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GLOBAL STRATEGIES FOR E-WASTE MANAGEMENT

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Abstract*– This report highlights the global e-waste problem, projected to reach 74.7 million tons by 2030 due to mass consumption and technological obsolescence. E-waste poses environmental and social risks, releasing hazardous substances like lead and mercury while wasting valuable materials such as gold and copper. Europe leads with a 42.5% recycling rate due to its advanced infrastructure and strict regulations, while Africa lags with only 0.9%. The Americas and Asia show moderate progress at 9.4% and 11.7%, but still face significant structural and regulatory challenges. To address this, the report emphasizes the need for investments in infrastructure, uniform policies, and educational campaigns to promote sustainable e-waste management, recover valuable resources, and reduce environmental and health impacts.

Keywords--. e-waste, e-waste management, recycling, regulations, circular economy

I. Introduction

E-waste management has become a major challenge in the context of the growing reliance on electronic devices and rapid technological innovation. The increase in the production and consumption of these products generates volumes of waste that current management systems are not fully prepared to handle. According to estimates from the United Nations Environment Programme, around 50 million tonnes of waste from electronic devices are generated worldwide each year [1]. This study focuses on analyzing the main difficulties and approaches in the management of this waste, including the effectiveness of recycling systems, the implementation of extended producer responsibility (EPR) policies, the impact of informal waste processing, and the role of public awareness and education. It highlights the need for best practices and strategies at a global level to address the challenges of a consumption-driven economy and rapid technological obsolescence.

II. State of Art

A. *E-waste*

Waste electrical and electronic equipment (WEEE) is all those elements and components of electrical and electronic devices, both for domestic and commercial use, that have reached the end of their useful life or that have been discarded without the intention of reusing [2]. This concept ranges from large appliances to personal electronic equipment that, once its operational life is exhausted, is discarded [3]. Similarly, the definition of WEEE is understood to be any appliance powered by electricity that no longer meets the original needs of its owner [4]. As the useful life of these devices ends, the amount of e-waste grows exponentially.

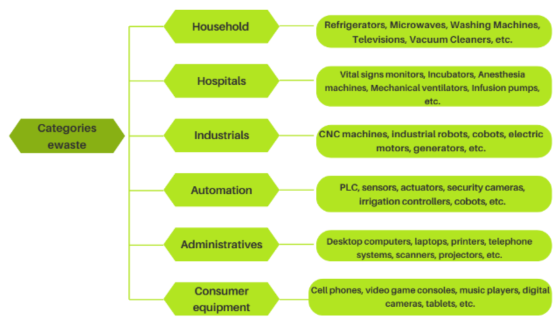


Figure 1 Categories of electronic waste, note: Own elaboration

WEEE can be classified into various sectors according to different criteria, such as their size, applications and area of operation. As time goes on, these sectors are experiencing a considerable increase in the generation of e-waste, which becomes a growing environmental concern [5].

B. *Mass Production*

The mass production of electronic devices has contributed significantly to the increase in e-waste worldwide, this activity is driven by population growth and consumption per person associated with economic development [6]. This phenomenon, together with technological advances, has led to a growing dependence on electronic devices and their rapid obsolescence [7].

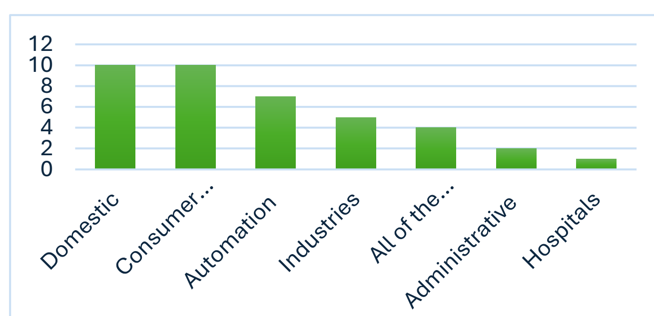


Figure 2 Categories of WEEE, note: Own elaboration

According to Figure 2, the categories of consumer and domestic equipment show the greatest changes in terms of obsolescence. This reflects the dynamic nature of these artifacts, driven by the rapid evolution of new technologies and the consumerism of the public. A large part of these artifacts do not complete their life cycle adequately; instead of being recycled they are simply discarded [8]. This exacerbates the problem of e-waste, as many devices become waste before reaching their full life cycle.

