnmowers to create jewelry, coins, and winding wire for motors in new electronic goods. Metals can also undergo recovery and recycling processes to create new steel products and other metal items [256]. By product plastic from printers can be reused to make fresh 3D prints. Recycled metals are sold at lower prices throughout Europe. Due to a dedicated recycling system, Japanese businesses must make more ecological products. These methods can safely salvage all computer building materials [257]. Reusing new products minimizes green product greenhouse gas emissions. Harmful smoke and gases are caught, restricted, and treated to reduce environmental damage [258]. Fig. 9 gives idea of whole E-waste recycling process.

Steel from video game consoles can be used to manufacture computer cases, vehicle parts, and structural beams. The circuit boards include precious metals such as platinum, silver, gold, and palladium. These can be used to make jewelry or mobile components. The valuable metals contained in phones can be used to produce other electronic products. Numerous exciting uses exist for the zinc present in mobile phones, including galvanizing steel, creating brass when combined with copper, and even preventing corrosion on ships [263]. Table 5 shows how materials recovered from E-waste can be utilized to manufacture other valuable items.

8.3. *Recovery*

The recycling industry can commercially exploit electronic scrap by extracting precious metals such as gold, palladium, silver, and platinum from it. Gold, in particular, is found in electronic scrap at a concentration over 40 times higher than gold ores found in the U. S. Furthermore, gold makes up approximately one-third of the precious metals reclaimed from E-waste processing. This underscores the importance of extracting precious metals from electronic scrap, as it plays a vital role in maximizing the commercial potential of the recycling industry [149,269]. Various methods such as pyrometallurgy, hydrometallurgy, electrometallurgy, bio metallurgy or bioleaching have been effectively employed for extracting valuable products from E-waste. Additionally, combinations of pyro- and hydrometallurgy have been crafted for optimal efficiency and reduced time consumption. Preparing E-waste through pre-treatment is an essential initial stage aimed at optimizing metal recovery [270]. Multiple steps can be utilized in the procedure for extracting metals

Table 5
Items recovered from E-waste and recycled into useful products.

Component	Item recovered	Recycled into	Reference
Radiators, air-conditioners heat sinks, computers compressors, refrigerators	Aluminium	Computers, CDs, electric power lines, cars, kitchenware, packaging for food and medicine, furniture, refrigerators, and aircraft	[264]
Elements in the motor housing, flat-screen TVs, and heat sinks	Copper	Appliances, heating and cooling systems, and telecommunications	[265]
Air-conditioners, anything with plumbing, cooling circuit fittings or pressure vessels, and things like liquid-cooled PCs	Brass	Brass can often be found in decorative, mechanical, and musical applications	[266]
CRTs (Cathode Ray Tubes) of TV and monitors.	Glass Mercury	extract to make newer screens Dental amalgams, metric instruments and fluorescent lighting	[267]
Circuit board	Numerous precious metals, including palladium, silver, gold, and platinum	Jewellery or mobile phone components	
Hard Disk	Aluminium ingots extracted from hard drives	Particularly effective for automobiles	
Toner and Ink Cartridges	Plastic and metals	Raw materials for other goods include cases, pipe fittings, musical instruments, and automobile bumpers	
Batteries	Cobalt, steel, cadmium, and nickel	Reusable in new batteries and beneficial in the production of stainless steel.	[268]

from electronic waste: (i) E-waste should be shredded (broken down into tiny pieces for proper sorting). These tiny costs are carefully sorted and disassembled using only human hands. As waste goods are currently being separated to recover different pieces, this often requires a lot of labor. (ii)Dust Extraction (The microscopic waste particles are evenly distributed on the conveyor belt by shaking. The evenly dispersed electronic trash particles are then broken down even more. The dust is removed and disposed of in an environmentally responsible manner [149]. In this manner, environmental damage is prevented (iii) Magnetic separation (A strong overhead magnet then separates steel and iron from other debris. This recycles steel from the waste stream). Non-ferrous metals are separated from other materials using an eddy current separator, which employs high-frequency vibration.(iv)Water separation (Subsequently, the utilization of water separation technology becomes crucial for the distinct separation of glass from plastic components) [271]. Since factories can get their raw materials from trash, recycling has become more popular. As a result, less mining of Earth's surface is required. Fig. 10 shows the step-by-step material recovery process.

Magnetic and eddy current separators are popular for separating metallic components. Permanent magnets or electromagnets separate ferrous components, while eddy current separators separate aluminium and copper from non-metallic elements.

Such separation plants typically comprise a sequence of physical treatment units designed for various processes, including grinding, crushing, screening, air classification, magnetic separation, electrical-conductivity separation, eddy-current separation, and more. Depending on the separation procedure and the number of units used, metal pieces of varying sizes and compositions are formed. Table 6 shows heavy metal recovery from PC and phone. The presence of valuable metals should motivate official recyclers and encourage informal recyclers to formal recycling. The amount of precious metal that can be found can be used to set up separate recycling infrastructure, especially for handsets waste. All in all, PCBs that are left over from old electronics are anything but waste. If these printed circuit boards are recovered and treated to the appropriate processing processes, the quantity of valuable metals produced will contribute significantly to the economy. Table 7 represents the number of metals recovered from 1 kg of PCBs with their market value.

8.4. Reduce

Consumers in developed countries purchase billions of dollars' worth of new electronics every year and then discard their old devices in landfills. Limiting use of technological devices, looking for multipurpose gadgets, keeping possessions, doing small changes

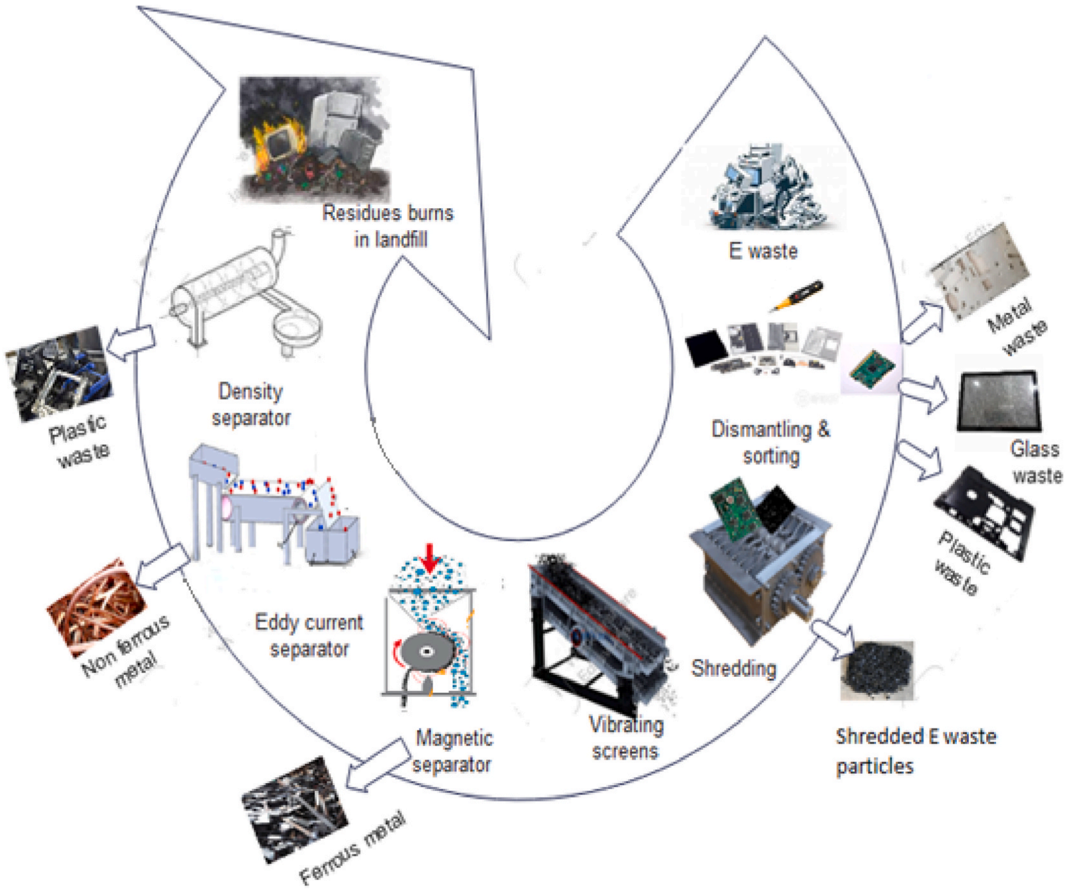

Fig. 10. A streamlined depiction of the stages involved in the process of recovering materials [272–278].

Table 6
Recovering valuable and heavy metals from mobile phone and computer PCB [279,280].

Recovered metal	PCB of mobile phones			PCB of computer		
	Reagent	Recovery method	Percentage of Recovery	Reagent	Recovery method	Percentage of Recovery
Gold	Cyanide generating Bacteria	Bio-leaching	11.31	Sodium Cyanide	Leaching Column technique	46.6
	HCl	Ion exchange process	95	Sulfuric acid, hydrogen peroxide, thiourea	Bio-recovery	69
	Sodium thio sulfate + ammonium hydroxide + copper sulfate	Hydro metallurgy	15	Ammonium thio sulphates, ammonia	Hydrometallurgy	90
	–	–	–	Sulfuric acid, hydrogen peroxide, thiourea, sodium hypochlorite, hydrochloric acid,	Hydrometallurgy precipitation	100
Silver	Sodium thio Sulfate + Ammonium hydroxide + Copper sulphate	Hydro metallurgy	3	Sodium Cyanide	Leaching column technique	51.3
Copper	Aqua regia	Hydrometallurgy + Electro winning	92.0	Nitric acid LIX-984	Hydrometallurgy solvent extraction	99.7
	Sulfuric Acid + Hydrogen peroxide	Super critical extraction	83.3	Sodium cyanide	Leaching column technique	62.3
	Acid Thiourea	Adsorption (CPT gel)	80.0	Acid thiobacillus ferroxidase	Bio-recovery	100
Lead	–	–	–	Sulfuric acid, hydrogen peroxide, thiourea, sodium hypochlorite, hydrochloric acid,	Hydrometallurgy precipitation	100
Nickel	–	–	–	Acid thiobacillus ferroxidase	Bio-recovery	100

Table 7
The quantity and expense associated with the metals extracted from 1 kg of PCBs [41,149,205].

Recovered Metal	Weight (gm/kg)			Market value USD/gm
	India	Bangladesh	Sri Lanka	
Gold	0.279	0.60	0.25	38
Silver	0.450	7.6	1.68	0.46
Copper	190.512	136.35	65	0.01
Tin	30.84	24g		0.03

help things last longer. For instance, cleaning electronic devices on regular basis, and restraining of overcharging are something that can be done to extend the longevity of the device [281]. Data can be stored in the cloud remotely, which can free up space and reduce the need for expensive hardware. Furthermore, because data is stored remotely, it is more unlikely to be completely lost if something bad happens Every year, large quantities of electrical and electronic equipment are discarded on a global scale. Even if most of the time, the equipment works fine, although newer models have replaced it. In that case, returning old items to the retailer to decrease E-waste and keep them out of landfills can be the preferable option. Many consumers may reduce their next purchase by returning an outdated item [282].

