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Analysis of Economic Impacts in the WEEE Demanufacturing Process: a Narrative Review

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Abstract: Waste Electrical and Electronic Equipment (WEEE) contains a wide variety of components—such as precious metals, plastics, glass, and others—that can be sold and reused as raw materials for new products, exploring its economic potential. This paper aims to provide an overview about the contribution of e-waste management to the circular economy, demonstrating that proper e-waste recycling can become an asset. A narrative review was prepared on this topic, in which 11 publications were included, containing articles and technical notes from several databases: Google Scholar, SciELO, World Meteorological Organization (WMO), World Economic Forum (WEF), Brazilian Agency for Industrial Development (ABDI), United Nations University (UNU) and United Nations Institute for Training and Research (UNITAR). From this review, it concluded that an economic approach towards recycling must be applied in Brazil to increase the cost-effective ratio of production. Thus, the economic power associated with recycling can transform a current challenge into an opportunity for economic growth and environmental preservation.
Keywords: WEEE, Demanufacturing process, Economic impacts, Circular economy, Electronic waste management

1.Introduction

According to the Global Annual to Decadal Climate Update by the World Meteorological Organization (WMO), the year 2024 was the hottest year on record globally, a metric that has steadily increased since the 1960s due to high atmospheric concentrations of greenhouse gases (GHGs). One of the causes of this physical phenomenon is the high level of e-waste across the planet. By definition, e-waste refers to all components, subassemblies and consumables from electrical or electronic equipment that is considered waste [1,2].

Waste Electrical and Electronic Equipment (WEEE) contributes to these atmospheric emissions through improper handling, such as landfill disposal and open burning. These practices necessitate re-extracting raw materials from nature, causing further environmental impact. When burned, these materials release highly polluting GHGs like carbon dioxide (CO_2) and methane (CH_4). When e-waste is landfilled, its heavy metals and flame retardants can leach into soil, groundwater, rivers, and oceans [3].

This practice of improper disposal is common in developing countries, which lack education and resources for correct waste management. Coupled with high social inequality, this drives an urgent need to monetize the demanufacturing process, which aims to disassemble the e-waste devices and components, so that they can be recycled and disposed correctly [4]. Since this process is often performed without adequate safety measures, workers are exposed to health risks due to hazardous components like lead and mercury.

To implement reverse logistics, the main obstacle is shifting its perceived role by society. There is a need to build a formal recycling industry and start to view this process as an economic asset rather than a cost in the several sectors on the market. This requires recognizing the sustainable and strategic value these practices can generate based on a circular economy. According to the World Economic Forum [5], the circular economy applied in e-waste could increase the number of valuable components that move back in the production of a new electronic product.

In this context, the aim of this paper is to provide an overview about the contribution of e-waste management to the circular economy, and how recycling these materials can become profitable. Section 2 describes the literature review approach adopted, exploring and synthesizing existing knowledge in a broad and contextualized manner. Section 3 will discuss the economic impacts of e-waste management, with a focus on the financial costs and benefits. We will delve into potential strategies to make managing e-waste economically attractive. Besides, we will evaluate the existing e-waste management strategies in Brazil, which include improvements in recycling technologies and stringent legislation for e-waste disposal. Section 4 presents the conclusion and future works.

2.Methods

For this study, a narrative review was conducted to present the document analysis. This paper uses a qualitative and exploratory research method to investigate the economic impacts of e-waste demanufacturing, and the current landscape of electronic waste management.

The literature review consisted of an extensive search across multiple databases, such as Google Scholar, SciELO, World Meteorological Organization (WMO), World Economic Forum (WEF), Brazilian Agency for Industrial Development (ABDI), United Nations University (UNU) and United Nations Institute for Training and Research (UNITAR). This search aimed to find articles, news reports, and publications addressing e-waste, its added value and current management practices.

In total, 11 publications were selected based on their relevance to the main topics: “Economic benefits of e-waste recycling”, “Strategies to make the reverse logistics process economically attractive”, and “Current E-Waste Management and Its Challenges In Brazil”. The inclusion criterion required sources to provide relevant information about electronic waste management, the added value of recycling, and climate impact. Furthermore, the selection of articles for this narrative review was based on their contribution and credibility criteria.