C. Service life in terms of machinery

Remanufacturers try to recover and reuse valuable parts of these products, reducing the need for new raw materials [9]. The success of remanufacturing depends on a proper initial inspection to assess the condition of the products. This process makes it possible to identify which components can be reused and which need to be replaced, which directly affects the costs and quality of the final product [10]. The performance of remanufacturers can vary depending on the state in which the product arrived, which can affect the quality of the new product they want to make.

Table 1 Classification of organizations and countries that support them, note: Prepared by the authors

ORGANIZATIONS	COUNTRIES
(LPUR) Resource Efficiency Promotion Act (LRHA) and Specified Appliances Recycling Act (LRHA).	Japan and South Korea.
(CRT) Basel Convention	Pakistan and Africa.
(UEEE) Used Electrical and Electronic Equipment	Hong Kong, Thailand and Nigeria.
(RoHs) Restriction of Hazardous Substances Directive	Turkey, Australia, Russia and Switzerland.
(EPR) Extended Producer Responsibility	India, China, Vietnam, Brazil and Africa.
(WEEE) Waste electrical and electronic equipment	Singapore, Pakistan, the United States, Belgium, Finland, France, Germany, the Netherlands, Norway, Italy and Spain.

In Japan, e-waste legislation includes the Resource Efficiency Promotion Act (LPUR) and the Specified Household Appliances Recycling Act (LRHA), which promote recycling and reuse through Extended Producer Responsibility (EPR), requiring manufacturers to manage products at the end of their life. In Africa, the Basel and Bamako Conventions regulate e-waste, treating it as hazardous and prohibiting its import to reduce environmental risks. Policies like EPR hold manufacturers financially responsible for waste management, focusing on direct reuse, repair, and renovation to extend product life and minimize waste, though implementation challenges remain.

The lack of legislation or effective enforcement in developing countries has led to serious environmental and social consequences. In countries such as Nigeria, Pakistan and several African nations, WEEE is managed informally, with practices such as burning electronic components to extract valuable metals. These activities release toxic substances that affect the health of workers and pollute local ecosystems. In addition, the absence of strict regulations has turned many of these countries into dumping grounds for WEEE imported from industrialized nations.

Developed countries have demonstrated that best practices in WEEE management include the implementation of advanced recycling systems, incentives for sustainable product design and educational campaigns to raise public awareness. Germany, for example, leads with recycling rates above 60%, thanks to adequate infrastructure and active citizen participation [11].These models highlight the importance of combining strict regulations with collaboration between governments, businesses and citizens to address the challenges associated with WEEE.

D. Management methods for disposal

Globally, EEE end-of-life options include practices such as reuse, repair, and recycling, although implementation is not always straightforward. In regions such as Africa, waste often ends up in open landfills or is incinerated, depending on the infrastructure available [7]. The physical durability of devices often outweighs their functional utility, and despite efforts to promote recycling, the complexity of their composition makes this process difficult, making it more complicated than recycling other materials [12].