Many manufacturers, including Apple, Walmart, Samsung, and Best Buy, and Walmart, offer trade-in programs in which consumers get shop credit for turning in old electronic equipment. This is shown by the Samsung upcycling at-home program. Samsung extended its upcycling initiative in April 2021 to allow people to transform their old Galaxy phones into smart home gadgets [283]. Fig. 11 illustrates the possible ways to reduce E-waste.

8.5. Rethinking

Before making any electronic purchase, careful consideration is needed regarding its usefulness. For instance, upgrading the software instead of purchasing a new device can be a wise option if the existing device is in good condition. Investigating the products and raw materials involved in the production of electronic devices aids in comprehending the impacts of toxic chemicals. Examples of these discarded items include products bearing the 'Energy Star' label or those certified by the Electronic Product Environmental Assessment Tool (EPEAT) [281]. In other words, searching for things with a longer expected lifespan so that they do not have to be replaced after a few years or even just a few months. Making products with shorter lifespans so that more money may be made later on when they fail, or malfunction is a well-known practice in the electronics industry. The average lifespan of commonly used electronic items south Asian region has been displayed in Table 8.

Fig. 11. Potential strategies to reduce E-waste.

Table 8
Average lifespan of commonly used electronic products.

Electronic items	India	Pakistan	Bangladesh	Srilanka	Nepal	Bhutan	Afghanistan	Myanmar
Personal computers	3-7 [284,285]	5-10 [47]	3-8 [285–287]	3-8 [95]	–	3-8 [285,287,288]	2-7 [289–291]	–
Television	2-8 [292,293]	Above 10	5–10	15–20	10 [294]	10 [292,295,296]	–	–
Printers		2–10	–	1–8	–	–	–	–
Mobile phones	6-8 [297]	1–5	2.5	2	3-4 [298]	1-6 [289,299,300]	–	2-4 [289,301]
Refrigerators	10-14 [302–304]	14-17 [305]	14–17	15–20	14-17 [305]	14–17	–	–
Air conditioners	10	–	–	5–15	–	–	–	–
Washing machines	–	–	–	15–20	–	–	–	–

9. Way forward to sustainable E-waste management

The key of achieving sustainable management of E-waste is to handle it in an environmentally friendly manner. This can be accomplished through various strategies, such as minimizing E-waste by reducing the consumption of electronic materials and re-evaluating the need for new products. Moreover, implementing measures to save energy, such as recycling electronic items and batteries, optimally locating recycling bins for E-waste to ensure they are readily accessible, reconditioning sizable electronic appliances, donating pre-owned electronics to charitable causes, selecting electronics designed with environmental consideration, and enhancing the durability of electronic gadgets, are all vital actions in fostering responsible management of E-waste. However, it is imperative to take decisive actions to curb the rapid escalation in E-waste generation to safeguard a healthier environment for future generations.

At the very first place, it is necessary to implement strict laws and regulations on E-waste generation and sub-sequent processing. It is essential to make and apply specific laws on regular waste collection and mandatory enforcement for uncollected wastes. Furthermore, laws or policies should incorporate subsidized garbage collection rates and provisions to ensure regular collection from informal settlements. Establishing a central collection point in informal neighborhoods and providing incentives for residents to utilize it are also essential measures to be considered. It is also advised to closely monitor trash segregation and disposal at those places.

Moreover, enhancing the recycling process is critical. By engaging stakeholders in collaborative workshops, the initiation of waste segregation at the source, particularly in residential settings, can be encouraged to mitigate the escalating hazards of dumpsites due to inadequate segregation practices. It is essential for households to be motivated to distinguish their organic waste from plastics, adopting a communal collection schedule. Organic waste from kitchens ought to be gathered daily, while recyclable materials that are not biodegradable could be picked up 4–5 times a week. To promote recycling, reusing, and sorting of waste, governments might introduce a rewards program that offers incentives for the return of empty plastic containers or other recyclable items. Responsibility for overseeing the disposal in compostable and non-compostable bins should be jointly held by local communities and entities focusing on Science, Technology, and Society (STS). Key individuals involved in the process have suggested utilizing waste as a resource and exploring the generation of gas from organic waste in landfills. Additionally, they propose implementing rooftop gardening as a means of managing compost waste effectively.

On top of this, creating targeted awareness campaigns is an effective approach to influence public behavior and promote effective waste management practices in general. These campaigns should emphasise the critical role of segregating waste at the household level, with clear policies outlining the allocation of financial and human resources and the establishment of a regulatory body. Residents living in close proximity to waste management facilities are often curious and concerned about how waste is handled. It is important to ensure that all stakeholders are well-informed about the risk assessment policy and can engage in discussions using a shared understanding and analysis. This promotes public involvement in environmental decision-making processes. These residents desire safe and reliable waste management practices that do not harm the environment or public health. Risk assessment serves as the foundation for making scientifically and logically sound decisions. Governments, tribes, facilities, and other concerned parties should engage in dialogue before reaching any conclusions. Furthermore, it is imperative to articulate the importance of mitigating environmental impacts associated with waste management. This entails promoting strategies to reduce solid waste and wastewater flow, enhance the efficiency of E-waste treatment procedures, and lower energy usage. Moreover, emphasizing the avoidance of incineration and landfill disposal while outlining clear responsibilities for stakeholders, including the recycling industry, retailers, manufacturers, and consumers, is crucial for effective waste management strategies.

E-waste management is a professional and financial process that emphasizes the importance of sustainable product production. It requires the implementation of a circular economy, which can only be achieved through collaboration among governments, corporations, and consumers [306]. For the sustained well-being of the global economy, it is crucial to consider both technical consumer behavior and consumer economics. This highlights the need for improved developmental strategies to enhance E-waste management and establish a satisfactory professional economy. Adopting a circular economy model seeks to curb the consumption of electrical goods and electronics by limiting their production through effective product design and innovative business models. The 7R systems, encompassing reuse, reduce, reject, reconsider, redesign, and recycle, underscore the significance of considering economic, social, and environmental factors in waste management. Nevertheless, various challenges, such as insufficient collection systems, technological constraints, inadequate training within the informal sector, and financial limitations, can impede the advancement of these initiatives. The idea of a circular economy promotes the adoption of renewable, sustainable, and cleaner technologies by planning strategies, adopting developmental models and implementing regulations that prioritize waste reduction and optimize the utilization and value of product materials.

It is recommended to dispose of E-waste after conducting appropriate physical and chemical treatments. The government should allocate designated areas for safe E-waste disposal. To effectively raise awareness regarding the hazards of E-waste, it is crucial to ensure proper advertisement and promotion of disposal facilities post-approval. Site owners and operators of E-waste disposal sites must exhibit technological proficiency and a comprehensive understanding of associated hazards. Obtaining approval from regulatory bodies such as the Department of Energy and local governments is essential in this regard. It is crucial for owners and operators to possess the necessary knowledge and expertise regarding E-waste and its effects. Therefore, considering future factors and implementing potential solutions such as (using advanced technologies to manage hazardous components and extract valuable metals from E-waste, using of novel adsorbents to recover e waste, performing economic analysis to explore suitable recycling methods, proper guidelines and implementation of rules, creating awareness)can help mitigate environmental dangers, reduce the likelihood of risks, and minimize health hazards associated with E-waste processing.

It is crucial to enforce stringent laws and regulations that define the functioning of waste management systems and outline the responsibilities of the primary implementing agencies. The successful execution of these policies necessitates investments, rigorous monitoring, and collaboration among stakeholders. Effective communication, dialogue, education, and dissemination of information are crucial elements. Additionally, allocating adequate budgets for safety equipment and integrating health and safety considerations for waste handlers into the policies are essential measures for ensuring their effectiveness.

The government can contribute by offering health insurance and safety training for individuals working in waste management. Stakeholders suggest enacting a reward-punishment mechanism to motivate resident throughout every phase of the waste management cycle. Developing such policies, strategies, or action plans should involve public-private partnerships to establish strong linkages between various sectors involved in waste management. Lastly, a centralised institution or authority should oversee the entire waste management process and coordinate the efforts of all authorized institutions involved, from waste generation to disposal, in order to streamline and improve solid waste management practices.

10. Conclusion

E-waste poses significant threats to both the environment and human health; however, numerous countries stand to benefit from structured recycling and metal recovery processes for E-waste. The advent of the Internet of Things (IoT) and cloud computing has the potential to streamline the electrical device manufacturing industry by reducing material consumption. Implementing advanced product monitoring systems and embracing new service and takeback business models can facilitate the transition of global value chains toward circularity. Enhancing electronic material efficiency, bolstering E-waste recycling infrastructure, and expanding the use of recycled materials to fulfill the demands of the electronics supply chain are paramount for sustainable progress in this domain. If properly managed, the industry may produce millions of good jobs worldwide. Electrical and electronic product use and manufacture require a new perspective. Electronic waste is sometimes portrayed as a post-consumer concern, yet it includes the lifecycle of everyone's electronic gadgets. Policymakers, consumers, raw material producers, miners, merchants, investors, manufacturers, designers, and others must reduce E-waste. They also maintain system value, extend product life, and enable recycling, reuse, and repair.

Data availability statement

The research data used in this study has not been deposited into a publicly available repository.

CRediT authorship contribution statement

Md. Kaviul Islam: Writing – original draft, Data curation. **Mst. Sharifa Khatun:** Writing – original draft, Data curation. **Monjur Mourshed:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Y.-L. Cheng, C.-Y. Lee, Y.-L. Huang, C.A. Buckner, R.M. Lafrenie, J.A. Dénommée, J.M. Caswell, D.A. Want, G.G. Gan, Y.C. Leong, P.C. Bee, E. Chin, A.K.H. Teh, S. Picco, L. Villegas, F. Tonelli, M. Merlo, J. Rigau, D. Diaz, M. Masuelli, S. Korrapati, P. Kurra, S. Puttugunta, S. Picco, L. Villegas, F. Tonelli, M. Merlo, J. Rigau, D. Diaz, M. Masuelli, M. Tascilar, F.A. de Jong, J. Verweij, R.H.J. Mathijssen, We Are IntechOpen , the World ' S Leading Publisher of Open Access Books Built by Scientists , for Scientists TOP 1 %, vol. 11, Intech, 2016, p. 13. https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics.

[2] R. Rautela, S. Arya, S. Vishwakarma, J. Lee, K.H. Kim, S. Kumar, E-waste management and its effects on the environment and human health, Sci. Total Environ. 773 (2021) 145623, https://doi.org/10.1016/J.SCITOTENV.2021.145623.

[3] K.C.-P. today, undefined 1997, Population growth and consumption, Pubmed.Ncbi.Nlm.Nih.Gov. (n.d.). https://pubmed.ncbi.nlm.nih.gov/12319715/ (accessed May 21, 2023).

[4] U.N. Ngoc, H. Schnitzer, Sustainable solutions for solid waste management in Southeast Asian countries, Waste Manag. 29 (2009) 1982–1995, https://doi.org/10.1016/J.WASMAN.2008.08.031.

[5] R. Rana, R. Ganguly, A.K. Gupta, Evaluation of solid waste management in satellite towns of mohali and PANCHKULA–India, J. Solid Waste Technol. Manag. 43 (2017) 280–294, https://doi.org/10.5276/JSWTM.2017.280.