3. Results and discussion

3.1. Economic benefits of e-waste recycling

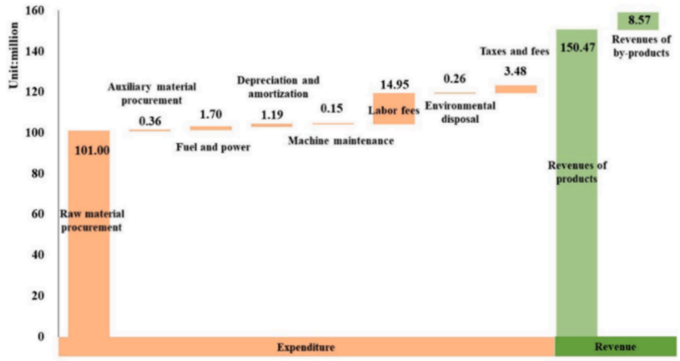
Research by the CNI (National Confederation of Industries) shows that 62% of companies in Brazil develop at least one circular economy practice. It is also possible to observe that this transition is more widespread in large industries. For them, the circular model offers advantages such as optimized use of raw materials, reduced waste, increased job creation, greater operational efficiency, economic growth, public awareness, opportunities for new businesses, and job creation [6].

Studies already show that there's an economic potential of € 55 bi in WEEE, making urban mining, where valuable components are extracted from circuit boards, becoming more profitable than using virgin raw material. According to the World Economic Forum, one recycler in China already produces more cobalt against a cobalt mine in a year [5,7].

According to Lee, Choi and Kim [1], to analyze the e-waste recycling in a cost-effective way, this process can be classified into capital expenditures (CAPEX) and operational expenditures (OPEX). CAPEX covers the initial costs of investments in recycling, for example all the equipment, facilities and land acquisitions. On the other hand, OPEX includes all the operational costs, like the expenses for collecting, processing and transporting e-waste.

Furthermore, the profit that the recycle system provides, as seen in Figure 1, overcomes the CAPEX and OPEX costs, which contribute to show other benefits from the WEEE management besides the sustainable ones.

Figure 1. Example of an economic analysis of e-waste recycling.



Source: [1].

3.2. Strategies to make the reverse logistics process economically attractive

There is an opportunity to make e-waste reuse a profitable business, as it contains a wide variety of components, from precious metals like gold, silver, and copper, to base materials such as plastic and iron, which can become part of countless objects, as described in Table 1.

Table 1. Average composition of a printed circuit board.

Components of a PCB		Average quantities	
Metals	28%	Metals	Average values
		Cu	14%
		Fe	6%
		Ni	2%
		Zn	2%
		Sn	2%
		Ag	0.3%
		Au	0.04%
		Pd	0.02%
Plastics	19%		
Bromine	4%		
Ceramic materials, glass and oxides	49%		

Source: Adapted from [8]

According to the United Nations [9], the value of raw materials collected through e-waste recycling was around US$57 billion. It is estimated that one ton of smartphones can contain 100 times more gold than one ton of mined auriferous ore [5].

A single phone contains electronic components worth approximately $100. In 2017, 1.46 billion smartphones were sold globally, which could have led to an $11.5 billion return to the market. The world urgently needs a more effective way to manage these products. E-waste is worth US$62.5 billion annually, yet the lack of investment and incentives in this sector ends up contributing to the problem.

Besides, in an ideal scenario where the 25 Mt of Waste Electrical and Electronic Equipment (WEEE) collected in 2019 were recycled to create new electronics, 14Mt of virgin raw material would still be needed to meet market demand, a consequence of the continuous growth in sales in this market [9].