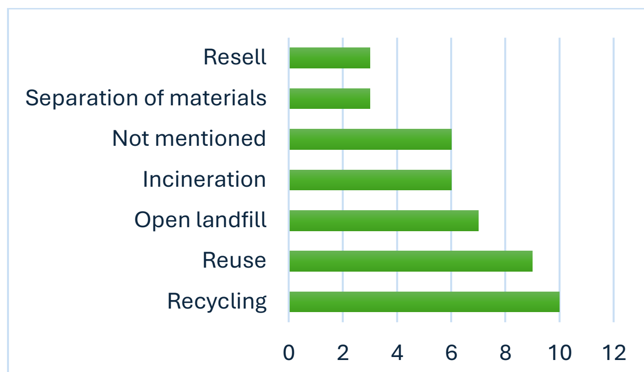


Figure 3 WEEE e-waste management methods, note: Own elaboration

In regions such as Africa, e-waste often ends up in open dumps or is incinerated, depending on the available infrastructure. According to Figure 4, the most common management methods are recycling, reuse and open landfill. However, the challenges faced by different countries in managing e-waste vary significantly [13]. For example, in Nigeria, recycling systems are often underdeveloped or non-existent, leading to unsustainable methods such as open dumping. Similarly, in India, much of e-waste management relies on informal recycling sectors, which lack the infrastructure and resources to manage it sustainably [14]. This highlights the need to explore approaches and barriers to e-waste management, especially in regions where infrastructure, legislation, public awareness and economic conditions influence the methods available for handling e-waste.

III. ANALYSIS AND RESULTS

Figure 4 Continents that have partially adequate methods. Note: Own elaboration.

Globally, there are multiple ways to manage the end-of-life of electrical and electronic equipment, such as reuse, repair, refurbishment, use of parts in other products, recycling, and resource recovery. However, inappropriate methods such as landfilling, incineration, uncontrolled dumping and simple disposal as garbage are also observed, which highlights the importance of responsible management [7].

A. AMERICA

The American continent (North America, Central and South America) is one of the largest generators of electronic waste, reaching very high levels (14 billion kg), however, the legislation to manage it varies significantly between countries [15] . In the United States and Canada, its regulation is carried out at the state or provincial level, while in South America it is managed at the national level and the countries of Central America are still developing the project of managing their e-waste.

1. *REGULATIONS FOR E-WASTE MANAGEMENT METHODS*

North America

There is no unified federal legislation governing waste management. Instead, various approaches are adopted, including the Extended Producer Responsibility (EPR) model. This a policy and regulatory framework that assigns manufacturers the responsibility for the entire lifecycle of their products, particularly their end-of-life management. This includes tasks such as product collection, recycling, and the proper disposal of waste.

Extended Producer Responsibility (EPR) programs typically require producers to take an active role in managing the waste generated by their products. This often includes setting up accessible drop-off locations for used electronics. In many cases, companies are also responsible for covering the costs or directly overseeing recycling operations to ensure environmentally sound waste treatment. Additionally, EPR encourages the development of more eco-friendly products by motivating manufacturers to prioritize durability and the use of recyclable components in their designs.

An example is the state of California opting to fund recycling through consumer fees, the EPR model encourages more responsible practices by manufacturers, reducing e-waste in landfills and illegal export [29]. However, its implementation is not uniform, as not all states have laws in place, leaving significant gaps in e-waste management and, in some cases, limiting its scope to certain types of devices.

State laws also vary with respect to "covered entities," i.e., the consumer groups from which products can be collected for recycling under these systems. These entities can include households, public administrations, non-profit organizations, businesses, and schools [13]. Generally, programs focus on household e-waste collection, although some also include nonprofits, small businesses, and other entities. However, large companies are often excluded from these end-of-life recycling programs.

Central America

Many nations have adopted frameworks like the WEEE Directive, the Basel Convention, and Extended Producer Responsibility (EPR) to regulate electronic waste. In contrast, countries like Honduras are still in the early phases of establishing effective e-waste management systems, with current efforts focused on building and formalizing sustainable recycling practices. In 2010, Costa Rica established a legal framework specifically targeting the handling of electronic and electrical waste. This initiative, formalized under Law No. 8839, supports the broader objectives of the country's Integrated Waste Management strategy. The law seeks to optimize resource use by implementing structured actions across various domains, including logistics, funding, governance, education, environmental protection, and public health, with built-in systems for performance tracking and continuous improvement [17].

Honduras currently lacks dedicated national regulations addressing electronic waste. However, the country has taken steps toward hazardous chemical management through the implementation of its "National Plan for the Management of Polychlorinated Biphenyls (PCBs)." This strategy focuses on minimizing and ultimately phasing out the use of PCBs—chemicals identified as persistent organic pollutants due to their harmful effects on both human health and ecosystems. The initiative aligns with Honduras's international obligations, including its participation in the Stockholm Convention, which promotes the safe handling and elimination of toxic substances [18].