[6] M.H. Masud, W. Akram, A. Ahmed, A.A. Ananno, M. Mourshed, M. Hasan, M.U.H. Joardder, Towards the effective E-waste management in Bangladesh: a review, Environ. Sci. Pollut. Res. 26 (2019) 1250–1276, https://doi.org/10.1007/S11356-018-3626-2/METRICS.

[7] S. Kaza, L.C. Yao, P. Bhada-Tata, F. Van Woerden, What a waste 2.0, what a waste 2.0 A glob, Snapshot Solid Waste Manag. to (2018) 2050, https://doi.org/10.1596/978-1-4648-1329-0.

[8] H. Ismail, M.M. Hanafiah, A review of sustainable E-waste generation and management: present and future perspectives, J. Environ. Manage. 264 (2020) 110495, https://doi.org/10.1016/J.JENVMAN.2020.110495.

[9] S. Needhidasan, M. Samuel, R. Chidambaram, Electronic waste – an emerging threat to the environment of urban India, J. Environ. Heal. Sci. Eng. (2014) 1–9.

[10] E-waste generation globally by type 2019 | Statista, (n.d.). https://www.statista.com/statistics/499912/ewaste-generation-worldwide-by-type/(accessed May 21, 2023).

[11] M. Shahabuddin, M. Nur Uddin, J.I. Chowdhury, · S.F. Ahmed, · M.N. Uddin, · M. Mofijur, · M.A. Uddin, A review of the recent development, challenges, and opportunities of electronic waste (E-waste), Int. J. Environ. Sci. Technol. 20 (2023) 4513–4520, https://doi.org/10.1007/s13762-022-04274-w.

[12] S.B. Wath, P.S. Dutt, T. Chakrabarti, E-waste scenario in India, its management and implications, Environ. Monit. Assess. 172 (2011) 249–262, https://doi.org/10.1007/S10661-010-1331-9/METRICS.

[13] Y. Moriguchi, S. Hashimoto, in: Material Flow Analysis and Waste Management, 2015, https://doi.org/10.1007/978-3-319-20571-7_12.

[14] Q. Song, Z. Wang, J. Li, Sustainability evaluation of E-waste treatment based on emergy analysis and the LCA method: a case study of a trial project in Macau, Ecol. Indic. 30 (2013) 138–147, https://doi.org/10.1016/J.ECOLIND.2013.02.016.

[15] L. Saha Ankit, V. Kumar, J. Tiwari, Sweta, S. Rawat, J. Singh, K. Bauddh, Electronic waste and their leachates impact on human health and environment: global ecological threat and management, Environ. Technol. Innov. 24 (2021) 102049, https://doi.org/10.1016/J.ETI.2021.102049.

[16] A. Kumar, M. Holuszko, D.C.R. Espinosa, E-waste: an overview on generation, collection, legislation and recycling practices, Resour. Conserv. Recycl. 122 (2017) 32–42, https://doi.org/10.1016/J.RESCONREC.2017.01.018.

[17] S. Ilyas, R.R. Srivastava, H. Kim, S. Das, V.K. Singh, Circular bioeconomy and environmental benignness through microbial recycling of E-waste: a case study on copper and gold restoration, Waste Manag. 121 (2021) 175–185, https://doi.org/10.1016/J.WASMAN.2020.12.013.

[18] D.N. Perkins, M.N. Brune Drisse, T. Nxele, P.D. Sly, E-Waste: a global hazard, Ann. Glob. Heal. 80 (2014) 286–295, https://doi.org/10.1016/J.AOGH.2014.10.001.
[19] W. Zhang, F. Ma, M. Ren, F. Yang, Application with Internet of things technology in the municipal industrial wastewater treatment based on membrane bioreactor process, Appl. Water Sci. 11 (2021), https://doi.org/10.1007/s13201-021-01375-8.
[20] S. Ilyas, R.R. Srivastava, H. Kim, N. Ilyas, Biotechnological recycling of hazardous waste PCBs using Sulfobacillus thermosulfidooxidans through pretreatment of toxicant metals: process optimization and kinetic studies, Chemosphere 286 (2022) 131978, https://doi.org/10.1016/J.CHEMOSPHERE.2021.131978.
[21] R. Ahirwar, A.K. Tripathi, E-waste management: a review of recycling process, environmental and occupational health hazards, and potential solutions, Environ. Nanotechnology, Monit. Manag. 15 (2021) 100409, https://doi.org/10.1016/J.ENMM.2020.100409.
[22] A. Işıldar, E.R. Rene, E.D. van Hullebusch, P.N.L. Lens, Electronic waste as a secondary source of critical metals: management and recovery technologies, Resour. Conserv. Recycl. 135 (2018) 296–312, https://doi.org/10.1016/J.RESCONREC.2017.07.031.
[23] H. Ismail, M.M. Hanafiah, An overview of LCA application in WEEE management: current practices, progress and challenges, J. Clean. Prod. 232 (2019) 79–93, https://doi.org/10.1016/J.JCLEPRO.2019.05.329.
[24] S. Adrian, M.B. Drisse, Y. Cheng, L. Devia, O. Deubzer, F. Goldizen, J. Gorman, S. Herat, S. Honda, G. Iattoni, W. Jingwei, L. Jinhui, D.S. Khetriwal, J. Linnell, F. Magalini, I.C. Nnororm, P. Onianwa, D. Ott, A. Ramola, U. Silva, R. Stillhart, D. Tillekeratne, V. Van Straalen, M. Wagner, T. Yamamoto, X. Zeng, The Global E-waste Monitor 2020: quantities, flows and the circular economy potential, Quant. Flows, Circ. Econ. Potential. (2020) 1–119. http://ewastemonitor.info/. (Accessed 22 May 2023).
[25] M. Mourshed, S. Khatun, K. Islam, N.I. Masuk, M.H. Masud, Generation, composition, collection, and treatment of E-waste, Manag. Electron. Waste. (2024) 39–72, https://doi.org/10.1002/9781119894360.CH3.
[26] M.G. Kibria, N.I. Masuk, R. Safayet, H.Q. Nguyen, M. Mourshed, Plastic waste: challenges and opportunities to mitigate pollution and effective management, Int. J. Environ. Res. 17 (2023) 1–37, https://doi.org/10.1007/S41742-023-00507-Z/FIGURES/26.
[27] M. Iqbal, K. Breivik, J.H. Syed, R.N. Malik, J. Li, G. Zhang, K.C. Jones, Emerging issue of E-waste in Pakistan: a review of status, research needs and data gaps, Environ. Pollut. 207 (2015) 308–318, https://doi.org/10.1016/j.envpol.2015.09.002.
[28] U. Kingdom, And Electronic Equipment (WEEE), 2008.
[29] K. Breivik, J.M. Armitage, F. Wania, K.C. Jones, Tracking the global generation and exports of E-waste. Do existing estimates add up? Environ. Sci. Technol. 48 (2014) 8735–8743, https://doi.org/10.1021/es5021313.
[30] L. Wei, Y. Liu, Present status of E-waste disposal and recycling in China, Procedia Environ. Sci. 16 (2012) 506–514, https://doi.org/10.1016/j.proenv.2012.10.070.
[31] India's booming economy brings toxic hi-tech waste | Reuters, (n.d.). https://www.reuters.com/article/dcbrights-india-environment-ewaste-dc-idUSDEL15336620070223?fbclid=IwAR2iFEiXxWmecXcW8RR1JjdsOdU9HKuU4g7IhByHREP4CrBh3c-FfpZFAzU (accessed January 14, 2023).
[32] S. Kusch, C.D. Hills, The link between E-waste and GDP—new insights from data from the pan-European region, Resour. 2017 6 (6) (2017) 15, https://doi.org/10.3390/RESOURCES6020015, 15.
[33] India - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/india/2015/(accessed June 8, 2022).
[34] India - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/india/2016/(accessed June 8, 2022).
[35] India - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/india/2017/(accessed June 8, 2022).
[36] India - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/india/2018/(accessed June 8, 2022).
[37] India - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/india/2019/(accessed June 8, 2022).
[38] GDP of India 1987-2027 | Statista, (n.d.). https://www.statista.com/statistics/263771/gross-domestic-product-gdp-in-india/(accessed June 8, 2022).
[39] E-waste recycling has doubled, says Centre - The Hindu, (n.d.). https://www.thehindu.com/news/national/E-waste-recycling-has-doubled-says-centre/article30983383.ece (accessed June 8, 2022).
[40] Bangladesh GDP - 2021 Data - 2022 Forecast - 1960-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/bangladesh/gdp (accessed June 8, 2022).
[41] G. of the P.R. of B. Centre for Environmental and Resource Management (CERM), BUET, department of environment, Assessment of Generation of E-waste, Its Impacts on Environment and Resource Recovery Potential in Bangladesh (2018) 1–175. http://doe.portal.gov.bd/sites/default/files/files/doe.portal.gov.bd/page/1f58f60a_51d9_46c0_9fa1_79b7b565db05/2020-10-01-13-02-e522e1499ac288d119a6f7ae16c7f7d0.pdf.
[42] Bangladesh - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bangladesh/2015/(accessed June 8, 2022).
[43] Bangladesh - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bangladesh/2016/(accessed June 8, 2022).
[44] Bangladesh - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bangladesh/2017/(accessed June 8, 2022).
[45] Bangladesh - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bangladesh/2018/(accessed June 8, 2022).
[46] Bangladesh - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bangladesh/2019/(accessed June 8, 2022).
[47] S. Shaikh, A critical analysis of E-waste management and recycling in Pakistan, a life cycle assessment (2021). https://vuir.vu.edu.au/42515/1/SHAIKH_Salsabil-thesis_nosignature.pdf.
[48] Pakistan GDP - 2021 Data - 2022 Forecast - 1960-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/pakistan/gdp (accessed June 8, 2022).
[49] Pakistan - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/pakistan/2015/(accessed June 8, 2022).
[50] Pakistan - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/pakistan/2016/(accessed June 8, 2022).
[51] Pakistan - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/pakistan/2017/(accessed June 8, 2022).
[52] Pakistan - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/pakistan/2018/(accessed June 8, 2022).
[53] Pakistan - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/pakistan/2019/(accessed June 8, 2022).
[54] 'Country generates around 25,000 MT of E-waste annually'|Daily News, (n.d.). https://www.dailynews.lk/2021/10/14/local/261902/country-generates-around-25000-mt-E-waste-annually(accessed November 17, 2022).
[55] Sri Lanka GDP - 2021 Data - 2022 Forecast - 1960-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/sri-lanka/gdp (accessed June 8, 2022).
[56] Sri-lanka - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/sri-lanka/2015/(accessed June 8, 2022).
[57] Sri-lanka - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/sri-lanka/2016/(accessed June 8, 2022).
[58] Sri-lanka - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/sri-lanka/2017/(accessed June 8, 2022).
[59] Sri-lanka - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/sri-lanka/2018/(accessed June 8, 2022).
[60] Sri-lanka - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/sri-lanka/2019/(accessed June 8, 2022).
[61] What will Nepal do with its E-waste? | Nepali Times, (n.d.). https://www.nepalitimes.com/banner/what-will-nepal-do-with-its-E-waste/(accessed November 17, 2022).
[62] Nepal GDP 1960-2022 | MacroTrends, (n.d.). https://www.macrotrends.net/countries/NPL/nepal/gdp-gross-domestic-product (accessed June 8, 2022).
[63] Nepal - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/nepal/2015/(accessed June 8, 2022).
[64] Nepal - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/nepal/2016/(accessed June 8, 2022).
[65] Nepal - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/nepal/2017/(accessed June 8, 2022).
[66] Nepal - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/nepal/2018/(accessed June 8, 2022).
[67] Nepal - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/nepal/2019/(accessed June 8, 2022).
[68] E-waste recovery and recycling facilities in Bhutan is not feasible – The Bhutanese, (n.d.). https://thebhutanese.bt/E-waste-recovery-and-recycling-facilities-in-bhutan-is-not-feasible/(accessed June 9, 2022).
[69] Bhutan GDP - 2021 Data - 2022 Forecast - 1980-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/bhutan/gdp (accessed June 8, 2022).
[70] Bhutan - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bhutan/2015/(accessed June 8, 2022).
[71] Bhutan - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bhutan/2016/(accessed June 8, 2022).
[72] Bhutan - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bhutan/2017/(accessed June 8, 2022).