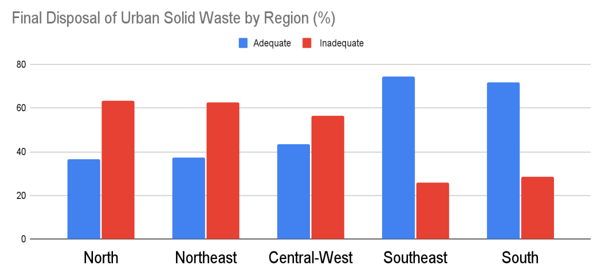
Moreover, when analyzing the amount of electronics per capita, it becomes apparent that, regardless of socioeconomic level, the smartphone experiences the smallest drop relative to income, establishing itself as a recurring electronic device across social classes.

3.3. Current E-Waste Management and Its Challenges In Brazil

In Brazil, the National Solid Waste Policy (in Portuguese, Política Nacional de Resíduos Sólidos – PNRS) was enacted in August 2010 to establish guidelines for integrated solid waste management. A key goal was to close all open-air dumps by 2014, yet this target remains unmet due to the lack of strict agreements establishing clear targets for WEEE processing in Brazil. Furthermore, implementing this policy leads to more discussions about public policies and investment in infrastructure and logistics. For example, European and North American countries already have specific goals to achieve regarding e-waste dismantling [10,11].

In 2022, Brazil improperly disposed of 33.3 million tons of solid waste, with the North and Northeast regions leading this negative trend, as illustrated in Figure 2. This stems from uneven distribution of recycling facilities across regions, compounded by the geographic remoteness of Northern/Northeastern areas from recycling hubs.

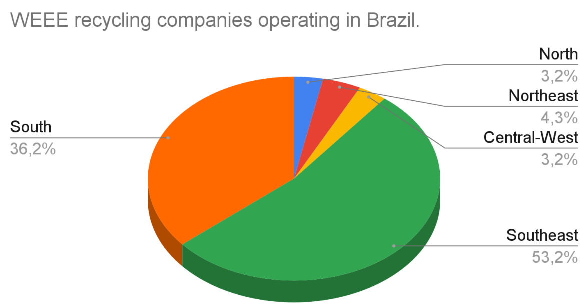
Figure 2. Final disposal of urban solid waste by region in Brazil.



Source: Adopted from [10]

According to ABDI (Brazilian Industrial Development Agency) [11], high informality and insufficient fiscal incentives for collection and logistics prevent Brazil's recycling sector from matching the pace of countries with formal economic support. As seen in Figure 3, the Southeast region in Brazil has the highest number of recycling facilities, as it is the region with the greatest industrial development and highest population density in the country. These factors are directly related to WEEE generation, large cities and industries are the biggest e-waste producers. On the other hand, the uneven distribution of the recycling companies makes it difficult to implement a circular economy policy.

Figure 3. WEEE recycling companies operating in Brazil.



Source: Adopted from [11]

For instance, Brazil lacks capacity to separate and process high-value materials (e.g., precious metals from circuit boards) compared to nations with advanced reverse logistics systems, leading to the export of WEEE for proper demanufacturing abroad [11].

Moreover, recyclers highlight the lack of tax incentives for recycled materials. Virgin materials often undercut recycled alternatives due to policies like the Manaus Free Trade Zone, which subsidizes new plastic production. This makes recycled resin more expensive than virgin plastic, disincentivizing circular economy practices.

4. Conclusion

This paper presented a reflective discussion on e-waste and the respective economic impacts, highlighting that investing in reverse logistics can be a sustainable and profitable business. It is concluded that e-waste management contributes to the circular economy, and processing these materials can be a profitable business. Besides that, the environmental and health benefits that adopting e-waste management brings, makes it more urgent, the reason to adopt innovative practices towards this subject and start to see this problem through the lens of economics. There is a need to recognize e-waste not merely as a mismanagement problem, but as an opportunity to achieve sustainable economic development.

Consequently, it becomes necessary the implementation of a circular economy policy, supported by the Brazilian government. For this change to happen, strategic approaches to the e-waste problem must be adopted, such as the reduction of the taxes in the recycling process and add more strict regulatory and legislative measures.

The adoption of a new measure towards the WEEE issue will bring sustainable and economical challenges. Nevertheless, there are several long-term benefits that e-waste management can bring, such as economic growth, reduced climate change impacts, and environment preservation, which are attractive reasons to overcome these challenges.

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