Latin America

A few countries across Latin America have established legal structures tailored to the treatment of electronic and electrical waste, placing strong emphasis on Extended Producer Responsibility (EPR) models. These systems assign end-of-life waste management duties to producers and suppliers, making them responsible for ensuring that discarded electronic products are properly collected, processed, and disposed of in an environmentally sound manner.

Latin America has also embraced global treaties that enhance oversight of electronic waste, notably the Basel Convention, which governs the cross-border movement and disposal of hazardous materials. This agreement aims to curb illegal trade and promote safe, environmentally responsible handling of e-waste. While several nations in the region have made strides in aligning with the convention's guidelines, obstacles persist in enforcement and in building the necessary infrastructure for effective monitoring and implementation [11].

In 2023, the target for recovering electronic devices was set at 3% of total units sold, with plans to gradually raise this percentage in the following years [18]. Chile has a law that includes awareness and education strategies to inform consumers on how to properly dispose of e-waste. Finally, producers can choose to meet the targets through collective systems, working with authorised management companies, or establish their own individual recycling systems.

2. *IMPLEMENTATION OF MANAGEMENT METHODS*

North America

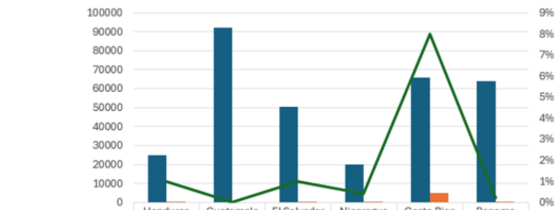
In the United States, some states opt for techniques such as burning electronic components and using corrosive acids to recover valuable metals such as copper and other precious metals. However, in certain cases, the waste is exported without processing, transferring the burden of handling and sorting to recyclers in receiving countries, which, in the absence of strict regulations, generates environmental pollution and health risks. These practices reflect the need for more rigorous control in the management of electronic waste [19].

Canada takes a more structured and sustainable approach. E-waste is collected at designated points and sent to certified facilities for sorting, dismantling, and recovery of valuable materials, while hazardous components are safely managed. In addition, compliance with the Basel Convention ensures that waste is not exported to countries without adequate recycling capacity. The country complements these practices with provincial programs that set collection goals, educational campaigns, and investment in advanced technologies, thus promoting a circular economy and minimizing environmental impact [11].

Central America

It faces serious challenges, with very low formal collection rates, which on average do not exceed 2.7% of the waste generated. Costa Rica stands out with a rate of 8% (1.0 kg/inhabitant), while in countries such as Honduras, Nicaragua and Guatemala, formal collection is practically non-existent or undocumented [18].

The informal sector dominates the recovery of valuable metals, but much of the remaining waste is improperly disposed of, leading to environmental pollution. The lack of clear targets in several countries makes it difficult to implement effective programs, and most waste ends up in common landfills, where it releases toxic substances such as lead and mercury, affecting human health and ecosystems [13].



	Honduras	Guatemala	El Salvador	Nicaragua	Costa Rica	Panama
RAEE gen (ton)	24823	92000	50437	20180	66000	64086
E-waste collected (ton)	12	0	435	60	5100	84
(%)	1%	0%	1%	0.40%	8%	0.20%

Figure 5 Statistics on e-waste generated in Central America, note: Own elaboration based on **[18]**.

The infrastructure for the treatment of electronic waste in Central America is extremely limited. Only Costa Rica and, to a lesser extent, Panama have authorized facilities, while countries such as Honduras, Nicaragua and El Salvador depend on general infrastructures for hazardous waste, lacking specialized facilities. This shortage causes most electronic waste to end up in landfills, releasing toxic components without adequate treatment. Technical and financial constraints hinder the adoption of modern technologies, and regional cooperation to address the problem remains insufficient. It is essential to invest in infrastructure and develop policies that promote sustainable and technologically appropriate treatment.