[73] Bhutan - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bhutan/2018/(accessed June 8, 2022).
[74] Bhutan - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/bhutan/2019/(accessed June 8, 2022).
[75] Myanmar GDP - 2021 Data - 2022 Forecast - 1998-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/myanmar/gdp (accessed June 8, 2022).
[76] Myanmar - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/myanmar/2015/(accessed June 8, 2022).
[77] Myanmar - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/myanmar/2016/(accessed June 8, 2022).
[78] Myanmar - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/myanmar/2017/(accessed June 8, 2022).
[79] Afghanistan - 2018 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/afghanistan/2018/(accessed June 8, 2022).
[80] Afghanistan - 2019 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/afghanistan/2019/(accessed June 8, 2022).
[81] Afghanistan GDP - 2021 Data - 2022 Forecast - 1960-2020 Historical - Chart - News, (n.d.). https://tradingeconomics.com/afghanistan/gdp (accessed June 8, 2022).
[82] Afghanistan - 2015 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/afghanistan/2015/(accessed June 8, 2022).
[83] Afghanistan - 2016 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/afghanistan/2016/(accessed June 8, 2022).
[84] Afghanistan - 2017 - E-waste statistics, (n.d.). https://globalewaste.org/statistics/country/afghanistan/2017/(accessed June 8, 2022).
[85] S. Hossain, J. Commentary, Heal. Pollut. 5, 2015.
[86] M. Streicher-Porte, H.P. Bader, R. Scheidegger, S. Kytzia, Material flow and economic analysis as a suitable tool for system analysis under the constraints of poor data availability and quality in emerging economies, Clean Technol. Environ. Policy 9 (2007) 325–345, https://doi.org/10.1007/S10098-007-0114-7/METRICS.
[87] M.K. Islam, M.S. Khatun, M.A. Arefin, M.R. Islam, M. Hassan, Waste to energy: an experimental study of utilizing the agricultural residue, MSW, and E-waste available in Bangladesh for pyrolysis conversion, Heliyon 7 (2021) e08530, https://doi.org/10.1016/J.HELIYON.2021.E08530.
[88] H. Latt, E-Waste Management in Myanmar, (n.d.).
[89] C.P. Baldé, E. D'Angelo, V. Luda, O. Deubzer, R. Kuehr, Global Transboundary E-Waste Flows Monitor 2022, 2022.
[90] H.O. Bergesen, G. Parmann, O.B. Thommessen, Convention on the control of transboundary movements of hazardous wastes and their disposal (Basel convention), yearb, Int. Coop. Environ. Dev. 1998–99 (2019) 87–89, https://doi.org/10.4324/9781315066547-15.
[91] R. Nuwematsiko, F. Oporia, J. Nabirye, A.A. Halage, D. Musoke, E. Buregyeya, Knowledge, perceptions, and practices of electronic waste management among consumers in kampala, Uganda, J. Environ. Public Health. 2021 (2021), https://doi.org/10.1155/2021/3846428.
[92] S. Jaibee, A.K. Abd Rahim, F. Mohamad, S. Jamian, S.C. Kiong, Y. Seiji, N.H. Muhd Nor, Review on current status of waste electric and electronic product in Malaysia, Appl. Mech. Mater. 773–774 (2015) 898–907, https://doi.org/10.4028/www.scientific.net/amm.773-774.898.
[93] Study-on-Ewaste, 2010.
[94] Mobile subscribers, internet users fall by 3.1m in Sept, (n.d.). https://www.tbsnews.net/bangladesh/telecom/mobile-subscribers-internet-users-fall-31m-sept-533270 (accessed January 3, 2023).
[95] W.W. Ranasinghe, B.C.L. Athapattu, in: Challenges in E-Waste Management in Sri Lanka, INC, 2019, https://doi.org/10.1016/B978-0-12-817030-4.00011-5.
[96] E-waste management in Nepal : Its challenges and way forward « प्रशासन, (n.d.). https://www.prasashan.com/2022/02/17/299228/(accessed December 11, 2022).
[97] Bangladesh mobile cellular subscriptions 2000-2020 | Statista, (n.d.). https://www.statista.com/statistics/497091/number-of-mobile-cellular-subscriptions-in-bangladesh/(accessed June 9, 2022).
[98] , (n.d.). https://www.thefinancialexpress.com.bd/trade/bangladesh-eyes-an-end-to-handset-import-by-2021-1612100824 (accessed June 9, 2022).
[99] Bangladesh Mobile phone Import data with price, buyer, supplier, HSN code, (n.d.). https://www.volza.com/imports-bangladesh/bangladesh-import-data-of-mobile+phone (accessed June 9, 2022).
[100] Bangladesh - Personal Computers (per 100 People) - 2022 Data 2023 Forecast 1997-2006 Historical, (n.d.). https://tradingeconomics.com/bangladesh/personal-computers-per-100-people-wb-data.html (accessed June 9, 2022).
[101] Bangladesh Laptop Import data with price, buyer, supplier, HSN code, (n.d.). https://www.volza.com/imports-bangladesh/bangladesh-import-data-of-laptop (accessed June 9, 2022).
[102] Beximco communications delivers A new world of tv entertainment to Bangladesh, Forbes, 2021. https://www.forbes.com/sites/beximco-group/2021/09/21/beximco-communications-delivers-a-new-world-of-tv-entertainment-to-bangladesh/?sh=7dc6c67b21ef. (Accessed 9 June 2022).
[103] Bangladesh Imports: Television, 1995 – 2022 | CEIC Data, (n.d.)..https://www.ceicdata.com/en/indicator/bangladesh/imports-television (accessed June 9, 2022).
[104] MRC Bangladesh Ltd, Report on ELECTRONICS SECTOR IN BANGLADESH, 2017.
[105] India's growing data usage, smartphone adoption to boost Digital India initiatives: Top bureaucrat - The Economic Times, (n.d.). https://economictimes.indiatimes.com/news/india/indias-growing-data-usage-smartphone-adoption-to-boost-digital-india-initiatives-top-bureaucrat/articleshow/87275402.cms (accessed June 9, 2022).
[106] India is a mobile phone exporter now, but can it mute the Dragon ring tone? - DIU News, (n.d.). https://www.indiatoday.in/diu/story/india-is-a-mobile-phone-exporter-now-but-can-it-mute-the-dragon-ring-tone-1687706-2020-06-10 (accessed June 9, 2022).
[107] Mobile Phone Importer in India - Mobile Import Report of April 2017, (n.d.). https://www.exportgenius.in/blog/mobile-phone-importer-in-india-mobile-import-report-of-april-2017-31.php (accessed June 9, 2022).
[108] Indian education can't go online – only 8% of homes with young members have computer with net link - CBGA India, (n.d.). https://www.cbgaindia.org/blog/indian-education-cant-go-online-8-homes-young-members-computer-net-link/?fbclid=IwAR0vuFsaoZaMWFIbTOJRzcQskoT8YCtGyJKwbx43anuiPe3ABdC55pVxI8M (accessed June 9, 2022).
[109] Laptops import data and price | import of Laptops to India., (n.d.). https://connect2india.com/global/Laptops-import-to-india/1?fbclid=IwAR3aOahB27UQqfol43CgUNlj-k6GI_7wl0PJm5Z82q6Aj1LbxVxn7Huag1E (accessed June 9, 2022).
[110] TV-owning households in India grew 6.9% to 210 mln in two years: BARC | Business Standard News, (n.d.). https://www.business-standard.com/article/current-affairs/tv-owning-households-in-india-grew-6-9-to-210-mln-in-two-years-barc-121041500923_1.html?fbclid=IwAR0PTYmVcHmV3xc8COVmBZ0nk1Kj7Tg2PqX7Rbt_tsUuwbAOpOfAoVpWlwA (accessed June 9, 2022).
[111] India Imports: Television, 1995 – 2022 | CEIC Data, (n.d.). https://www.ceicdata.com/en/indicator/india/imports-television (accessed June 9, 2022).
[112] India: penetration rate of home appliances | Statista, (n.d.). https://www.statista.com/statistics/370635/household-penetration-home-appliances-india/ (accessed November 21, 2022).
[113] How can India Scale up Energy Efficienct Appliances? CEEW Research, (n.d.). https://www.ceew.in/publications/business-model-to-scale-up-energy-efficient-appliances-ceiling-fans-india (accessed October 18, 2022).
[114] fridge imports: India mulls curbing fridge imports to boost domestic industry: Sources - The Economic Times, (n.d.). https://economictimes.indiatimes.com/industry/cons-products/durables/india-mulls-curbing-fridge-imports-to-boost-domestic-industry-sources/articleshow/92102917.cms (accessed October 18, 2022).
[115] India: white goods penetration rate among electrified households by urbanization 2020 | Statista, (n.d.). https://www.statista.com/statistics/1230276/india-white-goods-penetration-rate-among-electrified-households-by-urbanization/(accessed October 18, 2022).
[116] Pakistan mobile cellular subscriptions 2000-2020 | Statista, (n.d.). https://www.statista.com/statistics/501049/number-of-mobile-cellular-subscriptions-in-pakistan/(accessed June 9, 2022).
[117] Pakistan eyeing to boost cell phone exports, (n.d.). https://tribune.com.pk/story/2337404/pakistan-eyeing-to-boost-cell-phone-exports (accessed June 9, 2022).
[118] M. Iqbal, K. Breivik, J.H. Syed, R.N. Malik, J. Li, G. Zhang, K.C. Jones, Emerging issue of E-waste in Pakistan: a review of status, research needs and data gaps, Environ. Pollut. 207 (2015) 308–318, https://doi.org/10.1016/j.envpol.2015.09.002.