Latin America

Formal collection systems stand out as a key method of managing e-waste. These systems integrate strategic collection points, often in collaboration between public infrastructure and private companies, facilitating access in urban areas. However, rural communities continue to face significant barriers to benefiting from these services [18].

Formal recycling, supported by advanced technologies, allows valuable materials such as metals and plastics to be recovered, reducing environmental impact. Countries such as Ecuador and Peru have specialized plants that ensure safe waste management, promoting the circular economy through the reintegration of recycled materials into new production processes [20]. Despite this, informal recycling is still prevalent in countries such as Brazil and Mexico, where rudimentary and dangerous methods make up for the lack of formal infrastructure, generating risks to health and the environment [9].

Other strategies, such as the controlled export of e-waste to countries with greater technological capacity, have been adopted in places with limited infrastructure, such as Bolivia, Ecuador and Venezuela. Although this practice ensures proper treatment of hazardous materials, it faces logistical challenges and associated costs. At the same time, community initiatives and educational campaigns seek to raise awareness among the population about recycling, encouraging participation and creating environmental awareness, although their impact is still insufficient in the face of the needs of the region [20].

3. ECONOMIC FACTOR

North America

In 2016, the United States generated 6.3 million tons of e-waste, equivalent to 19.4 kg per capita, worth an estimated billions of dollars for its valuable materials, such as precious metals and rare earths. However, low recycling rates limit the recovery of these resources, wasting an important source of wealth [21].

Adopting a circular economy model in the electronics sector in North America could yield huge economic benefits, reducing costs for consumers by 7% by 2030 and by 14% by 2040 [22]. The recovery of valuable resources, supported by better designs and technologies, not only addresses material shortages, but also reinforces the profitability of recycling and encourages a more sustainable approach.

Central America

The lack of specific data on e-waste recycling revenues makes it difficult to assess its economic impact in the region, although in Costa Rica it is estimated that its proper management could generate up to 87 million dollars [23]. This economic potential highlights the value of recoverable materials, which would not only strengthen the national economy, but also reduce dependence on virgin resources, promoting environmental sustainability.

Latin America

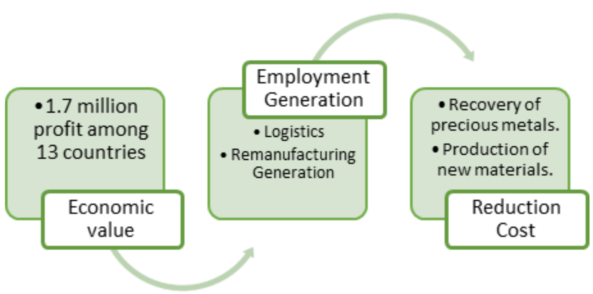


Figure 6 Economic impact, note: Own elaboration

In 13 countries analysed, it represents an estimated value of 1.7 billion dollars, highlighting the economic potential of recoverable materials such as precious metals [18]. This value can be reintegrated into the economy through appropriate recycling systems, encouraging the reuse of valuable resources.

The region still faces challenges such as lack of infrastructure, informality, and the absence of clear policies. With strategic investment and regulatory strengthening, Latin America can maximize the benefits of recycling, promoting employment, saving materials and developing a more sustainable circular economy.

B. EUROPE

1) *1. REGULATIONS FOR E-WASTE MANAGEMENT METHODS*

European regulations highlight the importance of the collection and separation of WEEE to avoid its disposal in landfills without treatment. States should guarantee free collection points and require stores larger than 400 m² to accept small WEEE without prior purchase, in addition to distributors collecting old devices when purchasing a new one [25]. This approach ensures that waste is managed safely, promoting sustainable practices.

The treatment of WEEE includes transport to approved facilities where reuse, recycling and safe disposal are prioritised. Valuable materials, such as precious metals, are recovered using advanced techniques, while others, such as plastics and metals, are reincorporated into the circular economy. This system not only reduces the extraction of raw materials, but also prevents contamination by toxic substances, protecting health and the environment [38].