[119] Number of Households in Pakistan | Helgi Library, (n.d.). https://www.helgilibrary.com/indicators/number-of-households/pakistan/(accessed June 9, 2022).
[120] Average computer price 2019 | Statista, (n.d.). https://www.statista.com/statistics/722992/worldwide-personal-computers-average-selling-price/(accessed June 9, 2022).
[121] Pakistan - Computers and Peripherals, (n.d.). https://www.trade.gov/country-commercial-guides/pakistan-computers-and-peripherals (accessed June 9, 2022).
[122] Computers in Pakistan | OEC - The Observatory of Economic Complexity, (n.d.). https://oec.world/en/profile/bilateral-product/computers/reporter/pak (accessed June 9, 2022).
[123] Pakistan: amount of televisions owned 2018 | Statista, (n.d.). https://www.statista.com/statistics/618174/amount-of-televisions-in-pakistan/(accessed June 9, 2022).
[124] Pakistan Imports: Television, 1995 – 2022 | CEIC Data, (n.d.). https://www.ceicdata.com/en/indicator/pakistan/imports-television (accessed June 9, 2022).
[125] Pakistan's not-so-cool refrigerator industry - Profit by Pakistan Today, (n.d.). https://profit.pakistantoday.com.pk/2021/02/28/pakistans-not-so-cool-refrigerator-industry/(accessed October 27, 2022).
[126] Refrigeration compressor Import in Pakistan - Import data with price, buyer, supplier, HSN code, (n.d.). https://www.volza.com/p/refrigeration-compressor/import/import-in-pakistan/(accessed October 27, 2022).
[127] Gallup Pakistan - Pakistan's Foremost Research Lab, (n.d.). https://www.gallup.com.pk/post/30287 (accessed October 27, 2022).
[128] Air conditioner Import in Pakistan - Import data with price, buyer, supplier, HSN code, (n.d.). https://www.volza.com/p/air-conditioner/import/import-in-pakistan/(accessed October 27, 2022).
[129] Sri Lanka mobile cellular subscriptions 2000-2020 | Statista, (n.d.). https://www.statista.com/statistics/501125/number-of-mobile-cellular-subscriptions-in-sri-lanka/(accessed June 9, 2022).
[130] New survey reveals 11 key factors contributing to increase in Sri Lanka's computer literacy - NewsWire, (n.d.). https://www.newswire.lk/2020/07/09/new-survey-reveals-11-key-factors-contributing-to-increase-in-sri-lankas-computer-literacy/(accessed June 9, 2022).
[131] K.V.A.H. Wijenayake, G.R.S.R. Samaraweera, Determinants of programme preferences and watching hours of television: with special reference to gampaha district, SSRN Electron. J. (2016), https://doi.org/10.2139/SSRN.2910307.
[132] Number of mobile phone users in Nepal is 34% higher than population - OnlineKhabar English News, (n.d.). https://english.onlinekhabar.com/number-of-mobile-phone-users-in-nepal-is-34-higher-than-population.html (accessed November 28, 2022).
[133] Digital 2020: Bhutan — DataReportal – Global Digital Insights, (n.d.). https://datareportal.com/reports/digital-2020-bhutan (accessed June 9, 2022).
[134] Digital 2020: Myanmar — DataReportal – Global Digital Insights, (n.d.). https://datareportal.com/reports/digital-2020-myanmar (accessed June 9, 2022).
[135] Afghanistan mobile cellular subscriptions 2002-2020 | Statista, (n.d.). https://www.statista.com/statistics/497074/number-of-mobile-cellular-subscriptions-in-afghanistan/?fbclid=IwAR1AI066KUSd6LwrF2ZiglWUo34m3HjzV8cFBORjJgOCd-sIhO6AG7wkxzA (accessed June 9, 2022).
[136] T. Afghan, T. Reporters, W. Borders, Media Use in Afghanistan, 2014, pp. 4–5.
[137] Why Is E-waste Being Shipped To Developing Countries? - ERI, (n.d.). https://eridirect.com/blog/2017/06/why-is-E-waste-being-shipped-to-developing-countries/(accessed January 22, 2023).
[138] E-waste in Developing Countries: Treasure to Trash? - BORGEN, (n.d.). https://www.borgenmagazine.com/E-waste-developing-countries/?fbclid=IwAR2Uxxlc8iSfgauSyT4bUeMMubLkv5pE80U-UItfsIDIg74zpQ4_CgzMjH8 (accessed June 9, 2022).
[139] The Crisis of E-waste in Developing Countries - The Borgen Project, (n.d.). https://borgenproject.org/the-growing-crisis-of-E-waste-in-developing-countries/?fbclid=IwAR1WQj4TUq7Mj2TcTk8ernZLBIqIqpw71puIUNhrl7szXtwZGfgbTjTR51s (accessed January 5, 2023).
[140] Schools Start Benefiting from E-waste Plant – KT PRESS, (n.d.). https://www.ktpress.rw/2017/12/schools-start-benefiting-from-E-waste-plant/(accessed January 22, 2023).
[141] Afrose Meem Romana, Arif Ahmed, Md Shamim Hossain, Ruhul Amin Khan, A Review on the environmental and health impacts due to electronic waste disposal in Bangladesh, GSC Adv. Res. Rev. 8 (2021) 116–125, https://doi.org/10.30574/gscarr.2021.8.2.0174.
[142] Electronics Stewardship — Basel Action Network, (n.d.). https://www.ban.org/e-stewardship (accessed January 22, 2023).
[143] L. Saha, V. Kumar, J. Tiwari, S. Rawat, Environmental Technology & Innovation Electronic waste and their leachates impact on human health and environment : global ecological threat and management, Environ. Technol. Innov. 24 (2021) 102049, https://doi.org/10.1016/j.eti.2021.102049.
[144] K. Liu, Q. Tan, J. Yu, M. Wang, A global perspective on E-waste recycling, Circ. Econ. 2 (2023) 100028, https://doi.org/10.1016/J.CEC.2023.100028.
[145] Z. Yao, M. Reinmöller, N. Ortuño, H. Zhou, M. Jin, J. Liu, R. Luque, Thermochemical conversion of waste printed circuit boards: thermal behavior, reaction kinetics, pollutant evolution and corresponding controlling strategies, Prog. Energy Combust. Sci. 97 (2023) 101086, https://doi.org/10.1016/J.PECS.2023.101086.
[146] D. Mmereki, B. Li, A. Baldwin, L. Hong, D. Mmereki, B. Li, A. Baldwin, L. Hong, The generation, Composition, Collection, Treatment and Disposal System, and Impact of E-waste, E-waste Transit. - From Pollut. to Resour (2016), https://doi.org/10.5772/61332.
[147] Cell phone composition | GRID-Arendal, (n.d.). https://www.grida.no/resources/5862 (accessed January 6, 2023).
[148] S. Park, M. Jung, S. Kim, S. Han, I. Jung, J. Park, J. Park, Evaluation of recycling resources in discarded information and communication technology devices (smartphones, laptop computers), J. Korean Inst. Resour. Recycl. 27 (2018) 16–29, https://doi.org/10.7844/kirr.2018.27.3.16.
[149] V. Ari, A review of technology of metal recovery from electronic waste, E-waste transit. - from pollut. To resour. https://doi.org/10.5772/61569, 2016.
[150] T. Bin Yousuf, D. North, C. Corporation, A. Reza, E-Waste management in Bangladesh : present trend and future implication, in: Proceedings of 2011 World Congress of International Solid Waste Association (ISWA), October 17-20 , 2011 , EXCO Daegu , Korea, 2011, https://doi.org/10.13140/2.1.3261.7927.
[151] ESDO, Guidelines for E-waste Management in Bangladesh Prepared by Guidelines for E-waste Management in Bangladesh (2012) (esdo.org/images/Guidelines for E-waste management in Bangladesh_ESDO.pdf).
[152] K. Dharini, J. Bernadette Cynthia, B. Kamalambikai, J.P. Arul Sudar Celestina, D. Muthu, Hazardous E-waste and its impact on soil structure, IOP Conf. Ser. Earth Environ. Sci. 80 (2017), https://doi.org/10.1088/1755-1315/80/1/012057.
[153] C. Gangwar, R. Choudhari, A. Chauhan, A. Kumar, A. Singh, A. Tripathi, Assessment of air pollution caused by illegal E-waste burning to evaluate the human health risk, Environ. Int. 125 (2019) 191–199, https://doi.org/10.1016/J.ENVINT.2018.11.051.
[154] J. Huang, P.N. Nkrumah, D.O. Anim, E. Mensah, E-waste disposal effects on the aquatic environment: accra, Ghana, Rev. Environ. Contam. Toxicol. 229 (2014) 19–34, https://doi.org/10.1007/978-3-319-03777-6_2/COVER.
[155] M.R. Islam, S.A. Ruponti, M.A. Rakib, H.Q. Nguyen, M. Mourshed, Current scenario and challenges of plastic pollution in Bangladesh: a focus on farmlands and terrestrial ecosystems, Front. Environ. Sci. Eng. (17) (2022) 1–22, https://doi.org/10.1007/S11783-023-1666-4, 2022 176.
[156] M.H. Masud, M. Mourshed, M.S. Hossain, N.U. Ahmed, P. Dabnichki, Generation of waste: problem to possible solution in developing and underdeveloped nations, Waste Manag. Resour. Recycl. Dev. World. (2023) 21–59, https://doi.org/10.1016/B978-0-323-90463-6.00021-X.
[157] P. Vetrivel, P.K. Devi, REVIEW ARTICLE A Focus on E-Waste : Waste : Effects on Environment and Human Health, vol. 2, 2012, pp. 47–51.
[158] Y. Xu, L. Zhang, S.T. Ghulam, H. Abushammala, Challenges and opportunities in the management of electronic waste and its impact on human health and environment, Sustain. 2023 15 (15) (2023) 1837, https://doi.org/10.3390/SU15031837, 1837.
[159] K. Brindhadevi, D. Barceló, N.T. Lan Chi, E.R. Rene, E-waste management, treatment options and the impact of heavy metal extraction from E-waste on human health: scenario in Vietnam and other countries, Environ. Res. 217 (2023) 114926, https://doi.org/10.1016/J.ENVRES.2022.114926.
[160] X. Li, Q. Ren, X. You, Y. Yang, M. Shan, M. Wang, Material flow analysis of discarded refrigerators from households in urban and rural areas of China, Resour. Conserv. Recycl. 149 (2019) 577–585, https://doi.org/10.1016/J.RESCONREC.2019.06.027.
[161] B. Ádám, T. Göen, P.T.J. Scheepers, D. Adliene, B. Batinic, L.T. Budnik, R.C. Duca, M. Ghosh, D.I. Giurgiu, L. Godderis, O. Goksel, K.K. Hansen, P. Kassomenos, N. Milic, H. Orru, A. Paschalidou, M. Petrovic, J. Puiso, J. Radonic, M.T. Sekulic, J.P. Teixeira, H. Zaid, W.W. Au, From inequitable to sustainable E-waste processing for reduction of impact on human health and the environment, Environ. Res. 194 (2021) 110728, https://doi.org/10.1016/J.ENVRES.2021.110728.