2) *REUSE MANAGEMENT METHOD*

In 2020, Germany generated 1,607 kt of e-waste, managed under the ElektroG law, which requires manufacturers and importers to collect, recycle, or properly dispose of end-of-life electronics [13]. The country uses advanced technologies such as artificial intelligence and automated systems to separate valuable materials, as well as offering tax incentives and subsidies to promote the circular economy through recycling and remanufacturing.

Germany leads in recycling technologies, with a global market share of 24% and 64% in material separation technologies [27]. More than 11,000 companies and 270,000 workers are involved in waste management, generating annually 70,000 million euros.

3. ECONOMIC FACTOR GENERATED BY THE REUSE OF E-WASTE

In 2019, Europe generated 12 million tonnes of e-waste, with an estimated value of $60 to $72 billion in recoverable materials. However, only 42.5% was recycled, leaving a great economic potential untapped[28].

C. OCEANIA

In Oceania, e-waste management is limited, especially in the Pacific Islands, where attention to policy and practice is scarce. Studies focus mainly on Australia and New Zealand [29]. Unlike Australia, New Zealand lacks a mandatory regime for the management of this waste, resulting in more than 98.2% of household e-waste being sent to landfill or incinerated [30]. Globally, e-waste is growing three times faster than the population, and in Oceania this trend is even more accentuated, as recycling is not advancing at the same pace, evidencing the lack of a proportional response [31]. The New Zealand Government is currently evaluating the implementation of a mandatory plan to improve waste management [30].

Figure 9 Waste management through collection points in Australia. Note: Own elaboration.

1. MANAGEMENT METHOD

Australia has improved its e-waste management, going from recycling just 10% in 2007-2008 to implementing more efficient systems. In that period, 80% of waste was sent to landfills, stored or incinerated, and some was exported to countries such as Singapore, India and China, despite the restrictions of the Basel Convention [32]. Currently, the country has a collection system accessible to households and small businesses, with permanent points at waste transfer centers, occasional collection events, and centers at technology stores to receive electronic devices [30].

2) . ECONOMIC FACTOR

In Oceania, the economics of e-waste management vary by country. Australia has excelled in its progress, recycling 35% of the 122 million kg of TVs and computers that reached the end of their useful life between 2014 and 2015. This contrasts with the 9% recycling rate recorded in 2008, evidencing an improvement in its collection and recycling system, driven by the recovery of precious metals, the generation of sustainable income and the creation of jobs [33].

However, geographical dispersion in Oceania presents economic challenges. Transporting e-waste to recycling facilities significantly raises logistics costs, especially when inter-island transportation is required. Export and import permits for hazardous waste further increase expenses, with fees that can reach $13,080 per operation in Australia [29]. For this reason, some countries choose to send waste to international recyclers, a solution that reduces immediate costs, but can lead to environmental and health risks in recipient countries. Creating national recycling systems requires a large investment in infrastructure, technology and training, which, while more sustainable in the long term, is often out of reach for many economies in the region.

D. ASIA AND AFRICA

Improper management of electronic waste generates environmental and health risks, especially due to the release of heavy metals such as cadmium, which can contaminate water and soil [34]. In Bangladesh, only 20% to 30% of this waste is properly recycled, while the rest is deposited in landfills or open spaces, aggravating pollution [35].

In Asia, Life Cycle Assessment (LCA) has shown that minimizes environmental impact compared to incineration or landfilling [36]. In Africa, the Bamako Convention (1998) prohibits the import of hazardous waste, including electronic waste, and encourages its proper local management. This treaty establishes guidelines for their transport and disposal, promoting sustainable practices and preventing illegal dumping [14].

1) INFORMAL AND FORMAL RECYCLING MANAGEMENT METHOD

There are two types of e-waste recycling: formal and informal. Formal recycling is characterized by structured and controlled activities that include the separation and recovery of materials under environmental regulations, guaranteeing the protection of workers and responsible management [37]. In China, the e-waste management regulation certifies recyclers after a three-year monitoring phase, assessing their compliance with environmental regulations before being included in the formal list to carry out legal recycling [38].

Figure 11 Characteristics of formal recycling. Note: Own elaboration.

Formal recycling is defined by characteristics such as regulatory compliance, controlled processes that minimize risks, worker protection, traceability of recycled materials, and a strong environmental commitment. However, in many countries in Asia and Africa, the lack of infrastructure and technological capabilities impedes the advancement of this model, delaying the reduction of pollution and the risks associated with inadequate management [31].

Informal recycling relies on unregulated methods, such as manual burning and dismantling without safety measures. In the long term, these practices can cause irreparable environmental damage and lead to remediation costs that outweigh the immediate economic benefits [39].

In South Africa, the informal sector handles 25% of recycled e-waste, although this percentage does not include waste that is not recycled or ends up in landfills, leaving out a significant part of the waste generated [14]. China and other Asian regions generate about 40% of global e-waste, but only 20% is formally collected and recycled. The remaining 80% is handled informally, often through practices such as illegal dumping or the extraction of precious metals in developing countries, revealing the lack of an effective safe recycling system [40].

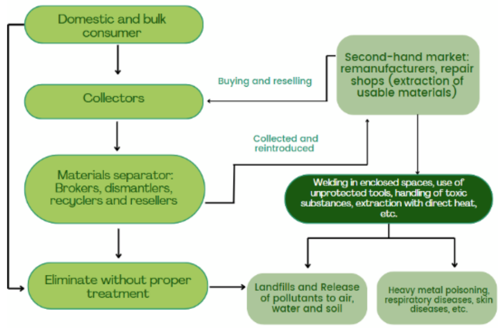


Figure 12 Flowchart of e-waste management by the informal sector in India
Note: Own elaboration based on **[41]**.

In India, informal recycling begins when old or damaged devices are acquired by collectors, who can resell, repair, or disassemble them to recover valuable parts [42]. However, this process generally does not consider the environmental damage it generates, such as soil and water contamination due to improper waste disposal, and the risk of exposure to toxic substances for workers [37].

Globally, approximately 23% of e-waste from developed countries is exported to developing countries, a common process between both types of countries [43]. In Cambodia, a lack of manufacturing facilities drives the import of used electronics, increasing reliance on second-hand products [44].

2) ECONOMIC AND SOCIAL IMPACT

Despite the existence of international conventions that regulate the management of electronic waste, their implementation varies significantly between countries. Differences in trade links, economic development and industries complicate the creation of common regulations, as seen in Africa, where a standardized regional approach to transboundary movements of waste has not yet been established [49]. In addition, recycling in the informal sector becomes a source of income for communities with few economic opportunities, but productivity and the amount of material recovered are often prioritized, without considering job safety or environmental impact [43].

Figure 13 Relationship Electronic waste and the socioeconomic factor. Note: Own elaboration.

In some regions, e-waste is not seen as a hazard, but as a vital resource for livelihoods [49]. This economic approach is key in debates on regulating transnational waste streams, as imposing regulations without considering their impact on local economies could harm communities that depend on this informal recycling for their livelihoods.

The linear economy, which follows the "extract, produce, use and dispose" model, generates large volumes of waste and depends on natural resources. Instead, the circular economy seeks to reduce waste through reuse, repair, and recycling. In 2019, e-waste was worth US$57 billion, highlighting its economic potential to foster this model, especially in Africa. However, in emerging countries, the lack of policies, infrastructure and technical capacities hinders their implementation [50].

Countries such as Japan show how recycling and reuse policies can promote the circular economy, recover valuable resources and generate employment. In developed countries, recycling e-waste is an opportunity to recover critical raw materials, while in developing nations, such as Nigeria, it can be an important source of income, as long as sustainable practices are promoted. Adapting sustainable models to local realities can generate economic and environmental benefits.