[162] U. Swachh, B. Abhiyan, in: E-Waste Management in India : Opportunities and Predicaments E-Waste Management in India : Opportunities and Predicaments under, Researchgate.Net, 2016, pp. 745–756. https://www.researchgate.net/profile/Avdesh_Bhardawaj/publication/304996777_E-WASTE_MANAGEMENT_IN_INDIA_OPPORTUNITIES_AND_PREDICAMENTS_UNDER_SWACHH_BHARAT_ABHIYAN/links/57d407c408ae601b39a8a18c/E-WASTE-MANAGEMENT-IN-INDIA-OPPORTUNITIES-AND-PREDICAMENTS-UN.
[163] M.C. Vats, S.K. Singh, M.C. Vats, E-Waste characteristic and its disposal, Int. J. Ecol. Sci. Environ. Eng. Int. J. Ecol. Sci. Environ. Eng. 1 (2019) 49–61. http://www.aascit.org/journal/ijesee.
[164] Impacts of E-waste on Health - Blog, (n.d.). http://www.greenit.co.in/impacts-of-E-waste-on-health.html (accessed January 6, 2023).
[165] Is E-waste Hazardous? (If So, Why Isn't It Classified As Such?) - Recognized Trading & Shipping, Inc., (n.d.). https://recognizedtrader.us/is-E-waste-hazardous-if-so-why-isnt-it-classified-as-such/(accessed January 6, 2023).
[166] M. Alam, K.M. Bahauddin, Electronic waste in Bangladesh: evaluating the situation, legislation and policy and way forward with strategy and approach, Present Environ. Sustain. Dev. 9 (2015) 81–101, https://doi.org/10.1515/pesd-2015-0005.
[167] R. Rajesh, D. Kanakadhurga, N. Prabaharan, Electronic waste : a critical assessment on the unimaginable growing pollutant , legislations and environmental impacts, Environ. Challenges. 7 (2022) 100507, https://doi.org/10.1016/j.envc.2022.100507.
[168] Ankit, L. Saha, V. Kumar, J. Tiwari, Sweta, S. Rawat, J. Singh, K. Bauddh, Electronic waste and their leachates impact on human health and environment: global ecological threat and management, Environ. Technol. Innov. 24 (2021) 102049, https://doi.org/10.1016/j.eti.2021.102049.
[169] I. Labunska, D. Santillo, P. Johnston, Chemical Contamination at E-Waste Recycling and Disposal Sites in Accra and, 2008.
[170] E. Karwowska, D. Andrzejewska-Morzuch, M. Łebkowska, A. Tabernacka, M. Wojtkowska, A. Telepko, A. Konarzewska, Bioleaching of metals from printed circuit boards supported with surfactant-producing bacteria, J. Hazard Mater. 264 (2014) 203–210, https://doi.org/10.1016/j.jhazmat.2013.11.018.
[171] How to convert mg/kg to ug/m3? | ResearchGate, (n.d.). https://www.researchgate.net/post/How-to-convert-mg-kg-to-ug-m3 (accessed January 14, 2023).
[172] K.S. Patel, B. Ambade, S. Sharma, D. Sahu, N.K. Jaiswal, S. Gupta, R.K. Dewangan, S. Nava, F. Lucarelli, B. Blazhev, R. Stefanova, J. Hoinkis, K.S. Patel, B. Ambade, S. Sharma, D. Sahu, N.K. Jaiswal, S. Gupta, R.K. Dewangan, S. Nava, F. Lucarelli, B. Blazhev, R. Stefanova, J. Hoinkis, Lead environmental pollution in Central India, New Trends Technol (2010), https://doi.org/10.5772/7590.
[173] CONCAWE. Environmental Science for he European Refining Industry, R.J. Lewis, D.J. Caldwell, I. Exxon Biomedical Sciences, Scientific Basis for an Air Quality Standard for Nickel, 1999, pp. 1–64.
[174] Y.A. Iyaka, Nickel in soils: a review of its distribution and impacts, Sci. Res. Essays 6 (2011) 6774–6777, https://doi.org/10.5897/SREX11.035.
[175] O.M. Morakinyo, M.S. Mukhola, M.I. Mokgobu, Health Risk Analysis of Elemental Components of an Industrially Emitted Respirable Particulate Matter in an Urban Area, 2021.
[176] H.C. Ratsch, HM Accumulation in Soils and Vegetation from Smelter Emissions, 1974, pp. 1–31.
[177] Osha 3136-06r 2004, 2004.
[178] A.M. Sheikh, P.S. Correa, E. Leal da Silva, I.D. Savaris, S.C. Amico, C.F. Malfatti, Energy conversion using pd-based catalysts in direct ethanol fuel cell, Renew. Energy Power Qual. J. 1 (2013) 342–345, https://doi.org/10.24084/repqj11.300.
[179] Obligations Relating To EPR Target Under E-waste Management Rules, (n.d.). https://eridirect.com/sustainability/us-landfill-ban/(accessed August 10, 2023).
[180] E.R. Rene, M. Sethurajan, V. Kumar Ponnusamy, G. Kumar, T.N. Bao Dung, K. Brindhadevi, A. Pugazhendhi, Electronic waste generation, recycling and resource recovery: technological perspectives and trends, J. Hazard Mater. 416 (2021) 125664, https://doi.org/10.1016/J.JHAZMAT.2021.125664.
[181] A.Q. Mairizal, A.Y. Sembada, K.M. Tse, M.A. Rhamdhani, Electronic waste generation, economic values, distribution map, and possible recycling system in Indonesia, J. Clean. Prod. 293 (2021) 126096, https://doi.org/10.1016/J.JCLEPRO.2021.126096.
[182] H. Roy, T.U. Rahman, M.B.K. Suhan, M.R. Al-Mamun, S. Haque, M.S. Islam, A comprehensive review on hazardous aspects and management strategies of electronic waste: Bangladesh perspectives, Heliyon 8 (2022) e09802, https://doi.org/10.1016/J.HELIYON.2022.E09802.
[183] K. Ravindra, S. Mor, E-waste generation and management practices in Chandigarh, India and economic evaluation for sustainable recycling, J. Clean. Prod. 221 (2019) 286–294, https://doi.org/10.1016/J.JCLEPRO.2019.02.158.
[184] F. Cucchiella, I. D'Adamo, S.C. Lenny Koh, P. Rosa, Recycling of WEEEs: an economic assessment of present and future E-waste streams, Renew. Sustain. Energy Rev. 51 (2015) 263–272, https://doi.org/10.1016/J.RSER.2015.06.010.
[185] L. Meng, Y. Zhong, L. Guo, Z. Wang, K. Chen, Z. Guo, Recovery of Cu and Zn from waste printed circuit boards using super-gravity separation, Waste Manag. 78 (2018) 559–565, https://doi.org/10.1016/J.WASMAN.2018.06.022.
[186] F.F. Rochman, W.S. Ashton, M.G.M. Wiharjo, E-waste, money and power: mapping electronic waste flows in Yogyakarta, Indonesia, Environ. Dev. 24 (2017) 1–8, https://doi.org/10.1016/J.ENVDEV.2017.02.002.
[187] B. Bakhiyi, S. Gravel, D. Ceballos, M.A. Flynn, J. Zayed, Has the question of E-waste opened a Pandora's box? An overview of unpredictable issues and challenges, Environ. Int. 110 (2018) 173–192, https://doi.org/10.1016/J.ENVINT.2017.10.021.
[188] P. Nos, New Delhi, int. Soc. Secur, Rev. 47 (1994) 90–94, https://doi.org/10.1111/j.1468-246X.1994.tb00404.x.
[189] S. Ramzan, C.G. Liu, H. Munir, Y. Xu, Assessing young consumers' awareness and participation in sustainable E-waste management practices: a survey study in Northwest China, Environ. Sci. Pollut. Res. 26 (2019) 20003–20013, https://doi.org/10.1007/S11356-019-05310-Y.
[190] Bangladesh publishes E-waste Management Rule | Enviliance ASIA, (n.d.). https://enviliance.com/regions/south-asia/bd/report_2900 (accessed May 23, 2023).
[191] S. Chatterjee, Electronic waste and India, 1–15, www.greenpeace.org, 2011.
[192] NORTH AMERICA E-WASTE MANAGEMENT MARKET 2021-2028, (n.d.). https://www.tritonmarketresearch.com/reports/north-america-E-waste-management-market (accessed May 24, 2023).
[193] A Detailed Explanation of the EPR Responsibility Policy in India, (n.d.). https://corpbiz.io/learning/epr-responsibility-policy-in-india/(accessed December 21, 2022).
[194] A. Borthakur, M. Govind, P. Singh, Inventorization of E-waste and its disposal practices with benchmarks for depollution: the global scenario, Electron. Waste Manag. Treat. Technol. (2019) 35–52, https://doi.org/10.1016/B978-0-12-816190-6.00002-9.
[195] R.M.R. Turaga, K. Bhaskar, Epr and policy instruments for E- waste management: a review and lessons for India ' S new E-waste regulations, sixt, Int. Waste Manag. Landfill Symp. (2017) 1–9.
[196] A. Borthakur, Design, adoption and implementation of electronic waste policies in India, Environ. Sci. Pollut. Res. 30 (2023) 8672–8681, https://doi.org/10.1007/S11356-022-18836-5/TABLES/3.
[197] J. Yu, E. Williams, M. Ju, C. Shao, Managing E-waste in China: policies, pilot projects and alternative approaches, Resour. Conserv. Recycl. 54 (2010) 991–999, https://doi.org/10.1016/J.RESCONREC.2010.02.006.
[198] D. Dutta, S. Goel, Understanding the gap between formal and informal E-waste recycling facilities in India, Waste Manag. 125 (2021) 163–171, https://doi.org/10.1016/J.WASMAN.2021.02.045.
[199] D.A. Kumar, E-Waste Management in India Current Scenerio, 2013.
[200] Electronic waste: the need to reuse, repair, recycle and safely dispose, (n.d.). https://india.mongabay.com/2020/08/explainer-the-why-and-how-of-disposing-electronic-waste/(accessed June 10, 2022).
[201] D. Kumar Adhana, E-waste management in India: a study of current scenario, Int. J. Manag. IX (2019). https://www.researchgate.net/publication/342162923.
[202] The A-Z of E-waste management - The Hindu, (n.d.). https://www.thehindu.com/sci-tech/energy-and-environment/what-about-E-waste/article24193081.ece (accessed December 20, 2022).
[203] Y. Alahakoon, N. Gunarathne, in: E-Waste Management in Sri Lanka, 2022, https://doi.org/10.1201/9781003095972-7.
[204] Bangladesh publishes E-waste Management Rule | Enviliance ASIA, (n.d.). https://enviliance.com/regions/south-asia/bd/report_2900 (accessed December 21, 2022).
[205] P. Panduwawala, M. Samarakoon, Electrical and electronic waste management in Sri Lanka, 2018, 178–191, http://ir.kdu.ac.lk/handle/345/2979, 2020.

[206] Dangerous disposal: why Sri Lanka urgently needs to manage its E-waste - roar media. https://roar.media/english/life/in-the-know/dangerous-disposal-E-waste-sri-lanka. (Accessed 7 December 2022).
[207] B. Ceylon, P. Export, Licensed E-Waste Collectors in Sri Lanka, 2022, pp. 10–12.
[208] Licensed Collectors of Electronic Waste Management in Sri Lanka, (n.d.). https://www.cea.lk/web/en/index-php-option-com-content-view-article-layout-edit-id-983 (accessed June 9, 2022) .
[209] B.B. Khatri, E- waste management: an emerging challenge in Nepal, NUTA J 6 (2019) 1–4, https://doi.org/10.3126/nutaj.v6i1-2.23218.
[210] J. Giri, R. Adhikari, Urgency of proper E-waste management plan in Nepal: an overview, Nepal, J. Sci. Technol. 19 (2020) 107–118, https://doi.org/10.3126/njst.v19i1.29790.
[211] Erase Your Ewaste | Doko Recyclers, (n.d.). https://dokorecyclers.com/blog/erase-your-ewaste-36 (accessed June 9, 2022).
[212] WASTE MANAGEMENT POLICY IN BHUTAN, (n.d.). https://www.cseindia.org/waste-management-policy-in-bhutan-4584 (accessed December 21, 2022).
[213] A. Mk, M.S. K, M.A. K, Institutional Mechanism in E-Waste Management and Recycling, 2018, pp. 60–66.
[214] M.H. Masud, M. Mourshed, M. Mahjabeen, A.A. Ananno, P. Dabnichki, Global electronic waste management : current status and way forward, Paradig. Shift E-waste Manag (2022) 9–47, https://doi.org/10.1201/9781003095972-3.
[215] Electronic Waste Management in India: A Stakeholder's Perspective Anwesha Borthakur and Kunal Sinha Jawaharlal Nehru University, New Delhi, India and Central University of Gujarat, Gandhinagar, Gujarat, India, 2008, pp. 1–21.
[216] D. Punjab, U. Land, S. Enhancement, E-Waste Management Plan, 2021.
[217] D. Tiwari, L. Raghupathy, A.S. Khan, N.G. Dhawan, A study on the E-waste collection systems in some asian countries with special reference to India, Nat. Environ. Pollut. Technol. 18 (2019) 149–156.
[218] M. Sajid, J.H. Syed, M. Iqbal, Z. Abbas, I. Hussain, M.A. Baig, Assessing the generation, recycling and disposal practices of electronic/electrical-waste (E-waste) from major cities in Pakistan, Waste Manag. 84 (2019) 394–401, https://doi.org/10.1016/J.WASMAN.2018.11.026.
[219] S. De Meester, P. Nachtergaele, S. Debaveye, P. Vos, J. Dewulf, Using material flow analysis and life cycle assessment in decision support: a case study on WEEE valorization in Belgium, Resour. Conserv. Recycl. 142 (2019) 1–9, https://doi.org/10.1016/J.RESCONREC.2018.10.015.
[220] V. Ibáñez-Forés, C. Coutinho-Nóbrega, M. Guinot-Meneu, M.D. Bovea, Achieving waste recovery goals in the medium/long term: eco-efficiency analysis in a Brazilian city by using the LCA approach, J. Environ. Manage. 298 (2021) 113457, https://doi.org/10.1016/J.JENVMAN.2021.113457.
[221] M. Xue, Z. Xu, Application of life cycle assessment on electronic waste management: a review, Environ. Manage. 59 (2017) 693–707, https://doi.org/10.1007/S00267-016-0812-1/TABLES/2.
[222] J. Hong, W. Shi, Y. Wang, W. Chen, X. Li, Life cycle assessment of electronic waste treatment, Waste Manag. 38 (2015) 357–365, https://doi.org/10.1016/J.WASMAN.2014.12.022.
[223] A. Laurent, J. Clavreul, A. Bernstad, I. Bakas, M. Niero, E. Gentil, T.H. Christensen, M.Z. Hauschild, Review of LCA studies of solid waste management systems – Part II: methodological guidance for a better practice, Waste Manag. 34 (2014) 589–606, https://doi.org/10.1016/J.WASMAN.2013.12.004.
[224] S. Liu, M. Leat, M.H. Smith, State-of-the-art sustainability analysis methodologies for efficient decision support in green production operations, 10.1080/19397038.2011.574744 4 (2011) 236–250, https://doi.org/10.1080/19397038.2011.574744.
[225] V. Bhakar, A. Agur, A.K. Digalwar, K.S. Sangwan, Life cycle assessment of CRT, LCD and LED monitors, Procedia CIRP 29 (2015) 432–437, https://doi.org/10.1016/J.PROCIR.2015.02.003.
[226] L. Rocchetti, F. Beolchini, Environmental burdens in the management of end-of-life cathode ray tubes, Waste Manag. 34 (2014) 468–474, https://doi.org/10.1016/J.WASMAN.2013.10.031.
[227] M. Xue, A. Kendall, Z. Xu, J.M. Schoenung, Waste management of printed wiring boards: a life cycle assessment of the metals recycling chain from liberation through refining, Environ. Sci. Technol. 49 (2015) 940–947, https://doi.org/10.1021/ES504750Q/ASSET/IMAGES/MEDIUM/ES-2014-04750Q_0009.GIF.
[228] L.T. Lu, I.K. Wernick, T.Y. Hsiao, Y.H. Yu, Y.M. Yang, H.W. Ma, Balancing the life cycle impacts of notebook computers: Taiwan's experience, Resour. Conserv. Recycl. 48 (2006) 13–25, https://doi.org/10.1016/J.RESCONREC.2005.12.010.
[229] V.K. Soo, M. Doolan, Recycling mobile phone impact on life cycle assessment, Procedia CIRP 15 (2014) 263–271, https://doi.org/10.1016/J.PROCIR.2014.06.005.
[230] G. Rebitzer, T. Ekvall, R. Frischknecht, D. Hunkeler, G. Norris, T. Rydberg, W.P. Schmidt, S. Suh, B.P. Weidema, D.W. Pennington, Life cycle assessment: Part 1: framework, goal and scope definition, inventory analysis, and applications, Environ. Int. 30 (2004) 701–720, https://doi.org/10.1016/J.ENVINT.2003.11.005.
[231] C. Visentin, A.W. da Silva Trentin, A.B. Braun, A. Thomé, Application of life cycle assessment as a tool for evaluating the sustainability of contaminated sites remediation: a systematic and bibliographic analysis, Sci. Total Environ. 672 (2019) 893–905, https://doi.org/10.1016/J.SCITOTENV.2019.04.034.
[232] L. Andeobu, S. Wibowo, S. Grandhi, An assessment of E-waste generation and environmental management of selected countries in Africa, Europe and North America: a systematic review, Sci. Total Environ. 792 (2021) 148078, https://doi.org/10.1016/J.SCITOTENV.2021.148078.
[233] H. Ismail, M.M. Hanafiah, Evaluation of E-waste management systems in Malaysia using life cycle assessment and material flow analysis, J. Clean. Prod. 308 (2021) 127358, https://doi.org/10.1016/J.JCLEPRO.2021.127358.
[234] S.S. Muthu, Estimating the overall environmental impact of textile processing, Assess, Environ. Impact Text. Cloth. Supply Chain (2020) 105–129, https://doi.org/10.1016/B978-0-12-819783-7.00006-5.
[235] S. Shaikh, K. Thomas, S. Zuhair, F. Magalini, A cost-benefit analysis of the downstream impacts of E-waste recycling in Pakistan, Waste Manag. 118 (2020) 302–312, https://doi.org/10.1016/J.WASMAN.2020.08.039.
[236] I. Thushari, J. Vicheanteab, D. Janjaroen, Material flow analysis and life cycle assessment of solid waste management in urban green areas, Thailand, Sustain. Environ. Res. 30 (2020), https://doi.org/10.1186/s42834-020-00057-5.
[237] T.E. Graedel, Material flow analysis from origin to evolution, Environ. Sci. Technol. 53 (2019) 12188–12196, https://doi.org/10.1021/ACS.EST.9B03413/SUPPL_FILE/ES9B03413_SI_001.PDF.
[238] M.T. Islam, N. Huda, Material flow analysis (MFA) as a strategic tool in E-waste management: applications, trends and future directions, J. Environ. Manage. 244 (2019) 344–361, https://doi.org/10.1016/J.JENVMAN.2019.05.062.
[239] S.V. Withanage, K. Habib, Life cycle assessment and material flow analysis: two under-utilized tools for informing E-waste management, Sustain. 2021 13 (13) (2021) 7939, https://doi.org/10.3390/SU13147939, 7939.
[240] P.H. Brunner, H. Rechberger, Handbook of material flow analysis : for environmental, resource, and waste engineers, n.d. https://www.routledge.com/Handbook-of-Material-Flow-Analysis-For-Environmental-Resource-and-Waste/Brunner-Rechberger/p/book/9780367574093 (accessed May 24, 2023).
[241] O. Osibanjo, I.C. Nnorom, Material flows of mobile phones and accessories in Nigeria: environmental implications and sound end-of-life management options, Environ. Impact Assess. Rev. 28 (2008) 198–213, https://doi.org/10.1016/J.EIAR.2007.06.002.
[242] C.D. Tran, S.P. Salhofer, Analysis of recycling structures for E-waste in Vietnam, J. Mater. Cycles Waste Manag. 20 (2018) 110–126, https://doi.org/10.1007/S10163-016-0549-1/TABLES/7.
[243] P. Kiddee, R. Naidu, M.H. Wong, Electronic waste management approaches: an overview, Waste Manag. 33 (2013) 1237–1250, https://doi.org/10.1016/J.WASMAN.2013.01.006.
[244] A. Jain, R. Sareen, E-waste assessment methodology and validation in India, J. Mater. Cycles Waste Manag. 8 (2006) 40–45, https://doi.org/10.1007/S10163-005-0145-2/METRICS.
[245] A.R.K. Gollakota, S. Gautam, C.M. Shu, Inconsistencies of E-waste management in developing nations – facts and plausible solutions, J. Environ. Manage. 261 (2020) 110234, https://doi.org/10.1016/J.JENVMAN.2020.110234.
[246] S. Ilyas, R.R. Srivastava, H. Kim, O2-enriched microbial activity with pH-sensitive solvo-chemical and electro-chlorination strategy to reclaim critical metals from the hazardous waste printed circuit boards, J. Hazard Mater. 416 (2021) 125769, https://doi.org/10.1016/J.JHAZMAT.2021.125769.
[247] R. Nuwematsiko, F. Oporia, J. Nabirye, A.A. Halage, D. Musoke, E. Buregyeya, Knowledge, perceptions, and practices of electronic waste management among consumers in kampala, Uganda, J. Environ. Public Health. 2021 (2021), https://doi.org/10.1155/2021/3846428.