Table 2 Comparison of regions in e-waste management. Own elaboration based on [11]

Top 5 regions with better e-waste management (million kg)		**Top 5 regions with worst e-waste management (million kg)**	
1. Western Europe	4,200 ~ 58%	**1. Southeast Asia**	4,400~0%
2. North America	8,000~ 52%	**2. North Africa**	1,500~0%
3. Australia and New Zealand	680~43%	**3.Caribbean**	240~0%
4. East Asia	16,000~ 20%	**4.Melanesia**	21~0%
5. Southern Africa	580~4%	**5. Oriental Europe**	3,700~27%

The table shows inequalities in the overall management of e-waste. Western Europe leads with advanced systems and strict regulations, followed by North America and Oceania with effective local initiatives. In contrast, regions such as Southern Africa, Southeast Asia and the Caribbean face major challenges due to lack of infrastructure, highlighting the urgency of improving policies and resources in these lagging areas.

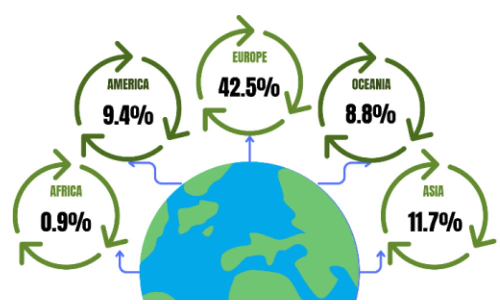


Figure 14: E-waste management at a global level. Note: Own elaboration based on **[35]**.

Europe leads with 42.5%, thanks to its advanced infrastructure and strict regulations, while Asia, despite being one of the largest generators of e-waste, only recycles 11.7%, evidencing a considerable gap. The Americas register 9.4%, reflecting challenges in recycling policies and systems, and Oceania reaches 8.8%, probably due to its smaller population and limited infrastructure. Africa has the lowest rate, at just

0.9%, highlighting the lack of adequate resources and technologies. Taken together, these data underscore the need for a comprehensive approach to improve e-waste management and reduce environmental damage.

IV. Conclusions

- Proper management of electronic waste reduces the release of toxic substances and prevents pollution, protecting ecosystems and biodiversity. In regions such as Europe, where advanced regulations and technologies are applied, air and water quality are improved, benefiting both the environment and nearby communities. The effectiveness of these methods is evident in the significant returns they provide, such as the recovery of valuable materials and the reduction of environmental hazards. Advanced recycling systems, specialized waste treatment facilities, and safe dismantling methods not only mitigate the negative impact of e-waste but also generate substantial environmental and economic benefits, demonstrating their overall efficiency.
- Europe leads with an average of 42.5% thanks to the WEEE Directive, which sets mandatory targets for collection and recycling, promoting extended producer responsibility (EPR). In Germany, for example, recycling exceeds 60%, supported by advanced infrastructure and strong citizen participation. In contrast, in Latin America, Chile stands out with its REP Law, while Costa Rica barely achieves 8% formal collection due to infrastructure challenges and lower public awareness. In Africa, the lack of legislation and resources encourages informal practices, such as the burning of electronic devices, which generates environmental and health risks. In Oceania, Australia is making progress in recycling programs, although problems persist in less developed areas. These differences reflect how regulations, infrastructure, public awareness and financial support are key factors in explaining disparities in collection rates between regions.
- Germany and Japan are benchmarks in e-waste management, thanks to effective regulations such as the WEEE Directive and the Household Appliance Recycling Act. Germany achieves collection rates above 24%, while Japan promotes an efficient circular economy. These cases demonstrate how legislation, adequate infrastructure, and public education can significantly reduce the environmental impact of this waste. In particular, improving infrastructure in developing countries is critical to establishing effective recycling and collection systems. Additionally, the implementation of stricter global policies could harmonize efforts across regions, ensuring that e-waste is managed responsibly regardless of geographic or economic disparities. Investing in public education campaigns and fostering international cooperation are also key strategies to mitigate the environmental and health risks associated with improper e-waste disposal. These future-focused initiatives would help create a more sustainable framework for managing electronic waste on a global scale.

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