[248] M. Ikhlayel, An integrated approach to establish E-waste management systems for developing countries, J. Clean. Prod. 170 (2018) 119–130, https://doi.org/10.1016/J.JCLEPRO.2017.09.137.
[249] Recycle coach how to repair, reuse, and recycle old electronics [avoid holiday E-waste]. https://recyclecoach.com/blog/how-to-repair-reuse-and-recycle-old-electronics-avoid-holiday-E-waste/. (Accessed 10 June 2022).
[250] Using refurbished technology is the new solution to E-waste management - education Today News. https://www.indiatoday.in/education-today/featurephilia/story/using-refurbished-technology-is-the-new-solution-to-E-waste-management-1563329-2019-07-06. (Accessed 10 June 2022).
[251] The benefits of refurbishing rather than recycling. https://rrrcomputers.org/blog/the-benefits-of-refurbishing-rather-than-recycling-and-E-waste/. (Accessed 10 June 2022).
[252] S. Ibrahim Mohammed, E-Waste management in different countries: strategies, impacts, and determinants, Adv. Green Electron. Technol. [Working Title] (2022) 1–15, https://doi.org/10.5772/intechopen.106644.
[253] 10 Advantages of recycling e waste - my waste solution, (n.d.). https://blog.mywastesolution.com/10-advantages-of-recycling-E-waste/(accessed January 7, 2023).
[254] E-waste management | E-waste recycling and disposal, (n.d.). https://www.rfwireless-world.com/Articles/E-waste-management-recycling-and-disposal.html (accessed January 8, 2023).
[255] R. Ahirwar, A.K. Tripathi, E-waste management: a review of recycling process, environmental and occupational health hazards, and potential solutions, Environ. Nanotechnology, Monit. Manag. 15 (2021), https://doi.org/10.1016/J.ENMM.2020.100409.
[256] What is E-waste Recycling and Process of Recycling Electronic Waste - Conserve Energy Future, (n.d.). https://www.conserve-energy-future.com/E-waste-recycling-process.php (accessed June 10, 2022).
[257] Six Benefits Of Recycling E-waste | Recycle Technologies, (n.d.). https://www.recycletechnologies.com/benefits-of-recycling-E-waste/(accessed May 23, 2023).
[258] BENEFITS OF E-WASTE RECYCLING - GCL Geri Kazanım ve Rafineri A.Ş., (n.d.). https://gclcevre.com/en/benefits-of-E-waste-recycling (accessed May 23, 2023).
[259] E-waste Management Process | ECS Environment, (n.d.). https://www.ecsenvironment.com/process/(accessed January 14, 2023).
[260] E waste Transportation To The Recycling Facility | Electronic waste recycling, Recycling facility, Recycling, (n.d.). https://in.pinterest.com/pin/E-waste-transportation-to-the-recycling-facility–564216659538005899/?amp_client_id=CLIENT_ID(_)&mweb_unauth_id=%7B%7Bdefault.session%7D%7D&simplified=true (accessed January 22, 2023).
[261] How does extraction of precious metals from E-waste help the environment?. https://www.researchdive.com/blog/precious-metals-E-waste-recovery-as-a-means-for-better-sustainability. (Accessed 22 January 2023).
[262] Recycling tech gadgets to reduce environmental pollution – the Mercury News. https://www.mercurynews.com/2016/03/13/recycling-tech-gadgets-to-reduce-environmental-pollution/. (Accessed 22 January 2023).
[263] How Is E-waste Recycled? - Devon Contract Waste, (n.d.). https://www.dcw.co.uk/how-is-E-waste-recycled/(accessed June 10, 2022).
[264] Uses of aluminum, (n.d.). https://www.riotinto.is/?PageID=119 (accessed December 22, 2022).
[265] Uses of Copper | Supply, Demand, Production, Resources, (n.d.). https://geology.com/usgs/uses-of-copper/(accessed December 22, 2022).
[266] Common Uses for Brass, (n.d.). https://www.meadmetals.com/blog/common-uses-for-brass (accessed December 22, 2022).
[267] 13 Mercury Uses in Everyday Life – StudiousGuy, (n.d.). https://studiousguy.com/mercury-uses/(accessed December 22, 2022).
[268] Recycled batteries can be processed and used in the making of other common goods, from kitchen tools to sports equipment | National Post, (n.d.). https://nationalpost.com/sponsored/life-sponsored/recycled-batteries-can-be-processed-and-used-in-the-making-of-other-common-goods-from-kitchen-tools-to-sports-equipment (accessed August 10, 2023).
[269] USGS fact sheet 060-01: obsolete computers, "gold mine," or high-tech trash?. https://pubs.usgs.gov/fs/fs060-01/. (Accessed 22 December 2022).
[270] D. Dutta, R. Rautela, L.K.S. Gujjala, D. Kundu, P. Sharma, M. Tembhare, S. Kumar, A review on recovery processes of metals from E-waste: a green perspective, Sci. Total Environ. 859 (2023) 160391, https://doi.org/10.1016/J.SCITOTENV.2022.160391.
[271] Precious metals recovery from E-waste, (n.d.). https://blog.emew.com/precious-metals-recovery-from-E-waste (accessed January 8, 2023).
[272] A. Khaliq, M.A. Rhamdhani, G. Brooks, S. Masood, Metal extraction processes for electronic waste and existing industrial routes: a review and Australian perspective, Resources 3 (2014) 152–179, https://doi.org/10.3390/resources3010152.
[273] Organic waste shredder – Filamaker, (n.d.). https://filamaker.eu/product/organic-waste-shredder/(accessed January 22, 2023).
[274] Round Vibrating Screen Applied for Mineral Screening,Xinhai - YouTube, (n.d.). https://www.youtube.com/watch?v=JOk8oyWnrsg (accessed January 22, 2023).
[275] Magnetic drum separator and housing | MPI. https://mpimagnet.com/products/metal-sorting-systems/drum-separator/. (Accessed 22 January 2023).
[276] Y.R. Smith, J.R. Nagel, R.K. Rajamani, Eddy current separation for recovery of non-ferrous metallic particles: a comprehensive review, Miner. Eng. 133 (2019) 149–159, https://doi.org/10.1016/J.MINENG.2018.12.025.
[277] G. Malcolm Richard, M. Mario, T. Javier, T. Susana, Optimization of the recovery of plastics for recycling by density media separation cyclones, Resour. Conserv. Recycl. 55 (2011) 472–482, https://doi.org/10.1016/J.RESCONREC.2010.12.010.
[278] 5 Critical Things to Know Before Getting Rid of Your E-waste | Cal Micro Recycling, (n.d.). https://www.calmicrousa.com/1471-2/(accessed January 22, 2023).
[279] P.A. Yunus, B. Sengupta, E-Waste Indian perspective and recovery of valuable metals from E-waste-A review, int. Ref, J. Eng. Sci. 5 (2016) 70–80. www.irjes.com.
[280] Y.M. Li, Y. Wang, M.J. Chen, T.Y. Huang, F.H. Yang, Z.J. Wang, Current status and technological progress in lead recovery from electronic waste, Int. J. Environ. Sci. Technol. (20) (2022) 1037–1052, https://doi.org/10.1007/S13762-022-04009-X, 2022 201.
[281] Simple Ideas on How to Reduce E-waste | Great Lakes Electronics, (n.d.). https://www.ewaste1.com/how-to-reduce-E-waste/(accessed June 10, 2022).
[282] 10 Ways To Reduce E Waste - Shrink That Footprint, (n.d.). https://shrinkthatfootprint.com/ways-to-reduce-E-waste/(accessed January 14, 2023).
[283] 7 Ways You Can Reduce E-waste, (n.d.). https://www.makeuseof.com/ways-you-can-reduce-E-waste/#here-s-why-reducing-E-waste-should-be-a-priority-for-you (accessed January 14, 2023).
[284] How Long Do Lenovo Laptops Last? (Explained) | WhatsaByte, (n.d.). https://whatsabyte.com/how-long-do-lenovo-laptops-last-explained/(accessed December 8, 2022).
[285] What is the Average Lifespan of a Computer? < Tech Takes - HP.com India, (n.d.). https://www.hp.com/in-en/shop/tech-takes/post/average-computer-lifespan (accessed December 8, 2022).
[286] Computer Market in Bangladesh in 2021 and What to Expect in 2022 | Infographic - Bikroy Blog EN, (n.d.). https://blog.bikroy.com/computer-market-in-bangladesh-2021/(accessed December 10, 2022).
[287] How Long Do Dell Laptops Last? (Updated 2022) | DeviceTests, (n.d.). https://devicetests.com/how-long-do-dell-laptops-last (accessed December 9, 2022).
[288] Laptops - Bhutan | Statista Market Forecast, (n.d.). https://www.statista.com/outlook/cmo/consumer-electronics/computing/laptops/bhutan (accessed December 9, 2022).
[289] What is the average smartphone lifespan? | Everphone, (n.d.). https://everphone.com/en/blog/smartphone-lifespan/(accessed December 10, 2022).
[290] Mobile Vendor Market Share Afghanistan | Statcounter Global Stats, (n.d.). https://gs.statcounter.com/vendor-market-share/mobile/afghanistan (accessed December 9, 2022).
[291] How long do iPhones last? How to know when to upgrade your iPhone. https://www.iphonelife.com/content/how-long-do-iphone-last-how-to-know-when-to-upgrade-your-iphone, 2022. (Accessed 9 December 2022).
[292] How Long Do Samsung TVs Last? (Explained), (n.d.). https://techpenny.com/samsung-tvs-longevity/(accessed December 8, 2022).
[293] Xiaomi Mi TV 4 55 owners, here's some good and bad news for you! | The Financial Express, (n.d.). https://www.financialexpress.com/life/technology-xiaomi-mi-tv-4-55-owners-heres-some-good-and-bad-news-for-you-1960235/(accessed December 8, 2022).

[294] TV Buying Guide - How to Buy a TV in Nepal in 2018?, (n.d.). https://techlekh.com/tv-buying-guide-nepal/(accessed December 8, 2022).
[295] Televisions - Bhutan | Statista Market Forecast, (n.d.). https://www.statista.com/outlook/cmo/consumer-electronics/tv-radio-multimedia/televisions/bhutan (accessed December 9, 2022).
[296] How Long Do LG TVs Last? Get The Most Out Of Your LG TV - Robot Powered Home, (n.d.). https://robotpoweredhome.com/how-long-do-lg-tvs-last/ (accessed December 9, 2022).
[297] Life of a mobile phone in india | Mint, (n.d.). https://www.livemint.com/Specials/dxyOahr9AIdGhcAkHjzzzI/Life-of-a-mobile-phone-in-india.html (accessed December 8, 2022).
[298] Possibility of Refurbishing and Assembling Phone Sets in Nepal, (n.d.). https://techlekh.com/refurbish-assembly-mobile-phones-nepal/(accessed December 8, 2022).
[299] Mobile Vendor Market Share Bhutan | Statcounter Global Stats, (n.d.). https://gs.statcounter.com/vendor-market-share/mobile/bhutan (accessed December 8, 2022).
[300] vivo UAE, (n.d.). https://www.vivo.com/ae/en/index/warrantyTerms (accessed December 9, 2022).
[301] Myanmar: market share of leading mobile brands 2022 | Statista, (n.d.). https://www.statista.com/statistics/938822/myanmar-market-share-of-leading-mobile-brands/(accessed December 10, 2022).
[302] India: market share of refrigerator by vendor 2022 | Statista, (n.d.). https://www.statista.com/statistics/1270855/india-market-share-of-refrigerator-by-vendor/(accessed December 8, 2022).
[303] Signs a Refrigerator is Dying - Blog - Howard's | Howard's, (n.d.). https://www.howards.com/blog/signs-a-refrigerator-is-dying/(accessed December 8, 2022).
[304] Samsung Refrigerator Lifespan? (Things You Must Know) 2022, (n.d.). https://homeguideinfo.com/samsung-refrigerator-lifespan/(accessed December 8, 2022).
[305] Pakistan, Bangladesh, Sri Lanka, Bhutan and Nepal White Goods Market Report – Industry Trends and Forecast to 2027 | Data Bridge Market Research, (n.d.). https://www.databridgemarketresearch.com/reports/pakistan-bangladesh-sri-lanka-bhutan-and-nepal-white-goods-market (accessed December 8, 2022).
[306] S. Thukral, D. Shree, S. Singhal, Consumer behaviour towards storage, disposal and recycling of E-waste: systematic review and future research prospects, Benchmarking 30 (2023) 1021–1072, https://doi.org/10.1108/BIJ-12-2021-0774/FULL/XML.